SOME CLINICAL APECTS OF THE EYE IN EXTENDED CONTACT LENS WEAR.

by

JUDITH ANN HUMPHREYS

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To my Mother

"Trust in the Lord with all thine heart, and lean not unto thine own understanding. In all thy ways acknowledge Him, and He shall direct thy paths."

Proverbs 3: 5-6.

THE UNIVERSITY OF ASTON IN BIRMINGHAM

Some Clinical Aspects of the Eye in Extended Contact Lens Wear

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Summary

The limbal vascular response to extended contact lens wear was examined in a group comparative study initially intended to last eighteen months.

After six months all patients wearing contact lenses had presented with micro-epithelial cysts. This unanticipated occurrence of the micro-epithelial cysts necessitated termination of the study, and limited the quantity of data collected. However, sufficient results were available to allow a limited description of the vascular response to this form of contact lens wear.

Interpretations of the data collected are discussed in relation to suggested vasostimulating factors in the cornea.

The micro-epithelial cysts observed after extended wear were classified and their rate of recovery recorded. A further clinical study was undertaken to observe cysts in both contact lens - and non contact lens-wearing eyes. Cysts were observed in every category of patient, although the characteristic patterns varied. These observations of micro-epithelial cysts are discussed with respect to the aetiopathogeneses of corneal epithelial cystic disorders. Subsequently, attempts were made to induce cysts in rabbit corneae by extended contact lens wear. Clinical observations revealed cyst-like appearances. Histological sections did not contain cysts but did exhibit signs characteristic of cystic disorders of the corneal epithelium.

In general, the results from the study indicate that extended wear is subjectively acceptable to contact lens wearers. However, the objective findings of significant vascular changes, micro-epithelial cysts and cases of acute red eye response cast considerable doubt on the recommendation of extended wear contact lenses for purely cosmetic applications.

Key words

Cornea - micro-epithelial cysts - extended wear - limbal blood vessels - contact lenses.

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LIST OF ABBREVIATIONS

ACh	Acetylcholine
ATP	Adenosine triphosphate
cAMP	Adenosine 3'.5' -cyclic monophasphate.
Å	Ångstrom
BM	Basement membrane
cm	centimetre
cm^2	square centimetre
ChAc	Choline Acetyltransferase
diam.	diameter
GMP	guanosine monophosphate
kg	Kilogram
LDH	Lactic acid dehydrogenase
λ	wavelength
mm	millimetre
mm Hg	millimetres of mercury
μ	micron (10^{-6} metres)
%	percent
PG	Prostaglandin
RI	Refractive index
Sec	Seconds
SDH	Succinic dehydrogenase
SD	Standard deviation
TCA	Tri-carboxylic Acid
TM	Trade Mark

CHAPTER 1

Introduction

Section 1.1 Gross Anatomy of the Eye

The globe of the eye consists of two partial spheres. The main part of the eye has a radius of curvature of approximately 12mm, but the anterior corneal surface has a radius of only 8mm or so, and the junction of the two partial spheres forms a circle approximately 13mm in diameter, known as the limbus (MANN, 1928; WHITNALL, 1932). The shape of the globe is determined by the structure of its layers, the ocular contents, the intra-ocular pressure and the attachments of the extra-ocular muscles. The eyeball comprises three layers (HIPPOCRATES); the outermost, fibrous coat is made up of the cornea and sclera; the middle layer, which is mainly vascular and nutritional in its function, consists of the iris, ciliary body and choroid, and the innermost layer is the retina. The globe is held in position, projecting somewhat beyond the anterior margin of the orbit, by a balanced group of forces. The six extra-ocular muscles form a muscle cone which fans out from the annular tendon of Zinn (ZINN, 1755), and one of major importance in the generation of three forces not only to maintain the eyes position but also to produce finely controlled movements. The eye, its muscles, nerves and blood vessels lie within connective tissue which is continuous with the periorbita. The composition of the connective tissue varies in composition from fibrous tissue (Tenon's Capsule) and adipose tissue to plain, visceral muscle (Muscle of Müller). The remaining anterior part of the orbit is protected by a pair of moveable folds, the eyelids (fig 1.1), which act

as shutters. The lids protect the eye from injury and excessive light. In addition, blinking of the upper eyelid spreads a film of tears over the cornea, stimulated rhythmically by evaporation, (WOLFF, 1954).

The adult diameters of the human eye are, on average, 24mm anterioposterially; 23.5mm tranversely and 23mm vertically. (GOLDNAMER 1923; MERKEL and KALLIUS, 1901; QUAIN, 1908; SCHWALBE, 1887; WEISS, 1890). The anterioposterior diameter may vary the most, being 20 to 29mm, the former in the hypermetropic eye, the latter in the myopic eye (STENSTRÖM, 1946).

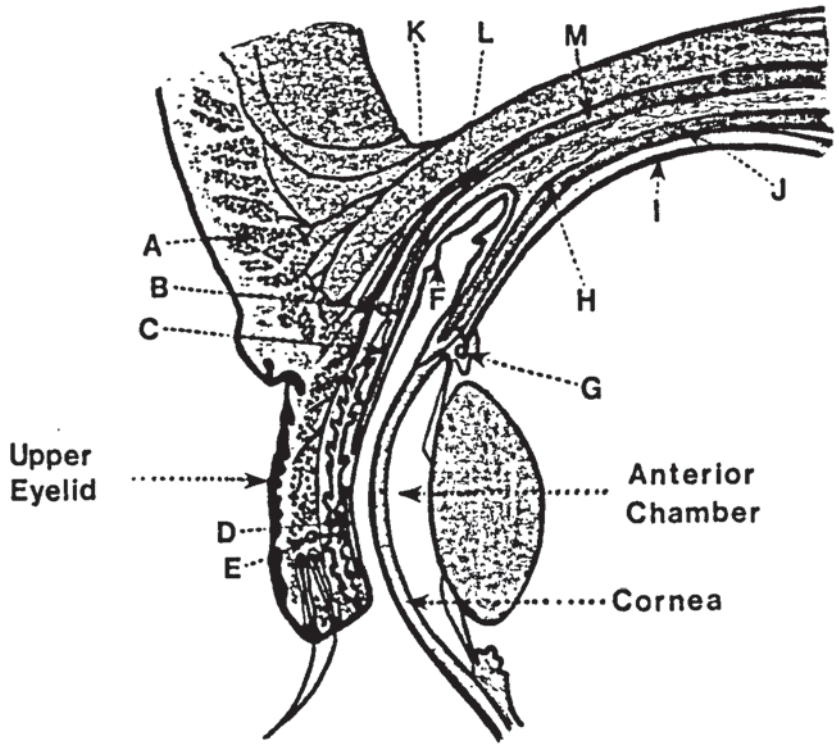


FIGURE 1.1 SECTION OF THE UPPER EYELID AND ANTERIOR PORTION OF THE EYE (After Wolff, 1976)

A - Orbicularis muscle,
B - Peripheral arterial arcade
C- Descending branch
D - Ascending branch
E - Marginal arcade
F - Conjunctiva
G - Circulus arteriosus iridis major
H - Anterior ciliary artery
I - Long posterior ciliary artery
J - Superior rectus
K - Conjunctival artery
L - Palpebral muscle
M - Levator palpebrae superioris

Section 1:2 The Anatomy and Physiology of Ocular Structures Associated with the cornea

1:2 i) The Eyelids

The eyelids are two musculo-membraneous folds of modified skin placed in front of the orbit, which they cover anteriorly, and act as organs of protection. They may fill the role of resting the retina and causing cerebal inactivity (WHITNALL, 1932). The upper lid is more extensive and mobile than the lower eyelid and acts as a swab to spread a film of tears over the cornea. When the eyes are open the palpebral tissue is asymmetrical and measures approximately 30mm by 15mm in adults (MERKEL, 1885).

The structure of the eyelid comprises six layers:

1. The skin of the eyelids is probably the thinnest to be found on the body surface (less than 1mm) (WHITNALL, 1932). It is elastic and contains many unicellular sebaceous glands (WOLFF, 1954). The nasal portion differs markedly from that of the temperal side, being smoother, shinier and greasier with practically no hairs. The hairs present are down-like with associated small sweat glands. Sweat glands, large pigment cells, mast and plasma cells are also found in the epithelium (PARSONS, 1905).

2. The subcutaneous areolar layer consists of loose connective tissue with adipose tissue in Caucasians (although adipose tissue has been noted in certain Oriental races (ADACHI, 1904)). The skin lying on this loose connective tissue is therefore very mobile and displaces readily when the eyelids become oedematous.

3. The layer of striated muscle consists mainly of the palpebral part of the orbicularis palpebrum (BURKITT and LIGHTOLLER, 1926) which is supplied by the facial nerve. The palpebral portion is further subdivided into the pre-septal fasciculi (lying anterior to the septum orbital) the pre-tarsal fasciculi (lying anterior to the tarsal plates) and the pars lacrimalis (HORNER, 1824; DUVERNEY, 1749). A further subdivision of the orbicularis is the ciliary bundle of Riolan, which is made up of extremely thin fibres. These lie in front of and behind the Meibomian ducts (KLODT, 1893; VIRCHOW, 1910) and are continuous medially with the pars lacrimalis. The striated muscle layer also contains the bulk of the cilia and their follicles, the small sebaceous "glands of Zeis" and their associated "sweat glands of Moll".

4. The submuscular areolar tissue resembles the subcutaneous layer and lies between the orbicularis and the tarsal plate. This space is traversed by the fibres of the levator and also contains the main nerves to the eyelids (WOLFF, 1905). In the lower lid the tissue occupies a single small space, the preseptal space, but in the upper lid the space in which the tissue lies is divided by the levator into the pretarsal and preseptal spaces (CLERMONT, 1909; CHARPY, 1911). The pretarsal contains the peripheral arterial arcade.

5. The fibrous layer forms a skeleton for the eyelid in the form of densely fibrous tissue which is orientated vertically. Some elastic tissue is also present which is mainly found around the acini. This fibrous network is intermingled with connective tissue, which is permeated by a system of lacunae and lymph spaces (PARSONS, 1904), in

which are found the tarsal glands. The tarsal or Meibomian glands (MEIBOMIUS, 1666), are composed of a network of gland units (25 in the upper lid and 20 in the lower lid), each comprising a single central canal with 30 to 40 acini which are surrounded by endothelial lined lymph spaces. The tarsal plate is firmly attached to the orbital margins by the medial and lateral palpebral ligaments and the septum orbitale.

6. Müller's muscle is a small band of visceral muscle joining the borders of the tarsal plates with the tendon of the levator palpebral muscle in the upper lid and the inferior rectus muscle in the lower lid (MÜLLER, 1859). Present in the muscle are fat cells, connective tissue and groups of nerve cells (GROYER, 1905).

The flat surface of the margin between the lids is termed the inter marginal region (TERSON, 1903). Structurally it consists of largely dense connective tissue in which hair follicles are located. The cilia are short and thick and number 100 to 150 (DONDERS, 1858). The follicles of the cilia are surrounded by a rich plexus of sensory nerves (VON MISES, 1882) and two large sebaceous glands are associated with each follicle (ZEIS, 1835). Sweat glands are also present, located between cilia (MOLL, 1857).

Section 1.2 (ii) The Conjunctiva

The conjunctiva is a thin, transparent mucous membrane which lines the posterior surface of the eyelids (Palpebral conjunctiva), is refracted to form a cul-de-sac (the fornix), covers the anterior part of the sclera (bulbar conjunctiva), and is continuous with the corneal epithelium at the limbus. It is thus a sac, open only at the palpebral fissure, but with walls that are in close apposition throughout (fig 1.1). The conjunctiva resembles other mucous membranes in that it comprises an epithelium and underlying lamina propria of vascular connective tissue. It is a continuous membrane throughout its whole extent, but the detailed structure of the epithelium varies in different regions.

The conjunctiva meets the skin at the muco-cutaneous junction which is just behind the openings of the Meibomian glands (WHITNALL, 1932). The skin of the lids and the marginal conjunctiva are stratified squamous epithelia, but various differences exit. The marginal conjunctiva is non-cornified epithelium; unlike that of the skin which is cornified and the conjunctiva does not contain the granular layer seen in the skin of the lids. However, the deep layers of the epithelium remain unaltered and the superficial cells retain their nuclei. The marginal conjunctiva is continued on the back of the lid for 2mm (PARSONS, 1904).

The tarsal or palpebral conjunctiva lies posterior to the tarsal plates. The epithelium of the tarsal conjunctiva shows a gradual reduction in the number of cells and their types. Many of the superficial columnar cells secrete mucous and become goblet shaped.

These small crypts (1 to 3 in diam.) are found at the junction of 3 or 4 cells (KESSING, 1968; DARK ET AL., 1974). They have since been shown to be empty goblet cells (GREINER ET AL., 1977) as they are identical to others found in different tissues (MARSH and SWIFT, 1969). Large crypts (10 to 60 in diam.) which appear to be infoldings of the conjunctival epithelium have also been noted (DUBREUIL, 1908; KESSING, 1968; GREINER ET AL., 1977). Three crypts correspond to those originally reported by Henle (1866) and are seen along the convex border of the tarsal conjunctiva. The accessory lacrimal glands of Wolfring and Ciaccio (WOLFRING, 1872; CIACCIO, 1873; DUBREUIL, 1908) lie in the upper border of the tarsal plates, and their ducts open at the junction of the tarsal and orbital conjunctiva. Ultrastructural studies of the palpebral conjunctival surface have discovered the presence of microvilli (TAKAKUSAKI, 1969; DARK ET AL., 1974; GREINER ET AL., 1977). Papillae (VIRCHOW, 1910) which were originally thought to present in the abnormal tarsal conjunctiva and not the normal (WOLFF, 1954; DUKE-ELDER, 1961; OSTERLIND, 1944) are now known to be present in the normal tarsal conjunctiva (NORN, 1960; KESSING, 1966). Due to agglutination between the upper parts of their lateral surfaces, giving a smooth surface, they are difficult to detect clinically.

The orbital conjunctiva lacks the support of the tarsal plate and is variably groved and folded (VIRCHOW, 1910). Its epithelium increases to three layers in the upper lid, with a possible increase in the number of goblet cells (KESSING, 1968).

In the conjunctival fornices goblet cells are numerous along most

meridians (GREEN, 1894) but not supero-laterally (KESSING, 1968). The epithelium has three to four layers of cells, and the looseness of the tissue allows it to be drawn back, to form the cul-de-sac of the fornix, by the surrounding connective tissue (CHARPY, 1912). In all the regions of the conjunctiva, the conjunctival fornices have the most well developed lymphoid layer (VILLARD, 1896). Evagination of the epithelium has produced numerous other accessory lacrimal glands (approximately 42 in the upper fornix and 8 in the lower fornix) in this region, which were first noted by Krause (1854).

The bulbar conjunctiva is a very transparent tissue. The cell layers of the epithelium increase with flattening of the superficial cells and the goblet cells progressively disappear (KESSING, 1966). The conjunctiva, at approximately 3mm from the limbus, lies loosely on the underlying tissue. Tissue fluid, blood and inflammatory exudates may therefore accumulate easily within this area.

The limbal conjunctiva blends perfectly with the anterior epithelium of the cornea. It contains basal cuboidal cells, several layers of polygonal cells and, on the surface, layers of squamous nucleated non-cornified cells. There are no goblet cells present in the limbus, but in the periphery of the limbal zone, goblet cells have been described (WANKO ET AL., 1964; RADNOT, 1971; HOGAN ET AL., 1971), as well as melanocytes in the deeper layers of the conjunctiva (HIWATARI, 1921). Pigment spots can form within the palpebral tissure, but it is uncommon in the white races (PERGENS, 1898; COPPEZ, 1905; FISCHER, 1905; KÜSEL, 1907). Sacculer glands in the limbal conjunctiva were first noted in animals (MANZ, 1859). Though they have been

described in humans (DRUAULT, 1912; DUBREUIL, 1908) their presence is not generally accepted. The epithelium and conjunctival stroma form rete pegs and papillae at the periphery of the cornea (VILLARD, 1896; NAKAGAWA, 1903; VIRCHOW, 1910).

The conjunctival arterial supply is mainly derived from the tarsal arcades. Posterior branches from these arcades supply the tarsal conjunctiva. The posterior conjunctival arteries pass, via the fornices, to supply the superficial bulbar conjunctiva, and at 3 to 4mm from the limbus they anastomose with the anterior conjunctival arteries (WHITNALL, 1932). After giving off their anastomotic twigs these anterior conjunctival vessels form a peri-corneal plexus which is about 4mm broad. This plexus is in two planes, the superficial or conjunctival, and deep or episcleral plexus. Veins, which are more numerous, follow approximately the same routes as the arteries and drain into either the muscular or the palpebral system. Tissue fluid from all parts of the conjunctival lamina propria, drains via minute lymphatic vessels to join with those of the skin of the lids (MOST, 1905).

1:2 iii) The Pre-Ocular Tear Film

The pre-ocular tear film(P.O.T.F.) is an important biosurface that covers the cornea, conjunctiva and conjunctival cul-de-sac. The volume of the tear fluid was estimated to be of the order of $7.0 \pm 2.0 \mu l$ (standard deviation), with a rate of production of $1.2 \mu l \, min^{-1}$ (MISHIMA ET AL., 1966), figures which were further supported by several authors (FURUKAWA and POLSE, 1978; BALIK, 1952; SZMYT, 1958; PUFFER ET AL., 1980; NORN, 1966). The tear film was therefore shown to be renewed in the course of a few minutes (NORN, 1966).

The P.O.T.F. is generally considered to comprise three layers (WOLFF, 1946), the total thickness of which was variously reported to be 6μ (MISHIMA, 1965; MAURICE, 1973), 10μ (HOLLY, 1980) and just less than 10μ (EHLERS, 1965).

The thin anterior layer of hydrophobic oils is secreted by the Meibomian glands of the tarsal plate, the glands of Zeis and the glands of Moll (McDONALD, 1968; ANDREWS, 1970; BRAUNINGER ET AL., 1972). It forms a thin homogeneous film over the aqueous layer of the tears retarding its evaporation (IWATA ET AL., 1969; MAURICE, 1961; ADAMSON, 1960) and increasing the stability of the P.O.T.F. by lowering its surface tension (HOLLY, 1973). Great variations in the composition of this layer were noted between individuals, but it was confirmed that the three principal components of tear lipids were wax esters, cholesteryl esters and tri-glycerides, with the presence in some individuals, of hydrocarbons and free fatty acids (TIFFANY, 1978).

The aqueous layer of the tear film makes up the major part of the P.O.T.F. It is derived from the lacrimal gland and the accessory glands of Krause and Wolfring. In this aqueous layer is a concentration gradient of mucins, which is lowest anteriorly (HOLLY, 1973). Observations showed that the homogeneity and mechanical properties of the lipid film eventually break down (HOLLY, 1972) which may be due to protein denaturation at the lipid-aqueous interface (CHEESMAN and DAVIES, 1954).

The innermost layer of the P.O.T.F. comprises mucin secretion from the goblet cells of the conjunctiva (LEMP and HOLLY, 1970; KESSING, 1968), the non-goblet cells of the conjunctiva (GREINER ET AL., 1979) and possibly the tear glands (JENSEN ET AL., 1969; ALLEN ET AL., 1972). The corneal epithelium is a relatively hydrophobic surface (LEMP ET AL., 1970; HOLLY ET AL., 1970), however, weak adsorption of the mucin layer in a hydrated form onto the corneal surface, forms a new hydrophilic area on which aqueous tears can spread readily (HOLLY and LEMP, 1971; LEMP ET AL., 1970). When blinking is prevented, the P.O.T.F. does not remain stable for long, and ruptures with the formation of dry spots after 15 to 40 sec. (LEMP and HAMILL, 1973; NORN, 1969). This is known as the tear film "break-up time" (B.U.T.), during which the tear film decreases in thickness by 10% due to evaporation (IWATA ET AL., 1969; MISHIMA and MAURICE, 1961 (a)). Deterioration of the tear film follows the initial tear break up, due to lipid contamination of the mucin layer coating the corneal epithelium (HOLLY, 1973). Holly (1973) further suggested that lipid, which has been demonstrated in the cell membrane of cells

in the corneal epithelium (BLÜMCKE and MORGENROTH, 1967), must be well masked by proteins and glycoproteins to render it wettable by the aqueous tear fluid. Therefore mucous glycoproteins play an important role in maintaining the normal surface of the eye(WRIGHT and MACKIE, 1977). Mucous glycoproteins are also important in the process of clearing sloughed cells, bacteria and foreign bodies from the eye (NORN, 1969). The mechanism for the control of mucous secretion is unknown and may depend on both nervous and chemical stimulation (WIDDICOMBE, 1978). The latter has been confirmed by the detection in the P.O.T.F. of mucous stimulating secretory substances (FRANKLIN and BANG, 1980).

The P.O.T.F. contains 98.2% water and 1.8% solids (RIDLEY and SORSBY, 1940). Within the aqueous layer of the tear film there is a complex mixture of proteins, which were recently stated to contain at least sixty protein components (GACHEN ET AL., 1979). The five principal tear proteins were reported to be secretory immuno-globulin A (TOMASI ET AL., 1965; IWATA, 1973), albumin (BOTELHO, 1964: FRANCOIS and RABAEY;1960; GACHON ET AL., 1979), "tear albumin" (TAPASZTO and VASS, 1965; JOSEPHSON and WEINER, 1968; BONAVIDA ET AL., 1969), lysozyme (BOTELHO, 1964; FRANCOIS and RABAEY, 1960; GACHON ET AL., 1979; SAPSE ET AL., 1969) and lacto ferrin (BROEKHUYSE,1974; GACHON ET AL., 1979). The bactericidal action of the P.O.T.F. has been noted for some time (KALT, 1903; STARLING, 1920; LINDAHL, 1907). One of the most important observations was that of the lytic activity of the enzyme lysozyme (FLEMING, 1922; RIDLEY, 1928). In addition, the presence of non-lysozymal anti-bacterial factor was detected (FRIEDLAND ET AL., 1972; FORD ET AL., 1976). Non-lysozymal anti bacterial factor was

indicated possibly to be Beta lysin (FORD ET AL., 1976) which, if so, would by virtue of its differing antibactericidal action, complement lysozyme in the defence mechanism of the tears. The major immunoglobulin in the tears, of which there was reported to be several others (BRAUNINGER and CENTIFANTO, 1971; GACHON ET AL., 1979; McCLELLAN ET AL., 1973), was determined as "secretory" immunoglobulin A (TOMASI ET AL., 1965; IWATA, 1973; McCLELLAN ET AL., 1973; LITTEL ET AL., 1969). The presence of these immunoglobulins were described as playing a major role in the defense mechanisms of the ocular surface (ALLANSMITH, 1973). Among the many other constituents of the tear film are transferrin (GACHON ET AL., 1979), antichymotrypsin and antitrypsin (KUEPPERS, 1970), prostaglandins (DHIR ET AL., 1979) histamine (ABELSON ET AL., 1977), various acid hydrolases (VAN HAERINGEN and GLASIUS,1976(b)),amylases (VAN HAERINGEN and GLASIUS, 1974 (a), (b)) and enzymes derived from the corneal epithelium (KAHEN and OTTOVAY, 1975; VAN HAERINGEN and GLASIUS,1976(a)). Constituents of the mucoid layer are also found in the P.O.T.F. The conjunctival mucin is made up largely of an insoluble gel which has been shown to consist of primary mucous-type glycoprotein molecules containing 70% carbohydrate (MOOR and TIFFANY, 1979). Mucopoly-sacchorides have been separated electrophoretically (McEWEN ET AL.,1958; KRAUSE, 1959; MISHIMA, 1965) and appreciable amounts of sulphated and sialylated glycoprotein material were identified (JENSEN ET AL., 1969; BERADZE ET AL., 1966). In addition, Adams (1979) demonstrated the role of mucous in removing debris from the surface of the anterior eye.

The two most prominant cations in the P.O.T.F. are sodium and potassium (THAYSEN and THORN, 1954), their concentrations given by

Botelho (1964) are 125 and 24.1 milli equivalents per litre of tears respectively. These two cations play an essential role in the osmotic regulation of the extracellular and intracellular spaces. Among the other less significant cations found in the tears is calcium, which may be of significance in soft contact lens patients, as calcium deposits can be an added complication to some (WINDER and RUBEN,1977). Chloride ions are present in the tears in a slightly higher concentration than in serum (128 milli equivalents/litre (BOTELHO, 1964)) and play an important role in osmotic regulation. The presence in the P.O.T.F. of bicarbonate together with carbonate ions may contribute to the regulation of pH (CARNEY and HILL, 1976). It has been noted that the bicarbonate system and many protein species that are present seem to be primary candidates for the buffering properties of the tears (DAVENPORT, 1975; TAPASZTO, 1973). Tear pH (on average 7.35) is a highly individualised function and varies continuously throughout the day (CARNEY and HILL, 1976), as well as from day to day (HILL and CARNEY, 1978).

Organic constituents of low moleculer weight include glucose. However, its concentration is insufficient for corneal nutrition (GIARDINI and ROBERTS, 1959; BALIK, 1961) and it was stated that there is no definite evidence that the cornea metalolizes glucose emanating from the tears. Also present in the tears are urea (JOLLÉS and JOLLÉS, 1967; THAYSEN and THORN, 1954) and free amino acids (BALIK, 1958, 1961).

The P.O.T.F. contains dissolved atmospheric oxygen which supplies the cornea (SMELSER, 1952; HILL and FATT, 1963) and is a sink for metabolic bi-products and cellular debris (FATT and BIEBER, 1968, HANNA ET AL., 1961).

Section 1.3 The Cornea

1.3 i) General Features of Corneal Anatomy

Hippocrates was the first to recognise the cornea, but Galen described, named and recognised it as an anatomic entity. The cornea, the principal refracting surface of the eyes optical system, is transparent and avascular except at the periphery. It is an elliptical meniscus (DRUAULT, 1912), the horizontal diameter (11.7mm) being slightly greater than the vertical (10.6mm) (HOGAN ET AL., 1971). Anteriorly it is limited by the P.O.T.F. and posteriorly by the aqueous. The superficial surface area of the human cornea is $1.3cm^2$ (MAURICE, 1969), with a central thickness of 0.52mm (MAURICE and GIARDINA, 1951 (a)) which thickens towards the periphery.

The cornea comprises five layers (BERLINER, 1949; DUKE-ELDER, 1961; WOLFF, 1968; SALZMANN, 1912; THOMAS, 1955) (fig. 1.2).

1. The anterior epithelium is stratified, squamous non cornified epithelium 5 to 6 cells deep (50 to 90 microns (μ)), which is about 10% of the total central corneal thickness in man (WOLFF, 1968). It is continuous with, and an extension of, the conjunctival epithelium (WALLS, 1963), their tranzitional zone is called the limbus. The life span of epithelial cells has been shown to be 3½ to 7 days (FRIEDENWALD and BUSCHKE, 1944; HANNA and O'BRIEN, 1960) and the corneal epithelium, by means of rapid cell production, can be replaced in 7 days by growth mainly form the basal cells (HANNA ET AL., 1961) and to a lesser extent from the wing cells (MACHEMER, 1966). This high rate of replacement is justified by the corneal epithelium's

importance as a refracting surface and its exposure to frequent injuries, which must be repaired with speed.

2. "Bowman's layer" was first noted in 1849, when it was considered to be a separate membrane. As this is no longer thought to be so, the term "layer" is preferred (McTIGUE, 1967). It is composed mainly of collagen fibres (averaging 240 to 270 Å in diam.) and measures 8 to 14μ m in thickness (THOMAS, 1955; HOGAN ET AL., 1971) Bowman's layer has a smooth anterior surface adjacent to the basement membrane (B.M.) of the epithelium and a less distinct posterior surface blending in with the corneal stroma. Fine extensions of Schwann cells have been observed along the canals of perforating nerves to the corneal epithelium (HOGAN ET AL., 1971), however, recently this has been disputed (LIM, 1977, LIM and RUSKELL, 1978). Towards the periphery Bowman's layer becomes thinner and less dense, and in this zone, cells and even capillaries may appear in its meshes. The collagen fibrils are quite randomly dispersed in Bowman's layer; they are smaller in diameter and less tightly packed than in the corneal stroma. In the periphery of the cornea the arrangement of the fibrils in Bowman's layer is even looser and gradually merges with that of the conjunctiva. The interstices surrounding the fibrils in the layer are filled with microprotein ground substance, probably of the same composition as that of the stroma.

3. The corneal stroma has a thickness of approximately 500μ in man (WOLFF, 1954) and this constitutes approximately nine tenths of the corneal thickness. It is composed almost entirely of collagenous lamellae in which are fibroblasts (VIRCHOW, 1910) and ground substance.

The fibroblasts occupy between 2 and 3% of the corneal stroma in man (MAURICE and RILEY, 1968), and lie flattened in the plane of the tissue within or between the layers anteriorly, or just between the lamellae in the posterior layers (GOLDMAN and BENEDEK, 1968). Though the fibroblasts make contact with each other they do not form a syncytium (JAKUS, 1964; TRIPATHI, 1971). There are approximately 200 lamellae in man which are parallel to each other and flow to the surface of the cornea; the collagen fibrills within each lamella are also all parallel. Each lamella is approximately 2.0μ thick, 9 to 260μ wide and its length encompasses the width of the entire cornea and is continuous with the lamellae of the stroma (SMELSER ET AL., 1965 ; HOGAN ET AL., 1971). The lamellae lie one upon the other, running at various angles in alternate layers (JAKUS, 1964; PAYRAU et al., 1967) and are less orderly arranged in the superficial third of the stroma (McTIGUE, 1967). The remainder of the stromal constituents are phagocytic leucocytes, glycosaminoglycans, ground substance, water salts (MAURICE, 1969; MAURICE and RILEY, 1970) and lymphatics, their presence being only recently confirmed (IMAI and OIKAWA, 1972).

4. Descemet's membrane is the posterior, homogeneous membrane (fig 1.2) which forms the B.M. for the endothelium. It was first noted by Jean Descemet in 1758. It is 10 to 20μ thick in the adult human cornea and is formed by a collagenous lattice. The intersections formed by crossing filaments, from nodes, which are quite exactly superimposed on each other to form a linear pattern (KAYE and PAPPAS, 1962; JAKUS, 1956, 1961; FEENEY and GARRON, 1961). The central unit which is repeated is hectagonal with the dense nodes marking the angles. It has been

described as almost a chrystalline structure (TRIPATHI, 1975). After pathological damage it regenerates, presumably from the corneal endothelium (JAKUS 1964; INOMATA ET AL., 1970).

5. The endothelium comprises a simple layer of thin polygonal (mostly hexagonal) cells, which contain large oval indented nuclei (MAURICE and RILEY, 1968; LAING ET AL., 1975). These are regularly spaced throughout the endothelium in youth, but become less regular with advancing age. It has been suggested that, as endothelial cells are unable to multiply by mitosis in man (MACHEMER, 1966), the replacement of endothelial cells is accomplished by thinning and spreading of the remaining cells and not by cell division (KAUFMAN and KATZ, 1977; OLSON ET AL., 1978). By electron microscopy (E.M.) these cells show all the features of a very active metabolism : large numbers of mitochondria, granules, vesicles, a well developed Golgi body and endoplasmic reticulum. Numerous pinocytotic vesicles are present at the anterior and posterior sides of the cell membrane, while in addition on the posterior surface of each cell are 20 to 30 microvillae (WOLFF, 1968; BLÜMCKE and MORGENROTH, 1967). The inter-cellular borders show complex interdigitations and between the lateral cell membranes there is a gap of 200 Å along most of their length. At the posterior end of the inter-cellular border is an area of dense cytoplasm, where the inter-cellular space narrows to 100 A. This terminal bar or zona occludens is usually covered at the apical end of the inter-cellular space by a flap like projection of the cell (JAKUS, 1962; KAYES and HOLMBERG, 1960; KAYE and PAPPAS, 1962; KAYE ET AL., 1962; DONN ET AL., 1961; IWAMOTO and SMELSER, 1965; OKINAMI ET AL, 1976).

The nerve supply of the cornea originates from the ophthalmic division of the 5th cranial nerve. Bundles of nerve fibres (70 to 80) enter the cornea radially from the limbus losing their myelinated sheaths after 2 to 3mm and dividing as they proceed towards the corneal centre (WOLFF , 1968) Some corneal nerves terminate in the stroma close to Bowman's layer, whilst the corneal epithelial nerves have been described as entering the epithelium, via Bowman's layer, as groups of naked axons (HOGAN ET AL., 1971). This penetration of Bowman's layer by axons has been questioned, suggesting that separate branching of the nerve fibres occur at the limbus to innervate the epithelium (LIM, 1977; LIM and RUSKELL, 1978). The corneal nerve endings are bare with no specialised structures, except occasionally at the limbus (WOLFF , 1968).

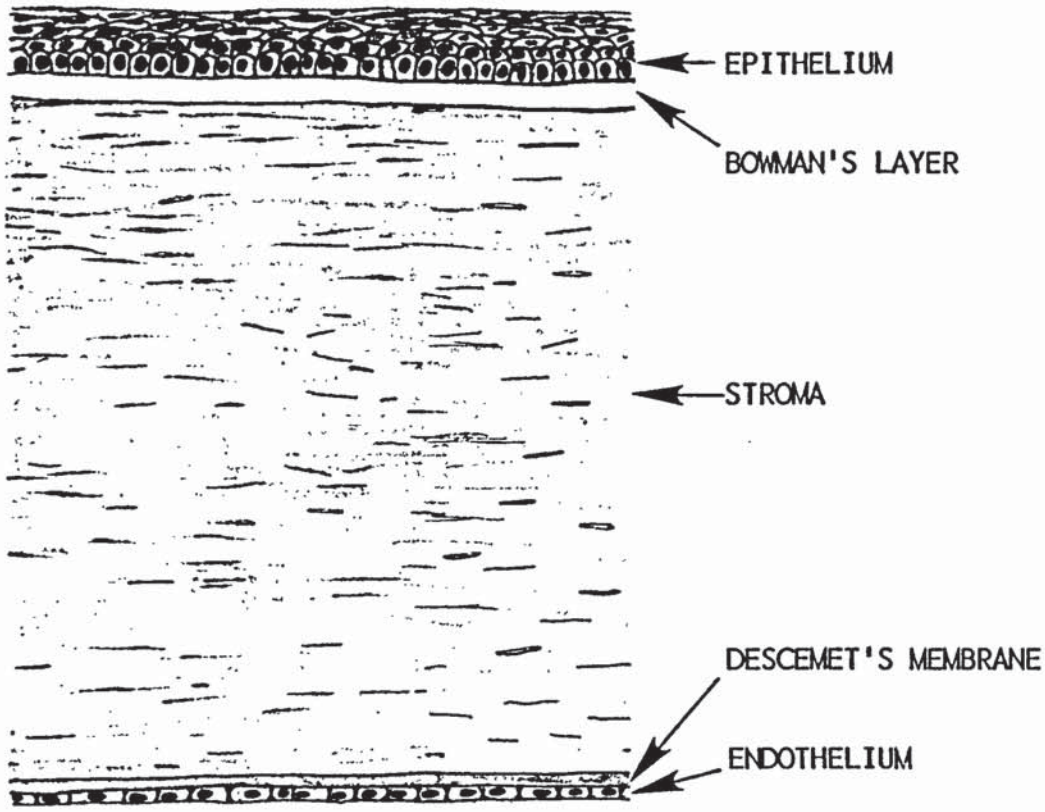


FIGURE 1.2 TRANSVERSE SECTION OF CORNEA

1:3 ii) Microscopic Anatomy of the Corneal Epithelium

The corneal epithelium is the external limiting membrane of the cornea. It therefore has to provide an optically perfect surface as well as fulfilling a protective and regulatory function. The thickness of the epithelium and its cellular arrangement are quite uniform. It consists of three groups of cells (VIRCHOW, 1910) : a single row of basal cells, an intermediate zone two or three cells thick of wing or polygonal cells, and two layers of flattened plate-like surface cells.

The basal layer of the epithelium was originally thought to contain two groups of cells, "clear" and "dark" cells (WOLFF, 1968; EISLER, 1930; VIRCHOW, 1910). Further observations revealed the presence of three more types of cells : polygonal cells (SUGIURA and WAKUI, 1961; SUGIURA ET AL., 1962; WAKUI, 1961) dendritic cells, (SEGAWA and NAKAIZUMI, 1962; SEGAWA, 1964; SUGIURA and WAKUI, 1961),and "pale stained" cells (WAKUI, 1968 (a), (b), 1969). A more recent report has noted that "dark cells" increase in some corneal disorders (TRIPATHI and GARNER, 1972). The structural and functional integrity of these cells and their existence remains controversial (PERERA, 1969; BAUM, 1970). It is generally accepted now that the basal cells are homogeneous (the previously reported differences may be attributed to artefacts in the various fixatives (PERERA, 1969; MARSHALL and GRINDLE, 1978)) tall polygonal in shape and measure 18 μ m by 10 μm. (SALZMANN, 1912; HOGAN ET AL., 1971) (fig 1.3). The basal cells sit on a fine B.M. to which they are attached by numerous hemidesmosomes (PEDLER, 1962; JAKUS, 1961, 1964; KHODADOUST ET AL., 1968). The slightly oval nucleus tends to be perpendicular to the basement

membrane, and is generally towards the apex of the cell in the cytoplasm. Mitosis frequently occurs in this layer.

Lowenstein (1940) and Busacca (1949) were the first to note the presence of the B.M. under the corneal epithelium. The B.M. is a well defined osmiophilic layer measuring 480 A in thickness and it contains fine fibrils and a mucoprotein matrix (HOGAN ET AL., 1971). Opposite the hemidesmosomes of the basal epithelium the B.M. thickens and projects tongue-shaped extensions of dense filaments into Bowman's layer; the length of these increases towards the peripheral cornea. (ISHIDA, 1958(a); HOGAN ET AL, 1971).

Removal of the epithelium usually leaves the desmosomal components of the basal cells and the B.M. attached to Bowman's layer, but in oedema and inflammatory processes the B.M. tends to separate from Bowman's layer and remain attached to the basal cells (TRIPATHI, 1972; TRIPATHI and BRON, 1972). As the B.M. is generated by the epithelium (BLÜMCKE ET AL., 1969) healing of an injury affecting both epithelium and B.M. takes a few weeks, but damage to the epithelium alone takes only a matter of days (KHODADOUST, 1968). Banded sub-epithelial fibrils observed in the limbus have been promoted as possible anchors for the B.M. to the epithelium (RINGVOLD, 1972; PALAD and FARQUHAR, 1965; BRUNS, 1970). Adjacent cells are held together by desmosomes (FAWCETT, 1966) which are fewer than in other cell layers and different in appearance to those seen at the B.M. (PEDLER, 1962). The anterior sides of these cells are in contact with the layer of wing cells through desmosomes and occasional maculae occludentes. The wing cells and basal cells are in close contact, separated by a gap of 100 to 200 Å (WHITEAR, 1960)

and are interlocked by numerous interdigitations (fig 1.3). The cytoplasm of the cell is characterised by the presence of diffusely distributed tonofilaments (which are mostly orientated perpendicular to the surface of the cornea), numerous free ribosomes, rough-surfaced endoplasmic reticulum, and a few small mitochandria and Golgi apparatus. Centrioles are seen more frequently than in other layers. The cells in the basal layer are more mitotic than the cells in the superficial layers of the cornea, and migrate forward into the wing cell layer. There is a certain degree of fluidity at the sites of intercellular adhesion, to allow the constant relocation of associations as cells migrate foward to the corneal surface. In addition to the basal cells lymphocytes, non-epithelial cells (MARSHALL and GRINDLE, 1978) and in the periphery dentritic cells (SEGAWA and NAKAIZUMI, 1962; SEGAWA, 1964) have been observed.

The wing cells, arising from division and forward migration of basal cells into the wing cell layer (HANNA and O'BRIEN, 1960), comprise 2 to 3 layers of closely interlocked polygonal-shaped cells with long oval nuclei (fig 1.3). The anterior surfaces of the cells are convex and the posterior surfaces concave. Each cell joins adjacent wing and basal cells by desmosomal junctions on thin lateral and wing-like extensions. The cell membranes are deeply interdigitated and the maculae occludentes are more numerous than in the basal cells. The cytoplasm of the wing cells contains many diffusely distributed tonofibrils, moderate numbers of mitochondria, a more apparent Golgi apparatus and vesicles which appear in the middle layer of wing cells and increase in size and number as the cells become more superficial.

The two layers of surface cells are flattened and plate-like, measuring up to 45μm in length by 4μm in thickness (HOGAN ET AL., 1971). They are formed by further flattening and migration of the wing cells. The desmosomal attachments and maculae occludentes are more numerous in these superficial cells. The surface cells are the only epithelial cells having a zonula occludent, which is a barrier to extra cellular diffusion preventing penetration of the P.O.T.F. (FAWCETT, 1966; OKINAMI ET AL., 1976). This zonula is found along the lateral walls of the cells near the surface, adjacent to the P.O.T.F.. The anterior cell membrane of the superior cells show many microplicae and microvilli (fig 1.3)(PFISTER, 1973; PFISTER and BURNSTEIN, 1977; BLÜMCKE and MORGENROTH, 1967; KAYE and PAPPAS, 1962). It was suggested that these may be important for retension of the P.O.T.F., but Maurice and Riley (1968) expressed doubt about this theory because of their small size (0.5μm to 1.0μ) in comparison to the thickness of the P.O.T.F. (6μ to 7μ) (MISHIMA, 1965; EHLERS, 1965). The cytoplasm is filled with membrane-bound vesicles, which increase in size towards the surface of the cornea. They seem to be associated with the Golgi apparatus and frequently open into the lateral and posterior intercellular spaces. Glycogen deposits exist only in these cells, and usually they are lost during the processing of the tissues. Observations of dark and pale cells in the squamous layer of the epithelium have been made (JAKUS, 1964). The pale cells were described as probably undergoing gradual disintegration before being sloughed from the epithelium.

FIGURE 1.3

Three Dimensional Drawing of the Corneal Epithelium

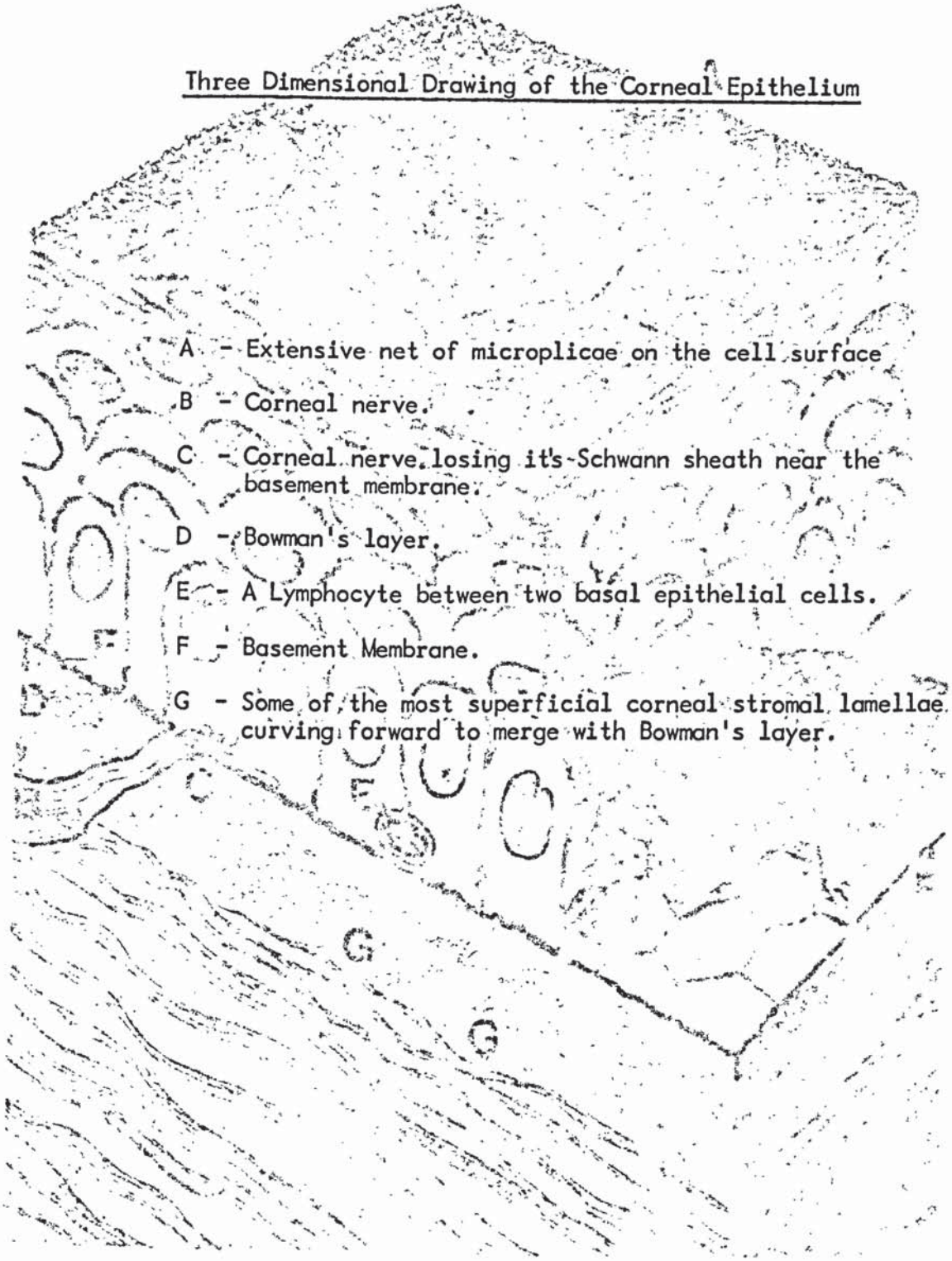


FIGURE 1.3 THREE DIMENSIONAL DRAWING OF THE CORNEAL EPITHELIUM (After Hogan et al., 1971).

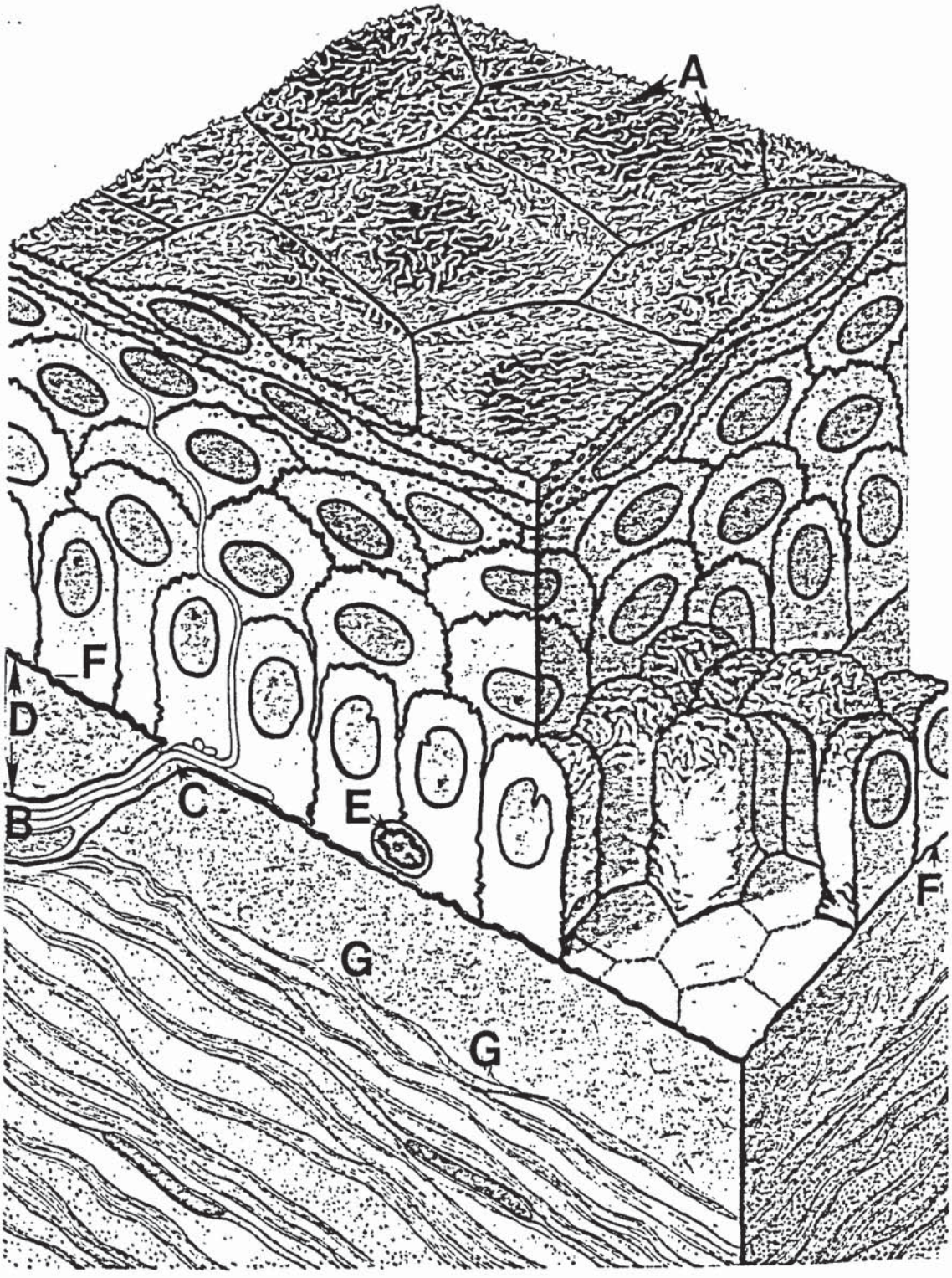


FIGURE 1.3 THREE DIMENSIONAL DRAWING OF THE CORNEAL EPITHELIUM (After Hogan et al., 1971).

1.3 iii) Corneal Transparency and Hydration

Hydration, thickness and transparency of the cornea are all inter-related. The maintenance of those features demands an intact epithelial and endothelial surface (HARRIS, 1957; STANLEY ET AL., 1966). Damage to either of these membranes causes rapid swelling of the stroma (MAURICE and GIARDINI, 1951 (b); MISHIMA and HEDBYS, 1967). Disruption of the P.O.T.F., not only reduces the optical quality of the corneal surface but also results in severe epithelial damage (MAURICE and MISHIMA, 1961). This further leads to epithelial oedema and a resulting reduction in its transparency (POTTS and FRIEDMAN, 1959; ZUCKER, 1966). Damaged epithelium is replaced by epithelial sliding of cells adjacent to the affected area, which rapidly cover the disrupted cells; the rapid rate of healing is vital in maintaining epithelial and stromal transparency (KUWABARA ET AL., 1976). The cornea is also avascular and lacks pigment, except at the periphery where optical properties are not as important.

The stroma is made up of collagen (R.I. 1.47) and ground substance (R.I. 1.34) (MAURICE, 1957). It has been suggested that transparency in the stroma is the result of promoted directional constructive interference along the path of the incident light; destructive interference of light occurring in all other directions (MAURICE, 1957). These interferences (MAURICE, 1957) occur provided that the separation of fibrils in the lattice of uniformly spaced callagen fibrils is less than the wavelength of light. However, later studies have shown that this perfectly orientated lattice is not necessary for transparency (COX ET AL., 1970; FEUK, 1970). A further theory suggested that the tissue remains transparent, provided the spacing between light

scattering elements (e.g. cells and collagen fibrils) is less than half the wavelength of light ($\frac{1}{2}\lambda$) (GOLDMAN and BENEDECK, 1967). Observations of apparent scattering of light corresponded to collagen free "lakes" (diam larger than $\frac{1}{2}\lambda$) in the oedematous cornea, and thus supported the previous theory (GOLDMAN ET AL., 1968). Summarising, transparency of the cornea is lost if disruption or deviation from the normal occur in the following:-

a) Adherance of P.O.T.F.

b) Regularity and integrity of the epithelium and endothelium.

c) Regularity of collagen fibrils and stromal lamellae.

d) Avascularity and lack of pigment.

The epithelium offers a small diffusion flux to water (COGAN and KINSEY, 1942 (a); DONN ET AL., 1963), however, the water permeability of the epithelium, as measured by many authors (MISHIMA and HEDBYS, 1967; GREEN and GREEN, 1969; RILEY, 1971; STANLEY and WINSTON-SALEM, 1972; GREEN and DOWNS, 1973; WILSON and FATT, 1974), is less than that of the endothelium (GREEN and GREEN, 1969). Also the epithelium shows a slightly higher resistance to ions and other fat insoluble substances than the endothelium (MAURICE, 1951, 1953, 1961; GREEN and GREEN, 1969; DONN ET AL., 1963), but never the less, both are extremely high (MAURICE, 1953).

When the eyelids are open, evaporation from the P.O.T.F. occurs, which results in hypertonicity of the P.O.T.F. and withdrawal of water from the corneal epithelium by osmosis (MISHIMA and MAURICE, 1961 (a) (b);

MISHIMA; 1965). A loss in corneal thickness of approximately 4% has been noted in the open eye of rabbit and man (MISHIMA and MAURICE, 1961 (a),(b); MANDELL and FATT, 1965). Further work however, has shown that the presence of the epithelial layer is not essential for the control of corneal hydration (MISHIMA and KUDO, 1967; RILEY, 1971; DIKSTEIN and MAURICE, 1972).

Temperature experiments indicated that a metabolic pump in the endothelium existed (HARRIS and NORDQUIST, 1955; HARRIS, 1960). Later work has supported and confirmed this theory; the endothelium is the major factor in the control of corneal hydration (RILEY, 1971; TRENBERTH and MISHIMA, 1968; DONN, 1966; MAURICE , 1972; HODSON, 1977). However, the precise nature of the pump is not completely understood, though current authors agree as to the likely nature (SILVERMAN and GERSTER, 1973; LÖNNERHULM, 1974; YOKOTA and WALLER, 1975; HODSON and MILLER, 1976; MAYES and HODSON, 1978, 1979; HODSON ET AL., 1981), where bicarbonate ions are pumped into the aqueous by the endothelium. The mechanism by which bicarbonate ions are actively pumped across the posterior membrane is unknown, though endothelial ATP-ase activity was shown to be stimulated in the presence of bicarbonate ions (RILEY, 1977) , which could link the pump mechanism to the energy producing systems of the endothelium.

Damage to the epithelium or the endothelium, results in stromal swelling. The swelling is greatest when the endothelium is damaged (MAURICE and GIARDINI, 1951 (b)), because the intra-ocular pressure forces the fluid into the stroma (ANSETH and DOHLMAN, 1957), while, in the case of epithelial damage, the intra-ocular pressure opposed the swelling. The site of expansion in the stroma seems to be the ground

substance surrounding the collagen fibrils (HERINGA ET AL., 1940; WOODIN, 1954). The corneal stroma therefore has a natural tendency to imbibe water from its surroundings, which must be inhibited to maintain corneal transparency (PAYRAU ET AL., 1967). The normal environment of the cornea must be maintained, by controlling the normal balance of other influential factors, which include pH in vitro, ionic environment (GOGAN and KINSEY, 1942, (a) (b); HODSON, 1977), intra-ocular pressure (if over 40 (mm Hg) (YTTEBORG and DOHLMAN, 1965), and the many factors that affect metabolic function.

1.3 iv) Nutrition and Metabolism of the Cornea

In the normal cornea, most energy is derived from glycolitic metabolism (MISHIMA and HEDBYS, 1968; DE ROETTH, 1950). The concentration of glucose in the tears is low (GIARDINI and ROBERTS, 1950; EHLERS, 1965; REIM ET AL., 1967 (a),(b)), which coupled with the fact that the epithelium is impermeable to glucose eliminates the P.O.T.F. as an energy source of any significance.

The cornea has a high resistance to lateral movement of solutes (MAURICE and WATSON, 1965; MISHIMA and HEDBYS, 1967; MAURICE and RILEY, 1968 1970; THOFT and FRIEND, 1972). The perilimbal vascular structure is therefore only to supply the peripheral cornea with oxygen and glucose.

The Aqueous Humour has a concentration of glucose ten times that of tears in the normal eye (WALKER, 1933; REIM and LICHTE, 1965; REIM ET AL., 1967 (a), (b); HALE and MAURICE, 1969; BRUUN-LAURSEN and LORENTZEN, 1973; STEVENS-ANDREWS, 1976) and is the main source of glucose supply in vivo (KNOWLES, 1961; POLLACK, 1962; BROWN and MISHIMA, 1966; TURSS ET AL., 1970, 1971; THOFT ET AL., 1971). Transport of glycogen via simple diffusion alone, would be insufficient (RILEY, 1969 (a), 1972; THOFT and FRIEND, 1972; MAURICE, 1969), therefore an active movement of glycogen across the endothelium has been suggested (HALE and MAURICE, 1969).

Glucose metabolism in the corneal epithelium proceeds partly by the direct oxidative pathway (hexosemonophosphate shunt) or via the glycolysis pathway to yield lactic acid (anaerobic glycolysis) or to

complete conversion to yield water and carbon dioxide (aerobic glycolysis) (KINOSHITA, 1962). The cornea stores glucose in the form of glycogen which can be used as substrate for energy - producing metabolism of the cornea (CALMETTES ET AL., 1956; HERRMANN and HICKMAN, 1948,(a), (b); KAMEI, 1959; LANGHAM, 1954; TURSS ET AL., 1970; THOFT and FRIEND, 1972; REIM and LICHTE, 1965, STEVEN-ANDREWS, 1976). The turnover rate of energy production from the epithelial glycogen pool is continuous but slow (MISHIMA and HEDBYS, 1968; MAURICE and RILEY, 1970; MAURICE, 1969). When the cornea is under stress and glucose supplies are reduced, the epithelial glycogen reservoir is capable of maintaining corneal hydration for approximately 34 hours (HERRMANN and HICKMAN, 1949 (a); MISHIMA and HEDBYS, 1968; MAURICE and RILEY, 1970). In the cornea the product of glycolysis, pyruvate, is converted to lactic acid by the action of LDH, and to carbon dioxide and water by the Krebs Citric Acid Cycle. The production of carbon dioxide from the breakdown of pyruvate is slower than the rate of pyruvate production, therefore there is a lactic acid excess in the tissues of the cornea, which can be classed as a carbohydrate energy reserve, as lactic acid may be used as a substrate in Krebs Citric Acid Cycle (KUHLMAN and RESNIK, 1959). The lactic acid produced from glycolysis is usually lost posteriorly to the Aqueous Humour (MAURICE and RILEY, 1970), with a small amount leaving the cornea via the tears (REIM ET AL., 1972; RUBEN and CARRUTHERS, 1972; RILEY, 1972). The lactic acid reservoir in the cornea is capable of maintaining corneal respiration for a period of up to 3 hours in the absence of glycogen (KUHLMAN and RESNIK, 1959).

The cornea obtains most of its oxygen from the atmosphere by direct diffusion across the epithelium (HEALD and LANGHAM, 1953, 1956; LANGHAM, 1952; WEISSMAN ET AL., 1981). This is promoted by the oxygen tension gradient across the cornea in the open eye, where the partial pressures of oxygen in the atmosphere and Aqueous Humour are 155 mm Hg respectively (FATT ET AL., 1974). Recently it was shown that the oxygen flux at the posterior surface of the cornea exists from Aqueous Humour to cornea (FATT ET AL., 1974; KWAN ET AL., 1972) in some disagreement with previous findings (FATT and BEIBER, 1968). The cornea receives sufficient oxygen in the closed-eye situation; it is generally considered that this supply is provided by the palpebral conjunctiva (LANGHAN 1954; FATT ET AL., 1969) which supplies oxygen at tension levels between 55 and 70 mm Hg (KWAN and FATT, 1971; FATT and BEIBER, 1968; WEGENER and MOLLER, 1971). The critical level of oxygen tension at the anterior corneal surface is 20mm Hg. At this level and below the corneal oxygen consumption rate is reduced (FATT ET AL., 1969).

Reduced oxygen and carbohydrate in the cornea results in breakdown of cellular integrity and deturgescence in the cornea (DE ROETTH, 1950; DUANE, 1949 (a),(b); SMELSER, 1952; DAVSON, 1955; SCHWARTZ ET AL., 1954; SMELSER and OZANICS, 1952; SMELSER and CHEN, 1955; LANGHAM and TAYLOR, 1956; HARRIS and NORDQUIST, 1955; HARRIS, 1957; RILEY, 1969 (b)).

Section 1.4 The Anterior Limbus

1.4 i) Introduction

Location and General Structure

The linked transition zone is composed of elements of both the cornea and the sclera. The pathologist considers the anterior limit of the limbus to be formed by a plane joining the peripheral termination of Bowman's Layer to Descemet's membrane, and the posterior limit to be formed by another plane constructed perpendicular to the surface of the eye 1.5mm posterior to the first plane, passing through the scleral spur (HOGAN, ET AL., 1971) (fig 1.4). Histologically, the junction of the cornea with the sclera is an arc commencing at Bowman's layer and ending close to Descemet's membrane in the trabecular meshwork (fig 1.4). The apex of the arc is adjacent to the midpart of the canal of Schlemm. The pathologists limbus is more useful in clinical descriptions, where surrounding tissue changes can be related to the circular zone of tissue, around the cornea. The limbal and peripheral conjunctival capillaries, which emanate from the limbus, provide nourishment for a small part of the peripheral cornea (MAURICE, 1960; HOGAN ET AL., 1971). The limbus is also the transportation media for the long posterior ciliary nerves which supply the cornea.

FIGURE 1.4

Drawing of a Meridional Section of the Limbal Area

The Limbus has the following gross anatomic parts:

a - Conjunctival Epithelium

b - Conjunctival Stroma

c - Tenon's Capsule and Episclera

d - Limbal or Corneoscleral Stroma

e - Longitudinal portion of the Ciliary Muscle.

f - Circular and Radial bundles of the Ciliary Muscle.

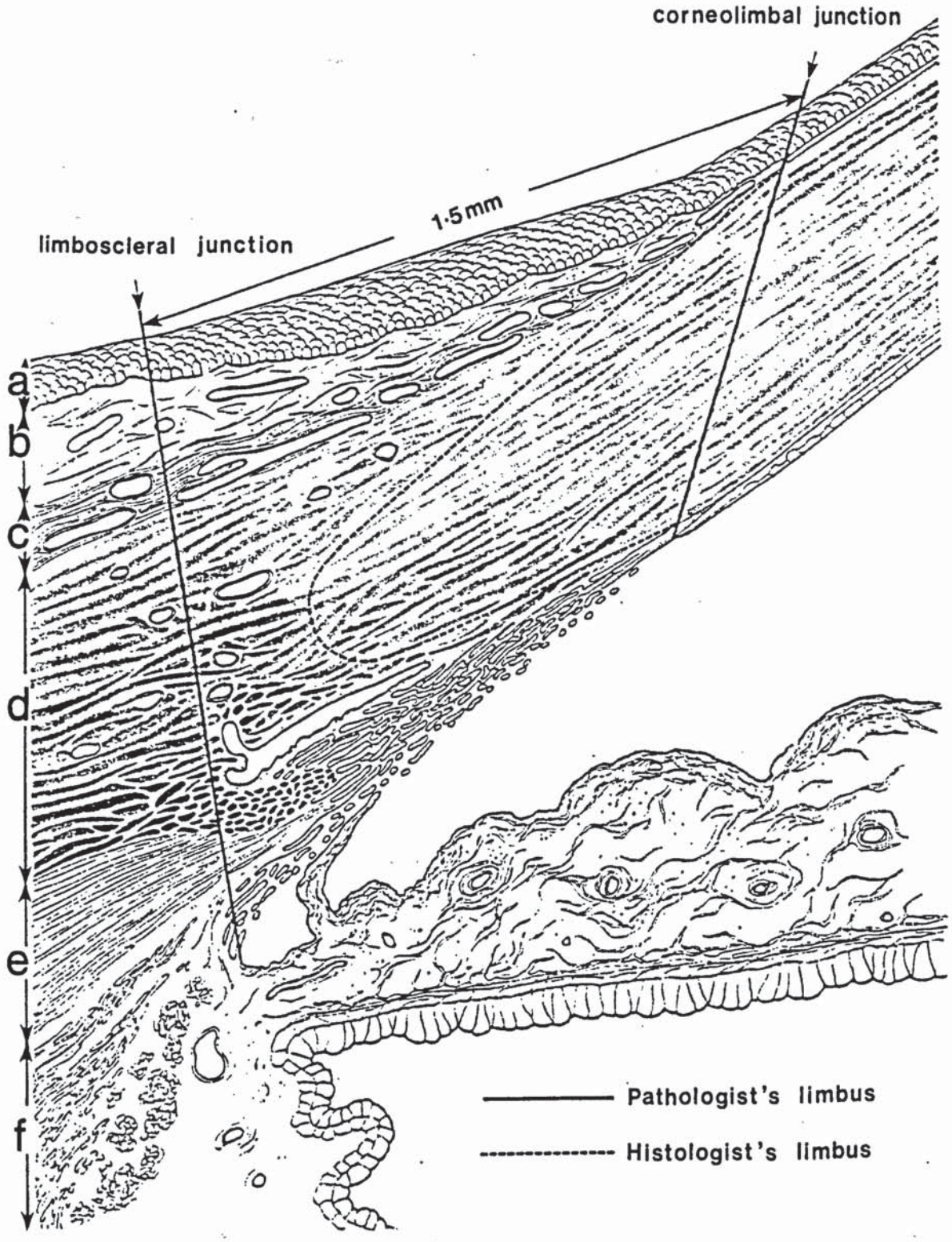


FIGURE 1.4 DRAWING OF A MERIDIONAL SECTION OF THE LIMBAL AREA (After Hogan et al., 1971).

1.4-ii) Microscopic Anatomy of the Anterior Limbus

At the corneal edge, the number of cell layers in the conjunctival epithelium increases from 3 to 4 or 10 to 15 (DUKE-ELDER and WYBAR 1961), this increase occurring mainly in the wing cells. The general appearance and organization of the perilimbal conjunctival epithelium is similar to that of the cornea. However, the superficial cells are not as smooth as those of the cornea and the basal cells follow the somewhat folded appearance of the conjunctival stroma. The basal cells are more closely packed (THOMAS, 1955), but the B.M. has the same thickness and structure as that of the cornea. Melanin granules are frequently seen in the basal and wing cells (HIWATARI, 1921); the amount of pigment being smaller in blue eyes than heavily pigmented eyes (PERGENS, 1898; COPPEZ, 1905; FISCHER, 1905; KUSEL, 1907). The ultrastructure of the limbal epithelial cells is similar to those of the corneal epithelium with only a few differences. The conjunctival cells have larger mitochondria and their cytoplasmic filaments form dense bundles, which occasionally are closely associated with desmosomes. The presence of vesicles in the cytoplasm of wing and surface cells gradually decrease towards the posterior limbus. Lymphocytes and melanocytes are found in the basal and suprabasal layers of the limbal conjunctival epithelium, while extending dendritic processes, which pass into the wing cell layers, have been observed. Langerhan's cells have been noted in the suprabasal portion of the epithelium at the limbus (SUGIURA and MATSUDA, 1968; SEGAWA and NAKAIZUMI, 1962; SEGAWA, 1964), which also have dendritic processes, but contain no pigment. Their function is unknown. Recent work on rats has shown that mitosis of the epithelium in the conjunctival perilimbal region occurs in the basal layer, and the dividing cells

are orientated with respect to the limbus (WORGUL and SRINIVASAN, 1978)

The epithelium and the conjunctival stroma from rete pegs and papillae at the periphery of the cornea (CIACCIO, 1873; VILLARD, 1896; NAKAGAWA, 1905; WHITNAL, 1932) in what is generally known as the palisades of Vogt (VOGT, 1921) (fig. 1.5). The palisade zones comprise two narrow crescent shaped bands of thickened epithelium at the upper and lower limbus. The papillae are richly vascularized and are orientated like the spokes of a wheel, radiating outward from the corneal edge into the conjunctiva. Between the papillae the thickened epithelium projects downwards forming counterparts of the rete-pegs of the skin. Using fluorescein angiography (BRON and GOLDBERG, 1980) it was recently noted that there is a wider variation between individuals than had been previously thought. Also it has been suggested that the palisade zones play an important part in regeneration of the corneal epithelium in normal and inflammed eyes (DAVANGER and EVENSEN, 1971; BRON, 1973). The small vessels and nerves run along the lateral edges of the papillae, while the lymphatics are central and deeper. The nerves are unmyelinated and branch considerably upon entering the conjuctival stroma and basal epithelial layer; whose sensory nerve supply they provide. The connective tissue is more dense near the end of Bowman's layer and contains numerous fibroblasts (Ringvold, 1972), macrophages, mast cells, lymphocytes, plasma cells and occasional plymorphonuclear and eosinophilic leucocytes. The rest of the stroma comprises coarse collagen which is in loosely arranged bundles. The presence of mast cells in the limbal region has been studied extensively because of their possible relation to allergic reactions (IWAMOTO and SMELSER, 1965; JAKUS, 1961; LEWIS, 1964; SPECTOR and WILLOUGHBY, 1964). In the limbal zone of the conjunctival epithelium banded sub-epithelial

fibrils have been noted (RINGVOLD, 1972; PALADE and FARQUHAR, 1965; BRUNS, 1970). Furthermore, it has been suggested (RINGVOLD, 1972; PALADE and FARQUHAR, 1965; BURNS, 1970) that as the banded sub-epithelial fibrils are associated with the B.M. they may act as an anchor for the B.M. to the epithelium. The posterior limiting membrane of the conjunctival stoma is Tenon's capsule. It is a dense collagenous layer which becomes thinner anteriorly and terminates a short distance from the cornea, in the limbal episclera (a thin layer comprising dense connective tissue).

The limbal or corneoscleral stroma is made up of an anterior part where the collagen bundles are arranged like those of the cornea and are orientated meridionally towards the recti muscles, the posterior section is more like the scleral stroma, where the collagan bundles are completely circular near the scleral spur. Collagen fibrils persist for a considerable distance in the limbus (posterior to the end of Bowman's layer and Descemet's membrane) where they frequently branch and form extensive intercommunications. Spacing of the fibrils is not so uniform and posteriorly they assume similar dimensions to those in the sclera (700 to 800 A) (HOGAN ET Al., 1971). Macrophages and leucocytes are seen here in small numbers. Nerves, both myelinated and unmyelinated which are destined for the cornea are also present in the limbus (SCHLEMM, 1830; BOCHDALEK, 1837). Near the periphery of the cornea Descemet's shows periodic thickenings which bulge into the anterior chamber; these protrusions are known as Hassall-Henle Warts (HASSALL, 1846; HENLE, 1866). The endothelium becomes extended over these warts and the endothelial cell size increases (WOLFF, 1968). Posterior to the termination of the endothelium is the corneal limbal junction, occasionally known as Schwalbe's ring (SALZMAN 1912; ALLEN

ET AL., 1955; BURIAN ET AL., 1955). However, the Schwalbe's ring must be considered as a variant of the structure of the chamber angle (ALKEMADE, 1970). At the periphery of Descemet's membrane electron microscopy has revealed the presence of different types of fibre (FEENEY and GARRON, 1961; JAKUS, 1956, 1962), which may represent a specific functional system, the nature of which is unknown (PREZIOSI, 1968).

FIGURE 1.5

A Drawing of the Peripheral Corneal Vascular Arcades and the Palisades of Vogt .

A - Termination of Bowman's layer at the periphery of the cornea.

Co - Cross-section of the Conjunctiva shows the Palisades of Vogt.

B - Epithelial rete pegs and stromal papillae (arrows) form the Palisades.

ACA - Anterior Ciliary Artery.

EA - Episcleral Arteries, formed from the Anterior Ciliary Artery.

D - Superficial Marginal Arterial Plexus of the Limbus.

E - Terminal vessels from the peripheral cornela arcades near the termination of Bowman's layer.

F - Recurrent vessels also form part of the peripheral arcades.

EVP - Episcleral Venous plexus is deep to the Palisades of Vogt.

The lymphatics are coloured green:

G - The peripheral Lymphatic system.

H - Superficial Radial Lymphatics

I - Deep Radial Lymphatics.

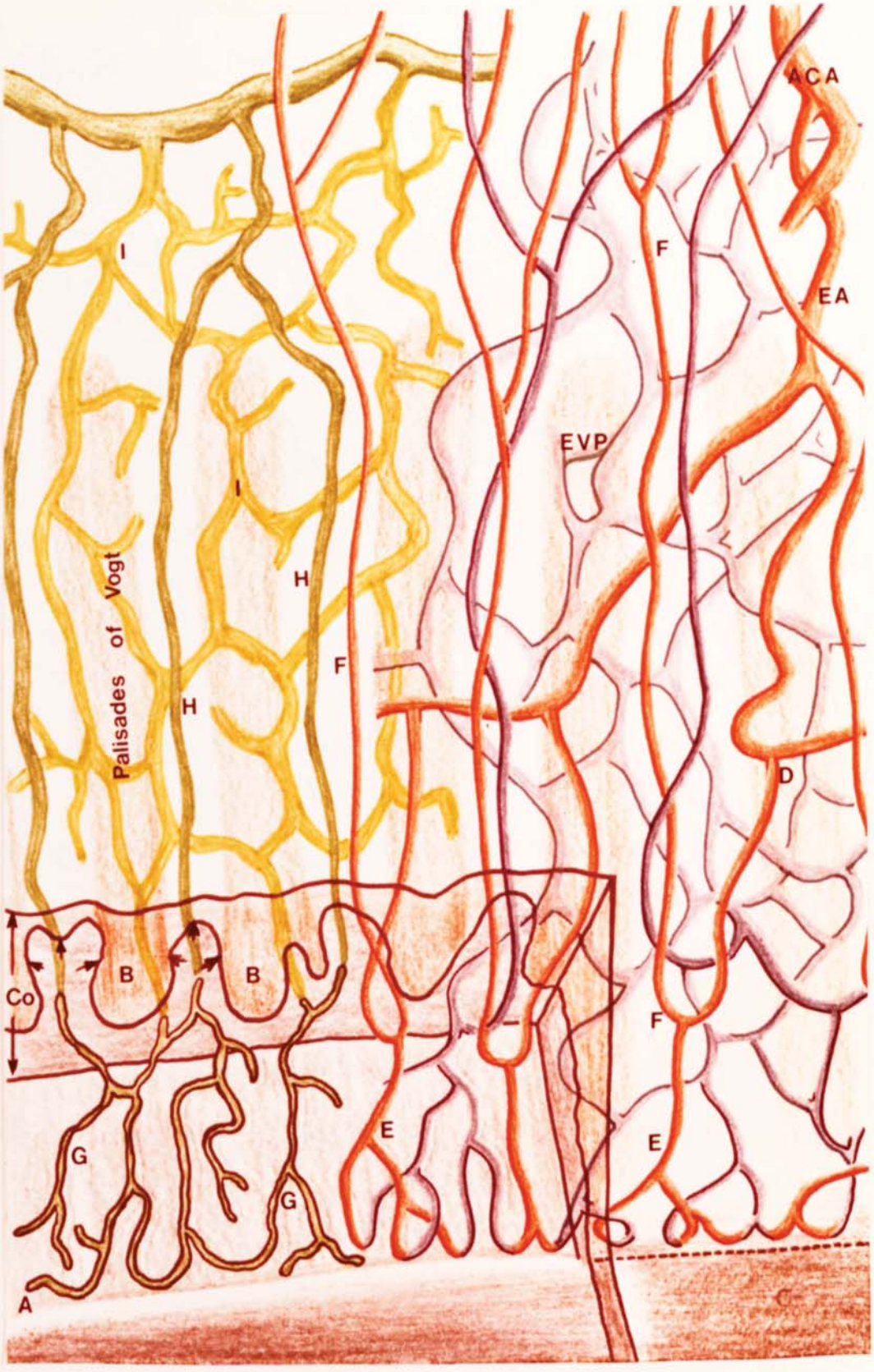


FIGURE 1.5 A DRAWING OF THE PERIPHERAL CORNEAL VASCULAR ARCADES AND THE PALISADES OF VOGT (After Hogan et al., 1971).

1:4 iii) The Blood Vessel Network of the Anterior Limbus

The superficial marginal plexus of the limbus is derived from the branches of the anterior ciliary arteries (KNÜSEL, 1924; ASCHER, 1924; BUSACCA, 1939, 1952; NATAF ET AL., 1951) it encircles the cornea and provides small branches which pass forward in the papillae of the palisades of Vogt giving off two sets of vessels (DUKE-ELDER and WYBAR, 1961) (fig1.5) : the "terminal" ones form the peripheral corneal arcades and then become venous, the second "recurrent", group of vessels form some of the peripheral corneal arcades and run posteriorly to supply 3 to 6mm of the perilimbal conjunctiva then they anastomose with the recurrent conjunctival vessels from the fornices (fig 1.6). The microscopic structure of the arterial channels is similar to that seen elsewhere.

The conjunctival capillaries are mainly of the nonfenestrated continuous type, having a relatively uniform thickness and a well defined B.M.. Some, however, do show thinning with fenestrations in the endothelium, which are not patent pores but are closed by a thin membraneous diaphragm (IWAMOTO and SMELSER, 1965; TAMURA, 1967; HOGAN, ET AL., 1971). The lateral endothelial cell membranes show extensive interdigitations, and a zonula occludens is found near the capillary lumen. Pericytes, which are sparse, are surrounded by a B.M. which is continuous with that of adjacent endothelial cells.

Episcleral arterial vessels mostly arise from the branches of the anterior ciliary arteries (BUSACCA, 1939, 1952). They supply all the subconjunctival tissue and anastomose with the more superficial conjunctival vessels (which are of a similar structure).

The venous return from the conjunctival capillaries flows posterior into the episcleral vessels. The limbal stroma has two venous nets : the deep scleral plexus and the intra-scleral plexus which also drain posteriorly into the episcleral veins.

The conjunctival lymphatics first noted by Leber (1876) comprise 3 groups (BUSACCA, 1952) : 1) a peripheral system which lies either sub-epithelially or deep in the conjunctiva and is associated with the terminal arcades of the limbal artery system; 2) radial lymphatics, extending through the palisades of Vogt deep to the blood vessels; and, 3) branches from the radial lympatics that become deep in the sub-conjunctival region, forming irregular net drains either temporally or nasally. Two large lymphatic trunks are found superiorly and inferiorly, about 7 to 8mm from the limbus and parallel to it (ORTS-LLORCA, 1929, 1930). From these two the nasal and temporal trunks are formed which drain into the submaxillary and preauricular lymph nodes respectively and thence to the superficial cervical nodes(MOST, 1905; ORTS-LLORCA, 1930; DUKE-ELDER and WYBAR, 1961; LOCKHART ET AL., 1959; WOLFF, 1968).

The lymphatics differ in structure from the capillaries in that they have a larger lumen (FRALEY and WEISS, 1961; LEAK and BURKE, 1966, 1968), a thinner endothelial lining, and an absence of complete B.M. (CASELY-SMITH, 1964; COLLIN, 1970 (a)), pericytes (FRALEY and WEISS, 1961; CASELY-SMITH and FLOREY, 1961), specialized junctions (CASELY-SMITH, 1964) and fenestrae (CASELY-SMITH and FLOREY,1961; CASELY-SMITH 1964; IWAMOTO and SMELSER, 1965). Later work described the presence of anchoring filaments in conjunctival lymphatics (LEAK and BURKE, 1966,

1968). This has been supported by Collin (1969), who has suggested that the anchoring filaments are responsible for maintaining the patency of the lymphatics in oedema of the surrounding tissue.

FIGURE 1.6

DRAWING of a Meridional Section of the Eye to show the Blood Supply of the Limbal Area.

Red indicates arterial channels.

ACA - Anterior Ciliary Artery.

E - Episcleral branch of the Major Ciliary Artery.

MP - Major Perforating branch of the Anterior Ciliary Artery.

C - Conjunctival vessel.

IS - Intra-sclera vessel.

SMP - Superficial Marginal Plexus of the Cornea.

a - Peripheral corneal arcade.

b - Recurrent vessels.

(Both "a" and "b" arise from the superficial marginal plexus).

MAC - Major Arterial Circle of the iris.

d - A branch from the major perforating artery passes forward to form the intra-scleral arterial channels of the limbus.

e - Episcleral vessel arising directly from the anterior ciliary artery.

Venous channels are blue.

f - The deep scleral venous plexus.

Sc - Schlemm's canal (Sc)

g - Aqueous vein.

h - The intra-scleral venous plexus.

CP - Ciliary plexus.

i - A deep, intra-scleral venous plexus channel.

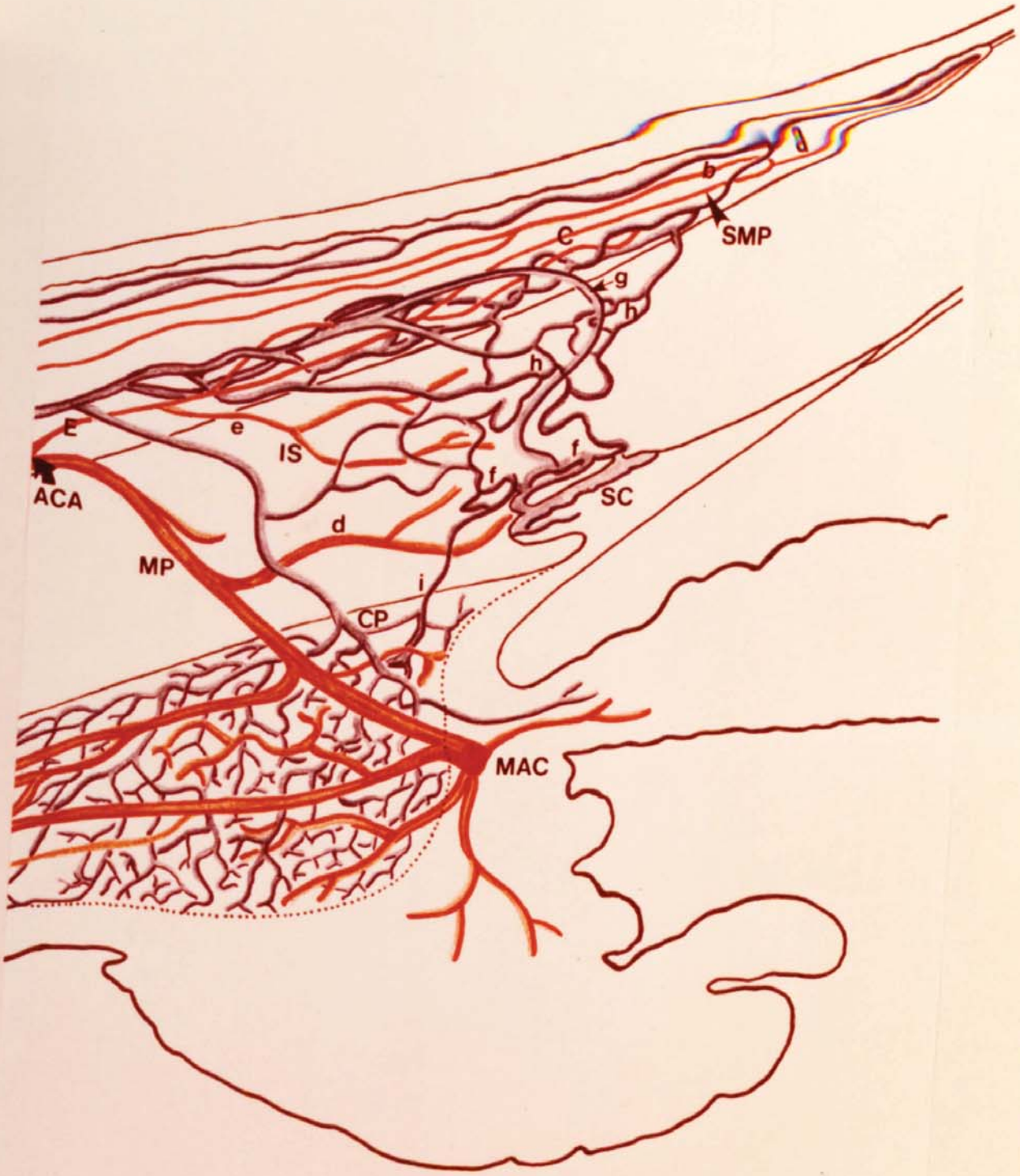


FIGURE 1.6 DRAWING OF A MERIDIONAL SECTION OF THE EYE TO SHOW THE BLOOD SUPPLY OF THE LIMBAL AREA (After Hogan et al., 1971).

CHAPTER 2

The Ocular Response to Contact Lens Wear

Section 2.1 Neovascularization of the Cornea

2.1 i) Introduction

The normal mammalian cornea, bathed posteriorly by the aqueous and anteriorly by the tear fluid, is devoid of vessels except in a narrow zone at its periphery. If the peripheral vessels grow into the cornea they must penetrate the extracellular phase, the permeability of which is determined mainly, but not wholly, by the state of the inter-fibrillar ground substance, a highly polymerised carbohydrate protein complex, which would indicate that an invasion of the cornea by new vessels must be preceded by a decrease in the compactness of this extracellular volume and possibly the addition of other factors. However, the conditions necessary for the induction of corneal vascularization are not completely understood. Corneal compactness (COGAN, 1948, 1949 (a)), hypoxia (BESSEY and WOLBACH, 1939; JOHNSON and ECKARDT, 1940), constitutional factors (LEOPOLD ET AL., 1969), inflammation (JULIANELLE and LAMB, 1934), hydrogen ion gradients (SWINDLE, 1938), toxins (HAESSLER, 1927), various vaso-stimulating factors (V.S.F.) (ASHTON and COOK, 1953; CAMPBELL and MICHAELSON, 1949; ZAUBERMAN ET AL., 1969; OFFRET and CHAUVET, 1950 (b); MAURICE ET AL., 1966; ELIASON, 1978), destruction of vascular inhibitors present in normal corneas (BASCHSICH and WYBURN, 1947; MEYER and CHAFFEE, 1940; SMITH, 1961), macrophages (SHOLLEY ET AL., 1978) and neutrophils and neutrophil products (JANOFF and SCHERER, 1968; JANOFF and ZELIGS, 1968; JANOFF, 1970; FROMER and KLINTWORTH, 1975,

(a), (b); KLINTWORTH, 1973, 1977) have all been implicated as stimulating factors in corneal vascularization. Before discussing the different theories of corneal vascularization stimulation, however, some of the known features of growing blood vessels will be considered.

2:1 ii) The Major Aspects of Corneal Neovascularization

2:1 ii)(a) The Formation and Classification of Growing Corneal Vessels

Clinically, corneal vascularization is initially characterized by an engorgement of the perilimbal plexus and then by an invasion of the cornea by newly formed vessels. The mode of development of corneal vessels has been described either as a sprouting of free-ending capillaries (SCHÖBLE, 1887; EHLERS, 1927; JULIANELLE and BISHOP, 1936; COGAN, 1949, (a), 1962), otherwise known as budding (COGAN, 1949 (a), (b)) or as the pushing forward of vascular loops (BRÜCKNER, 1909; KOEPPE, 1920; KREIKER, 1923; WOLTER, 1958). Both processes can, however, be active at the limbus (SWINDLE, 1938). Cogan (1948) and Mann and her colleagues (1948) have shown that neovascularization is preceded by the engorgement of the parent vessels, chiefly the venules and capillaries, with the formation of saccular aneurysms on their walls, more prominently on the side of the vessel toward the lesion (COGAN, 1949 (a), (b)). After a period of approximately two days, these aneurysms eventually burst and the resultant haemorrhages seep between the lamellae of the oedematous corneal stroma to form spicule-like masses, which are invaded by endothelial cells derived from the capillaries (JULIANELLE and BISHOP, 1936). It was suggested that stromal cells take part in the formation of new vascular channels (PAU, 1957), but this possibility has been denied (WOLTER, 1958). New vessels invade the cornea from the limbus at the level of the pathological process within this tissue, so that the depth at which they are seen may be indicative of the depth of the active changes. Vascularization is classified clinically, according to the depth at which it occurs, into superficial, interstitial on deep vascularization.

Superficial vascularization originates from the superior limbic plexus by budding or loop formation (COGAN, 1949) and passes without interruption onto the cornea from the conjunctival circulation (GRAVES, 1934; SWINDLE, 1938). The superficial marginal plexus of the cornea is derived largely from the episcleral branches of the anterior ciliary arteries, and may be divided into three zones (fig 2.1(a)) (DUKE-ELDER, 1965) : the palisade zone where the feeding vessels advance through the limbus, the zone of vascular loops running just beneath the epithelium, and a terminal narrow zone of end capillary loops. In normal circumstances many of these vessels are empty and most are difficult to see, but they are readily visible in conditions of congestion. These capillary loops do not normally extend beyond the serrated rim of the normal limbal opacity, but lie along the line where the limbal curve changes to the corneal, which is readily seen in the direct beam of the slit-lamp (fig 2.1(a))(WILSON, 1932). If they cross the limit of the limbus as a further series of vascular loops, the vascularization is pathological (fig 2.1(b))(WILSON, 1932). Graves (1934) illustrated the method of development of superificial vessels during growth (figs 2.2(a) - (d)). "Pilots" grow out to meet the exigences of changing inflammatory activities. Collateral channels are constricted to force the blood in the needed direction, and eventually channels become obliterated when these activities cease. The vascular invasion may be confined to a segment of the cornea (described as fascicular) or may extend around the entire limbus (termed a Pannus). In widespread disease of the epithelium, with no regularly arranged tissue to circumscribe their course, superficial vessels tend to run irregularly and tortuously, showing rich arborescent branching and disorderly anastomoses. The arteries are narrow, and as a rule,

straight; the veins are thicker and more sinuous, sometimes showing sacculations and tortuosities. The vessels are usually situated beneath the epithelium (BUSACCA, 1952) and during their active growth they are accompanied by inflammatory cells (COGAN, 1962).

Interstitial vascularization is generally derived from the anterior ciliary arteries. These interstitial vessels tend to be straight, following the divisions of the corneal lamellae, and branch in a characteristic brushlike manner (EHLERS, 1927). However, in severe conditions, the interstitial vessels may take on various different forms which have been classified into the following types : terminal loops, brush form, parasol form, umbel form, network form, interstitial arcades and aberrant vessels (SPICER, 1924; OFFRET and CHAUVET, 1950 (a); BUSACCA, 1952).

Deep vascularization is more rare than the other two types. It is a late phenomenon occuring in interstitial keratitis when associated with uveitis. The vessels invade the cornea, by budding, from the iris. They penetrate the oedematous uveal trabeculae, and enter the cornea immediately infront of Descemet's membrane (BUSACCA, 1945, 1952; OFFRET and CHAUVET, 1950 (a)). In such conditions the vessels may remain permanently as the infiltrate becomes organised into connective tissue.

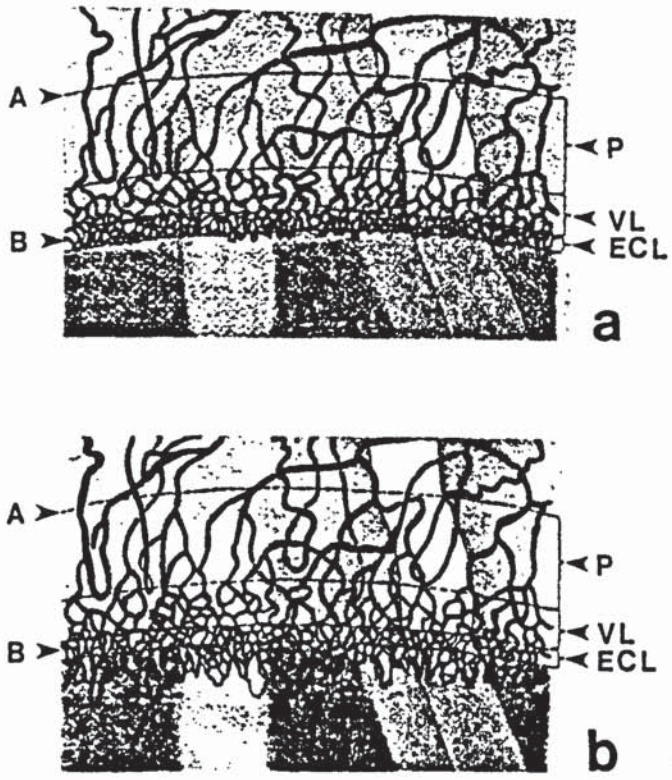


FIGURE 2.1 SLIT LAMP OBSERVATION OF THE LIMBUS

a) The normal limbus
b) Early trachomatous pannus showing the extension of the end-capillary loops into the cornea
(After Thygeson; from Wilson, 1932).

P - Palisade zone
VL - the zone of vascular loops
ECL - the zone of end-capillary loops
A - the primary groove
B - the secondary groove.

FIGURE 2.2

The Evolution of Superficial Corneal Vascularization.

a. Vascular structure prior to the superficial corneal vascularization.

b. Vascular activity has produced the new loop "A - L" along the course of a capillary bud.

c. Continued activity has produced the further loop "N" and at the same time abolished the circuiting branch "S".

d. Shortly afterwards, a further loop is formed, "K", with a pilot bud ahead of it; a second efferent channel, "B", is added, and to force all the available blood into the active area, the short-circuiting channels, "Z", are narrowed. When the two terminal loops meet, the circulation is reorganised, and the gradual meeting of the main loops at "D" (seen in "C") leads to the abolition of the redundant efferent "E".

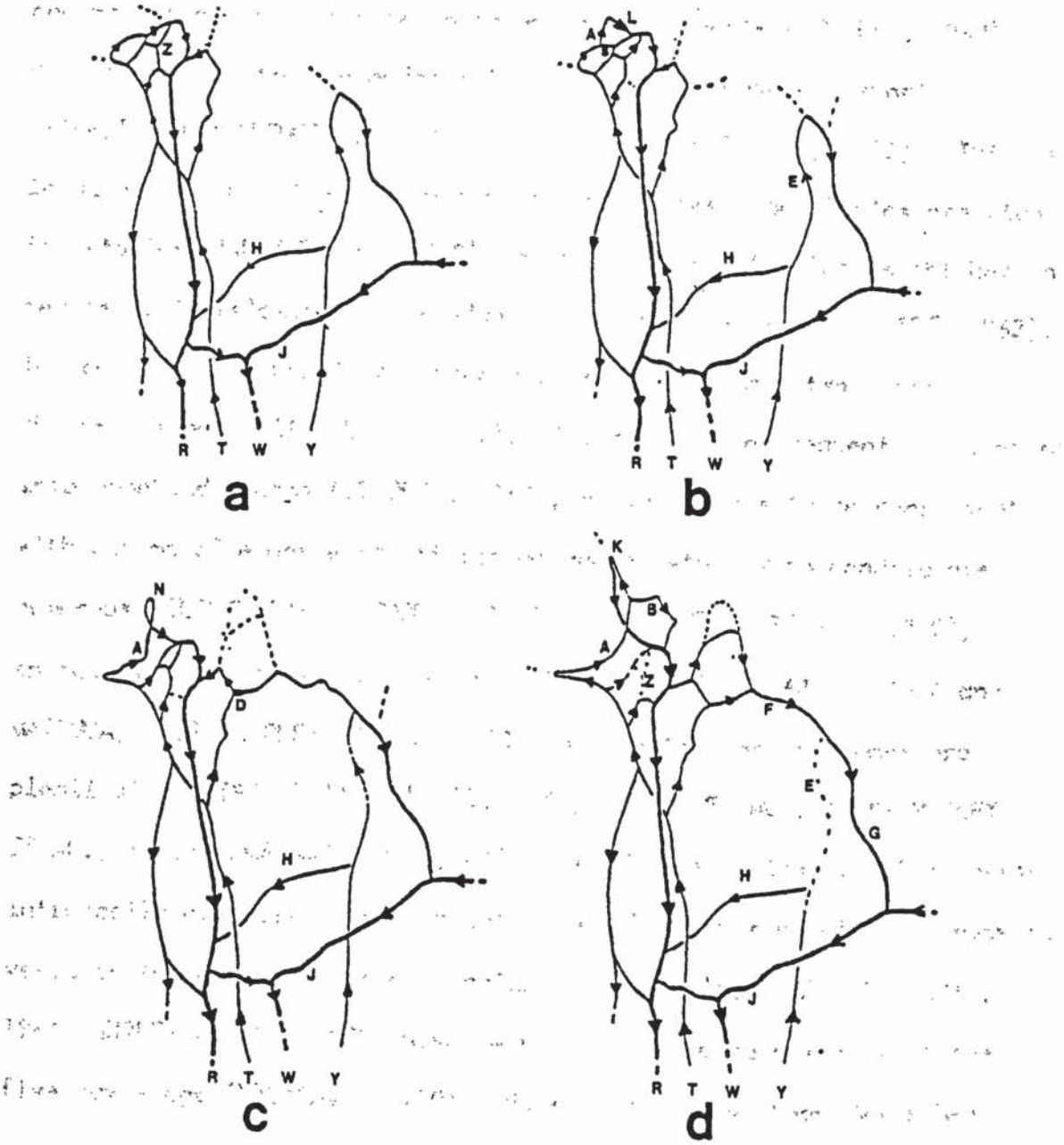


FIGURE 2.2 THE EVOLUTION OF SUPERFICIAL CORNEAL VASCULARIZATION (After Graves, 1934).

2.1 ii) (b) The fine structure of growing blood vessels

In the first few days of development the endothelial layer of regenerating blood vessels is thinner than the normal endothelium and may be as thin as a few hundred Angstrom units (SCHOEFL, 1963). By the seventh day the endothelium is often composed of short "plump" cells (SCHOEFL, 1963, 1964; SZALAY and PAPPAS, 1970). This is in agreement with the findings that newly formed capillaries are rich in cytoplasm (MATSUHASHI, 1962) and that the endothelium is thicker in new cells in relation to the size of the enclosed lumen (CLIFF, 1963). The endothelial nuclei are large and usually contain two distinct skein-like nucleoli (CLIFF, 1963). The nuclei are frequently distorted into amoeboid shapes (SCHOEFL, 1963), which appears to be consistent with claims of endothelial migration and growth. Mitochondria are numerous (CLIFF, 1963; SCHOEFL, 1963, 1964; HURLEY ET AL., 1970), endoplasmic reticulum is abundant (SCHOEFL, 1963, 1964; SUGIURA and MATSUDA, 1969; HURLEY ET AL., 1970) and clusters of ribosomes are plentiful (CLIFF, 1963; SCHOEFL, 1963; SHAKIB ET AL., 1968; HURLEY ET AL., 1970; YAMAGAMI, 1970), all of which are indicative of a marked intra-cellular activity and an active mobility of the cells. Pinocytic vesicles though sparse in new capillary endothelium (SCHOEFL, 1963, 1964; HURLEY ET AL., 1970) have been reported to be numerous at the five day stage (YAMAGAMI, 1970). Fine fibrils have been described as prominent in many of the new endothelial cells (HURLEY ET AL., 1970; SZALAY and PAPPAS, 1970), but the basement membrane has been reported by Yamagami (1970) and Schoefl (1963) to be extremely thin. Cytoplasmic protrusions have also been observed on the adventitial surface of new blood vessels (SCHOEFL, 1963; HURLEY ET AL., 1970) which have been found to be most frequent near the advancing vascular tip (SCHOEFL, 1964).

They were sometimes so extensive as to suggest a "bubbling activity" (SCHOEFL, 1963), and that the amoeboid endothelial cells (YAMAGAMI, 1970) were in motion (SCHOEFL, 1963). The cytoplasmic protrusions, which were mainly devoid of organells, resembled pseudopodia of migrating cells discussed by Allen (1961). In the cornea, these extensions appeared to be long slender threads, which penetrated between the collagen bundles (SCHOEFL, 1963, 1964). Several abnormal features of inter-cellular junctions have been described in developing blood vessels. In some cases the cell lining became discontinuous near the tip of the sprout so that the erythrocyte - filled lumen communicated with the extravascular spaces (SCHOEFL, 1963; SUGIURA and MATSUDA, 1969). Schoefl (1963) described the cells as fitting loosely at the 3 day stage of growth, even in the presence of adhesion plates at some cell junctions. In the case of vessels in the process of growing, however, there were frequently more junctions than cells (CLIFF, 1963), while in mature cells the number of cells equalled the number of junctions. Recently formed endothelium was found to be close to both fibrin and collagen fibres in the surrounding tissues (CLIFF, 1963). Leucocytes were found adhering to the endothelium of developing blood vessels and possibly migrated through this endothelium (CLIFF, 1963). Owing to the loose attachment of endothelial cells and their very thin basement-membrane, growing blood vessels are more permeable to dyes such as Evans blue (T-1824) (ABELL, 1946; COLLIN, 1973) and to red blood cells and particles such as carbon (SCHOEFL, 1963; HURLEY ET AL., 1970). An increased fragility of recently formed vessels was observed by Clark and Clark (1935). More recently this fragility has been attributed to the conditions near the cell junctions (CLIFF, 1963) and the same

morphological features that underlie the abornmally high permeability, which include the open gaps between endothelial cells and the extremely thin basement membrane (SCHOEFL, 1963; ARONSON ET AL., 1971; LANGHAM, 1953). Finally, the highly phagocytic power of the endothelium of developing blood vessels has been considered as evidence of a quantitative rather than a qualitative difference between such endothelium and that of mature vessels (CLIFF, 1963), as mature endothelium is also phagocytic (BUCK, 1958).

2.1 ii) (c) Lymphatic Vessels inthe Vascularized Cornea

There are no lymphatic vessels in the normal mammalian cornea, except at the limbus (IWAMOTO and SMELSER, 1965; IMAI and OIKAWA, 1972). In the injured and vascularized mammalian cornea, the presence of lymphatic vessels has been demonstrated (MANN ET AL., 1948; AOKI, 1951; KATAYAMA, 1957; SZALAY and PAPPAS, 1970; COLLIN, 1966 (a), (b), (c), 1970 (a); SMOLIN andHYNDIUK, 1971). The ultrastructural characteristics of the mature corneal lymphatic vessels has been well documented (SZALAY and PAPPAS, 1970; COLLIN 1970 (b), 1972 (a), (b)). The growing corneal lymphatic vessel has also been observed ultrastructurally (COLLIN, 1971) and quantitatively (COLLIN, 1974 (a)). It has been shown that an injection of protein into the centre of a lymph-vascularized rat cornea, may be carried to the lymph nodes of the neck within six minutes. This time corresponds to the time required for the same inoculum to be carried from the bulbar conjunctiva, a lymphatic - rich tissue (COLLIN, 1966 (a) BUSACCA, 1948; SUGAR ET AL., 1957), to the same lymph nodes. The removal of protein from the cornea, by diffusion, is much slower. From this observation it has been suggested that lymphatic vessels, when present in a vascularized mammalian cornea, may be as extensive as those in the normal conjunctiva and are channels of rapid movement of other similar - sized molecules in the cornea (COLLIN, 1970 (a)). The cell structure of newly formed lymphatics, like blood vessels, is indicative of a marked intracellular activity, and an active mobility of cells. Increased numbers of mitochondria, rough-surfaced endoplasmic reticulum and Golgi apparatus have been reported (COLLIN, 1971). As the endothelium nears maturity, there is a decrease in the organelle content, plasmalemmal vesicles appear and lymphatic anchoring filaments develop (LEAK and

BURKE, 1966, 1968; COLLIN, 1969 (b), 1970 (a)). The anchoring filaments have been proposed by Collin (1969 (b)) to be responsible for the maintenance of lymphatic patency in oedema of the surrounding tissue. An increase in the area of the lumen and in the overall size of the lymphatic vessel, along with a decrease in the thickness of the endothelium has been reported in the maturing lymphatic (COLLIN, 1974 (a)).

2.1 iii) Mechanisms of Neovascularization

2.1 iii) (a) Physical factors

2.1 iii) (a) (i) Breakdown of ground substnace

From analogies with hyaline cortilage Meyer and Chaffee (1940) were the first to suggest that the process of mucopolysaccharides was intimately connected with corneal transparency and avascularity. They showed that these characteristics were abolished by hyaluronidase and proposed that various pathological lesions may produce an increase in enzyme activity which would lead to corneal vascularization. Later this view was expanded, with a suggestion that this inhibitor of vascularization becomes altered in pathogenic states, which permits vascular invasion of the corneas (BACHSICH and RIDDELL, 1945; BACHSICH and WYBURN, 1947). Jones and Meyer (1950) considered that the inhibitory effect of cortizone on corneal vascularization might be due to its ability to prevent such a breakdown of corneal mucopolysaccharides. Many workers, in support of this theory, have shown that mucopolysaccharide composition of the stroma alters in the vicinity of a wound, after a lapse of about two days (AURELL, 1954; DUNNINGTON and SMELSER, 1958; DOHLMAN, 1957; ANSETH, 1961). However, there is no evidence directly linking these changes with the ingrowth of vessels. Work by Wislocki et al. (1947), Woodin (1950) and Wise (1943), has cast considerable doubt on the importance of the role played by mucopolysaccharides. Wislocki et al. (1947) demonstrated that hyaluronidase does not abolish the metachromatic staining reaction of the cornea. Woodin (1950) found that hyaluronidase is inactive as a spreading factor in the cornea, while Wise (1943) showed

that hyaluronidase acid ester was not diminished in quantity in the vascularizing cornea. In addition Ashton (1960) found vascularization could occur in corneas which appeared normal when their sections were stained for acid mucopolysaccharides.

2.1 iii) (a) ii Reduction in Tissue Compactness - a necessary condition for neovascularization

Mann et al. (1948) observed that vessels will only invade the corneal stroma, when the tissue is oedematous. This finding (MANN ET AL., 1948) was supported by further work (COGAN, 1949(a); ASHTON and COOK, 1953; LANGHAM, 1953; MAURICE ET AL., 1966). Szeghy (1960) was able to prevent oedema in peripheral wounds by protecting them with a thin colloidin cover. He found that vascularization was prevented, but when the cornea became oedematous vascularization occured after the customary one to two days. Growth of limbal blood vessels has been noted to occur when the cornea is swollen to x1¼ the normal thickness, but progress is slow (MAURICE ET AL., 1966). It has been suggested that this is a direct result of a reduction in the pressure of the stromal framework (HEDBYS ET AL., 1963), which permits the vessels to penetrate the spaces between the structural elements. Whether these structural elements are the stromal lamellae (ASHTON, 1960) or the collagen fibrils (MAURICE, 1962, (a)) is still uncertain. Levene et al.(1963) found that the considerably swollen cornea may comprise two distinct layers. The anterior layer was very oedematous, while the posterior layer was only slightly oedematous. This may account for the preference that vessels generally show for invading the anterior level of the cornea. More recently, Klintworth (1973) found that corneae did not necessarily become vascularized when the corneal lamellae were separated in a swollen cornea thus casting doubt on this theory.

2.1 iii) (a) iii Reduction in tissue compactness, a sufficient condition for neovascularization

Cogan(1949(a))advanced the hypothesis that oedema was in itself an adequate stimulus to neovascularization, a viewpoint which Ashton and Cook (1953) modified, suggesting that a chemical stimulus to vascularization is constantly present in the cornea, but that it is able to exert its own action only when pathways to vessel growth are opened up. The stimulus was supposed to result from the relatively low oxygen tension in the corneal stroma. Evidence has shown that the growth of vessels ceases a day or two before the tissue returns to its normal thickness, thus calling into question the thesis that oedema is an adequate stimulus for neovascularization (LANGHAM, 1953; MAURICE ET AL., 1966). Further criticisms of Langham's theory include the observations that vascularization was reported to be absent in oedematous corneae(IMRE and PAL, 1968) and also that in chronically swollen vascularizing corneae the central 2mm remain free of blood vessels, an appearance which was reported by Maurice et al. (1966). In terms of Ashton and Cook's refinement of the theory (ASHTON and COOK, 1953), it could be explained as the result of the close proximity of so many blood vessels leading to an adequate oxygen supply for the region. However, long term peripheral oedema (which has been noted in cases of congenital endothelial dystrophy and also in aphakic patients) has been observed with no detectable reaction in the perilimbal vessels (MAUMENEE, 1960: CATFORD, 1964; SCHEIE, 1964) therefore casting doubt on Ashton and Cook's theory. Further evidence which contradicts this theory has been produced by Baum and Martola (1968). They noted that patients with bullous keratopathy, having a corneal limbal thickness 47% greater that the normal thickness, showed

no stromal vascularization; while patients with an active corneal inflammation and neovascularization only exhibited a 27% increase in limbal thickness. They suggested that corneal stromal oedema per se is insufficient stimulus for corneal stromal vascularization.

2.1 iii) (a) iv Gradient of Oedema

Tissue oedema in itself may not be the stimulus to growth. However, a change in the degree of oedema in the vicinity of the capillaries may be the activating factor. This could make itself felt directly, as a lowered tissue pressure to one side of the vessel or, indirectly as a flow of tissue fluid the more oedematous area to the less, which impinges on the vessel wall. To some extent this would explain both the growth of vessels towards the focus of the trauma, which is generally the region of maximum oedema, and the cessation of further invasion of the stroma once this focus is engulfed. However, there are two major criticisms. The first is that it is not unusual to see vascularization progressing in corneas where there is no detectable difference of corneal thickness in the region of growth (MAURICE ET AL., 1966). The second is that in rare circumstances the growth of vessels may be noted from a region of greater to lesser oedema (MAURICE ET AL., 1966).

In summary, it would appear that though oedema of the stroma is an essential pre-requisite to stromal vascularization, it is not in itself a sufficient cause. There is no evidence that the breakdown of the ground substance can be an adequate substitute for oedema in this latter respect.

2.1 iii) (b) Chemical Stimulus

2.1 iii) (b) (i) Suboxidation

A shortage of oxygen or an excess of carbon dioxide in the tissues is a potent factor in the production of neovascularization generally. In the retina Michaelson (1948) showed that retinal capillaries developed from the retinal veins and left a capillary - free zone around the retinal arteris. This zone was noted to narrow significantly in animals when they were exposed to a low oxygen environment (MICHAELSON, 1948; CAMPBELL, 1951). This tended to indicate that oxygen tension is closely related to capillary growth. Anoxia was also considered to be the stimulater for anomalous vascular growth in various animal experiments (BYERLY, 1926; WINDLE ET AL., 1944; ASHTON ET AL., 1954). In conditions where ischaemia is present as a result of vascular occlusion (such as Eales's disease, occlusion of the central retinal vein, and diabetic retinopathy), anoxia has been held responsible for the new vessel formation which frequently follows. It has also been suggested that anoxia is the active stimulant in the angiomatosis of Lindau's disease (INGALLS, 1948) and in the neovascularization seen in retrolental fibroplasia (SZEWCZYK, 1952; INGALLS ET AL., 1952; CROSSE and EVANS, 1952).

The application of suboxygenation as a stimulater of blood vessel growth in the cornea was postulated by Ashton and Cook (1953). They put forward the theory that the avascular cornea is normally in a chronic suboxygenated state. Vasoproliferation, in response to this reduced oxygen environment, only occurs when the barrier, provided by the compactness of the corneal tissue, is broken down by oedema near the

limbal vessels. Ashton and Cook's theory (ASHTON and COOK, 1953) has been supported in several observations. Deficiency of riboflavin, a coenzyme of several respiratory enzymes, leads to corneal vascularization (BESSEY and WOLBACH, 1939; JOHNSON and ECKARDT, 1940). Langham (1953) has shown that there is a reduction of oxygen uptake by a section of cornea, excised after the administration of intracameral alloxan, compared to controls. Levene et al.(1963) demonstrated that lactic acid concentrations increase in the cornea adjacent to the corneoscleral limbus before neovascularization occurs, which was considered to be evidence of decreased aerobic glycolysis.

From the thesis that hypoxia is a stimulus for new vessel growth, it was postulated that hyperoxygenation might delay or inhibit corneal vascularization. However, numerous experiments, with one exception (CHHABRA and CONSUL, 1970) where oxygen injected into the cornea brought about the disappearance of newly formed vessels, showed that increasing oxygen concentration does not inhibit neovascularization in the cornea (MICHAELSON ET AL., 1954 ; ASHTON and COOK, 1954; HENKIND, 1964; LAZAR ET AL., 1968; KAISER and KLOPP, 1973). The possible explanations for the failure of hyperbaric oxygenation to inhibit corneal vascularization are: firstly that the theory that hypoxia is a stimulus to neovascularization is incorrect, secondly that a plentiful supply of tissue oxygen does not prevent hypoxia at a cellular respiratory level because of aerobic metabolic disorders, and thirdly that hyperbaric oxygenation itself may have an inhibitory effect on aerobic metabolism (HAUGAARD, 1965).

2.1 iii) (b)(ii) Vaso-stimulating factors

It is possible that in the case of capillary penetration the proliferating vascular buds move from a zone where some chemical substance is in low concentration, towards a region of traumatised or nectrotic tissue containing this substance in high concentration. It may also be postulated that vasostimulation arises from the neutralization of a normally present growth inhibiting substance. Growth stimulating factors have been extensively investigated in tissue cultures (FISCHER, 1930; CAMERON, 1935), and the application of this principle to the problem of corneal vascularization has been particularly emphasised by Campbell and Michaelson (1949). They suggested from their studies on standardized burns in rabbit corneae, that new vessel formation involves a factor released at the site of the lesion. This diffusable factor would be capable of directing capillary growth by provoking the budding of capillaries with which it came into contact. Further supportive evidence of this theory was provided by Maurice et al. (1966). They implanted fine plastic tubes which were open at both ends, into the corneal stroma. A small lesion near the one end of the tube, which was more central in the cornea, caused capillaries to grow from the limbus through the tube towards the wound. Intraluminal growth of blood vessels was absent when the central end of the tube was closed. Maurice et al. (1966) emphasised the essential role of the V.S.F. (vaso-stimulating factor), but also confirmed the necessity of the concomitant oedema. Maurice et al. (1966) further went on to suggest that the V.S.F. could be an oligopeptide with a molecular diameter, possibly half again as big as that of fluorescein. Maurice et al. (1966) were able to predict the approximate nature of the V.S.F. because it was shown that the rate

of loss of the V.S.F. across the corneal surface, and its rate of diffusion in the stroma, appear to depend mainly upon its molecular weight (MAURICE, 1962 (b)). With regard to corneal vascularization other investigators have alluded to the presence of one or more diffusible factors capable of initiating directional capillary growth which the normal cornea lacks (ASHTON and COOK, 1953; FOLCA, 1969; GRIMBRONE ET AL., 1974; IMRE, 1966; KLINTWORTH, 1973; ZAUBERMAN ET AL., 1969), however, both the factor and the origin have yet to be characterized.

Klintworth (1973) observed that corneal vascularization was always accompanied by cellular infiltration into the corneal stroma, and the absence of the cellular infiltrate, even in the presence of marked oedema, maintained corneal avascularity. This observation suggested that leucocytes liberated a substance, either directly or indirectly, which induced directional vascular growth into the cornea. Further work by Fromer and Klintworth (1975 (a)) demonstrated that a focal non-progressive lesion (e.g. silver nitrate cauterization) provoked a localized leucocytic and vascular infiltration into the damaged corneal stroma from the closest portion of the limbus. Topical alloxan (a metabolic inhibitor) when administered caused a diffuse circumferential leucocyte infiltration into the cornea. This stimulated vascular invasion into the periphery of the entire cornea. When leucocytes infiltrated the entire thickness of the corneal stroma (as in an immunological injury when antigen was instilled into the corneas of sensitized animals), so did the vascular ingrowth. The degree of vascularization was also directly proportional to the leucocyte infiltrate. Moreover the onset of corneal vascularization

was found to be temprally related to the time of the initial leucocyte infiltration, as demonstrated by: 1) injection of antigen into the sensitized animals produced an early leucocyte infiltration and corneal vascularization; 2) a longer latent period anteceded both the leucocytic and vascular invasion in rats on riboflavin - deficient diet (FROMER and KLINTWORTH, 1975 (a)). In earlier work leucocytic infiltration was also noted prior to the onset of vascular invasion in rats on a vitamin A - deficient diet (WOLBACH and HOWE, 1925), and also after the onset of vascular invasion in rats on a riboflavin - deficient diet (BESSEY and WOLBACH, 1939). Reports from the studies of corneal reactions to alkali (EY ET AL., 1968; BROWN ET AL., 1969), Silver nitrate (SCHOEFL, 1963) and intra-corneal injections of antigens into sensitized animals (JULIANELLE and LAMB, 1934; JULIANELLE and BISHOP, 1936; WESSELY, 1911; GERMUTH ET AL., 1962), although not investigating the pathogenises of corneal vascularization, do mention an early leucocytic invasion into the corneal stroma prior to the onset of vascular invasion. Additionally it has been suggested that the only models in which corneal vascularization may possibly occur without a leucocytic infiltration, are those in which neoplastic cells (known to be capable of stimulating vascular proliferation) are instilled into the cornea (GIMBRONE, ET AL., 1974). Fromer and Klintworth (1975 (b)) in later work prevented leucocyte infiltration by prior total body x—irradiation. The result was inhibition of corneal vascularization. The subconjunctival inoculation of the glucocorticoid methyl prednisolone acetate also inhibited leucocyte infiltration into the cornea as well as the vascular ingrowth, provided it was administered immediately after cauterization with silver nitrate. Fromer and Klintworth (1976) later went on to propose that the actual stimulus for corneal vascular invasion might originate

from leucocytes and that one or more componants of P.M.N.'s (polymorphonuclear leucocytes) may stimulate the endothelial cells of the limbal vascular plexus directly. Furthermore different types of proteolytic enzymes have been demonstrated to have a growth stimulating effect on various cellular components of the cornea (WEIMAR and HARAGUCHI; 1972). When thermal injuries were induced in the skin of x-irradiated rats, it was observed that 3H-thymidine uptake by vascular endothelial cells, as reflected by autoradiography, precedes early in the course of inflammation and in the absence of significant levels of circulating monocytes and lymphocytes (SHOLLEY ET AL., 1974). Also when observing vascular and endothelial proliferation in the retina Deem et al. (1974) noted that lympoid cells, while in an active metabolic state, secreted diffusible factors of lymphokines, which are known to activate or alter the behaviour of various cell types (MUNDY ET AL., 1974; DAVID, 1973; DAVID and DAVID, 1972). Simpson and Ross (1972) also found that there was no defect in granulation tissue formation when neutrophilic infiltration of incisional wounds was virtually eliminated. However, they did not specifically quantitate vascularization. If neutrophils do increase vascular growth, it would appear from the results discussed that the effect is not proportional to the amount of infiltrate and can be stimulated fully be small numbers of cells. Mixed leucocyte populations and constituents of P.M.N.'s have also been demonstrated to directly stimulate cellular proliferation (CARREL, 1922; ALEXANDER ET AL., 1971). Results from studies on endothelial injury has added further support to Fromer and Klintworth's theory. It has been suggested that neutrophilic infiltration increases local endothelial injury (JANOFF and ZELIGS, 1968; RYAN and MAJNO, 1977; SCHUMACHER and AGUDELO, 1972), which in

itself is a stimulus for endothelial proliferation (FISHMAN ET AL., 1975; GAYNOR, 1971; SCHWARTZ ET AL., 1975; SHOLLEY ET AL., 1977(b)).

The mechanism or mechanisms by which leucocytes might initiate corneal vascularization is still unknown. However, it has been suggested that collagenases (LAZARUS ET AL., 1972), elastases (JANOFF and SCHERER, 1968), proteases (JANOFF and ZELIGS, 1968; WRIGHT and MALAWISTA, 1972) and non-specific protease (which includes elastin among its susceptible substrates) (JANOFF, 1970), released from infiltrating neutrophils may, by loosening the extremely compact corneal stroma, facilitate migration of endothelial cells. In addition extractable vasoinhibitory antiproteolytic material has been isolated not only from cartilage but also from corneal tissue (SORGENTE ET AL., 1975; EISENSTEIN ET AL., 1975 (a), (b); KUETTNER ET AL., 1974). Thus, neutrophils, by their release of proteolytic enzymes might serve to counteract such vasoinhibitory substances. However, the observed directional vascular growth that occurs toward specific sites of corneal injury (FROMER and KLINTWORTH, 1975 (a); CAMPBELL and MICHAELSON, 1949) would suggest a positive chemotaxis. It has also been noted that migration of neutrophils into the corneal stroma do so only in the presence of a chemotactic stimulus (BASU and MINTA, 1976). This would indicate that the inhibition of a vasoinhibitory substance alone cannot account for corneal vascularization. The corneal endothelium plays a vital role in maintaining deturgescence of the cornea and damage to this layer results in corneal oedema (MISHIMA ET AL., 1969; QUIROGA and KLINTWORTH, 1967), and it has already been established corneal oedema generally precedes and accompanies corneal vascular invasion (COGAN, 1949(a); MAURICE ET AL., 1966; IMRE and PÁL, 1968). If neutrophils were to damage the

endothelium by release of hydrolytic enzymes and therefore cause corneal oedema, according to Cogan's theory (COGAN, 1949(a)), vascularization would ensue. However, reduction in corneal tissue compactness (as caused by oedema) is not necessarily followed by corneal vascularization (KLINTWORTH, 1973; BAUM and MARTOLA, 1968; MAUMENEE, 1960; FOLCA, 1969; LANGHAM, 1953), which casts doubts on this suggested mechanism of vaso-stimulation. If neutrophils are indeed inhibitors of vascular growth, then from recent studies, only relatively few neutrophils (compared to the number which infiltrate the corneas of non-leucopenic rats) must be able to elicit the maximal neovascular response (SHOLLEY ET AL., 1974).

More recent work, however, disagress with the theory that corneal vascularization is mediated by leucocytes (ELIASON, 1978; SHOLLEY ET AL; 1978). Sholley et al. (1978) showed that corneal vascularization was evoked by silver nitrate injury despite prevention of the characteristic leucocytic infiltration. When monocular infiltration was prevented and neutrophilic infiltration diminished by whole-body x-irradiation (800 rads), the vascular ingrowth was equivalent to that measured is non-irradiated rats. To suppress neutrophilic infiltration totally, it was necessary to eliminate circulating neutrophils; this was accomplished by a combined treatment with 800 rads of x-irradiation plus repeated heterologous antineutrophil serum (A.N.S.) injections. Complete suppression of neutrophilic and mononuclear infiltration with this method did not prevent initiation of vascular growth, although the length and density of the new vessels were signficantly reduced. They suggested that this may not have specifically been related to leucocytes, but that their

disturbed physiologic condition, being reduced by the combined treatment, was not conducive to optimum vascular growth. Also the A.N.S. injections alone slightly reduced corneal neovascularization despite neutrophilic infiltration, indicating a direct cytotoxic effect on the endothelial cells. In addition, the finding that prevention of mononuclear infiltration does not interfere with corneal neovascularization is supported by previous studies on endothelial proliferation in termally injured skin (SHOLLEY ET AL., 1976, 1977 (a)) and also in leucocyte studies (FROMER and KLINTWORTH, 1976). More specifically Sholley et al. (1978) disagreed with the findings that no vascular response occurred in the corneae of rats where neutrophils were eliminated (FROMER and KLINTWORTH, 1975 (b)). Sholley et al. (1978) suggested that this could have been due to the fact that the animals died, as a result of high doses of whole-body x-irradiation, before neovascularization became prominent. Eliason (1978) also demonstrated that vascularization occurred in leucopenic rabbits. This was unaffected by the few leucocytes that they observed in the cornea, as vascularization had occurred prior to their infiltration. Moreover, it has been suggested that plasmin may be involved in the initiation of polymorphonuclear chemotaxis (WEIMAR, 1957; KENYON ET AL., 1979; O'FLAHERTY and WARD, 1979) as well as angiogenesis (CAMPBELL and MICHAELSON, 1949; MAURICE ET AL., 1966), and the regulation of vessel permeability (COLLIN, 1973). In more recent work (BERMAN ET AL., 1980) the demonstration of a zone of plasminogen activator present near the periphery of the normal cornea would seem to indicate that the aforementioned theses may well apply to the corneal limbus.

In addition to the previously mentioned findings, there is much

evidence for increased macrophage function following various modes of stimulation (UNANUE, 1976). It has been postulated that the neovascularizing properties of macrophages are inducible rather than constitutive. The mechanisms responsible for the phenomenon may be by way of an active molecule, which may be secreted by the macrophages, as they are known to secrete a variety of macromolecules (CALDERON ET AL., 1974; CALDERON and UNANUE, 1975; LEIBOVICH and ROSS, 1976). Leibovich and Ross (1975) found diminished fibroplasia in healing wounds of guinea pigs in which macrophages were reduced by injections of anti-macrophage serum. They did not, however, quantitate the degree of new vessel growth in these experiments. It has also been shown that endothelial proliferations occur at the height of the delayed hypersensitivity reaction in the skin of guinea pigs (POLVERINI ET AL., 1977) and that such proliferation is associated with the mononuclear infiltration characteristic of this reaction. Further, when activated macrophages or conditioned medium derived from macrophages in culture were injected into the cornea, neovascularization occurred in 60 to 80% of instances (POLVERINI ET AL., 1977). This differed from other studies where the neovascularization produced by macrophages was also accompanied by acute inflammation (FROMER and KLINTWORTH, 1975 (b)). Corneal vascularization has also been induced by wound derived macrophages (CLARK ET AL., 1976). The variable effect of macrophages on vascular proliferation might be due to the state of activation of the macrophage, their interaction with other cell types, or the existance of two or more types of macrophage.

More recently further work has supported the hypothesis of lymphoid - induced neovascularization (NISHIOKA and KATAYAMA, 1978; BENEZRA, 1978 (a); PLISKIN, 1979; PLISKIN ET AL., 1980; MENNA ET AL., 1980;

EPSTEIN and HUGHES, 1981). It has been observed that lymphoid cells must be activated to induce neovascularization (PLISKIN, 1979; PLISKIN ET AL., 1980), although a more recent report claims that activation of the lymphocyte merely enhances the corneal vascularization induced by the non-activated lymphocyte (EPSTEIN and HUGHES, 1981). Recently it has also been postulated that neovasculogenic activity is mediated through the local release of prostaglandins, especially prostaglandin E_1 which was found to be the strongest and most consistant inducer of neovasculogenesis (BENEZRA, 1978 (b), 1979(a),(b)). It has been shown that growing tumour cells, activated lymphocytes, and macrophages all synthesise and release prostaglandins to fulfill the role of inter-cellular messangers and regulators of the immune response (JAFFE, 1974; FERRARIS and DE RUBERTIS, 1974: GOODWIN ET AL., 1977; HUMES ET AL., 1977; JURLAND and BOCKMAN, 1978). In studies on induced acute anterior uveitis in the rabbit eye (EAKINS ET AL., 1972 (a),(b); UNGER ET AL., 1980) raised levels of prostaglandins were noted in the anterior chamber. From these findings (EAKINS ET AL., 1972 (a), (b); UNGER ET AL., 1980) it was suggested that prostaglandins may be involved in the acute inflammatory response, possibly released from polymorphonuclear leucocytes (HIGGS and YOULTEN, 1972), as prostaglandin levels were substantially lower in open angle glaucoma (WYLLIE and WYLLIE, 1971) where there is no inflammation. Prostaglandins have also been reported as having induced ocular inflammatory characteristics such as increased vascular permeability (BEITCH and EAKINS, 1969; KALEY and WEINER, 1971 (a); WHITELOCKE and EAKINS, 1973; PEDERSEN, 1980), vasodilation (STARR, 1971; WHITELOCKE and EAKINS, 1973), oedema (VANE, 1976) and leucocyte migration in vitro (KALEY and WEINER, 1971 (b)). In eyes deprived of functional

sensory nerves it has been reported that though the prostaglandin levels are higher the actual vascular respone is smaller (UNGER ET AL., 1980). This finding (UNGER ET AL., 1980) may not be necessarily associated with the sensory denervation, as was suggested, but may be due to a dose dependency reaction, which would agree with the findings of Pliskin (1979) who reported that activated lymphoid cells in lower doses enhanced vascularization but inhibited vascularization when in higher doses. Further supportive evidence for the prostaglandin hypthesis (BENEZRA, 1978 (b); 1979 (a),(b)) has come from studies where suggested inhibitors of prostaglandins (PODOS and BECKER, 1974; HONG and LEVINE, 1976; MENTZ ET AL., 1980) have also significantly reduced not only inflammation (HARRIS ET AL., 1974; VANE, 1971; MENTZ ET AL., 1980) but also corneal neovascularization induced by alloxan and silver nitrate (COOPER ET AL.,1980), thermal burns (DEUTSCH and HUGHES, 1979), V2 carcinoma (GROSS ET AL., 1981) and epidermal growth factor (where a noticeable inflammatory response was absent (WATERBURY ET AL., 1981)). Furthermore, corticosteroids which have been useful agents in the prevention of corneal neovascularization for some time (ASHTON ET AL., 1951), have now been established as blockers of prostaglandin formation by preventing the activation of phospholipase A_2, a key enzyme in the prostaglandin biosynthetic pathway (HONG and LEVINE, 1976; TAM ET AL., 1977; LEWIS and PIPER, 1975; CHANG ET AL., 1977). Bhattacherjee and Eakins (1974) demonstrated that prostaglandins were generated in substantial quantities by conjunctival tissue, whereas corneal tissue had relatively little prostaglandin activity. Also it has been shown that a much greater degree of vascularization occurs in the denuded cornea regenerated with epithelium of conjunctival origin than in the cornea regenerated with epithelium of corneal origin (FRIEND and THOFT,

1977; FRIEND ET AL., 1978; MURPHY ET AL., 1978, 1979; THOFT ET AL., 1979). These observations (BHATTACHERJEE and EAKINS, 1974: FRIEND and THOFT, 1977; FRIEND ET AL., 1978; MURPHY ET AL., 1978, 1979; THOFT ET AL., 1979) give further support to the hypothesis that prostaglandins play a major role in vascularization. Furthermore, the observation that growing tumour cells can synthesise and release prostaglandins (JAFFE, 1974) might indicate that the various neovasculogenic factors detected in tumour growth (MICHAELSON, 1948; FOLKMAN ET AL., 1971; FOLKMAN, 1975) mediate their neovasculagenic activity through release of prostaglandins.

A low molecular weight fraction of bovine vitreous was observed to inhibit endothelial cell proliferation (BREM ET AL., 1977) a finding supported by additional work which described the failure of tumours, or retina, to vascularize when the tumour was planted in the vitreous and kept out of contact with the retina (GIMBRONE ET AL.,1973; BREM ET AL., 1976; FINKELSTEIN ET AL., 1977). Even under hypoxia, when angioblastic activity was noted to increase in the retina (CAMPBELL, 1951; ASHTON ET AL., 1954) no vitreal proliferations appeared (ASHTON ET AL., 1954). These findings also provide evidence in support of the concept viewed by Henkind (1978), that among the factors controlling the vascularization of ocular tissues, are local retardants of vascular growth. Further studies have indicated that cartilage, aorta and vitreous contain extractable materials, with relatively low molecular weights, which inhibit endothelial cell growth and vascularization in vivo (LANGER ET AL., 1976; EISENSTEIN ET AL., 1975(a), (b); GOREN ET AL., 1977; DOREY and SORGENTE, 1977; BREM and FOLKMAN, 1975; BREM ET AL., 1977; EISENSTEIN ET AL., 1978). The original suggestion that the factor which inhibits the growth of vascular

endothelial cells is a protease ibhibitor (GOREN ET AL., 1977; LANGER ET AL., 1976; DOREY and SORGENTE, 1977) which is a natural regulator of angiogenesis (KUETTNER ET AL., 1974), has been questioned. On the basis of tissue culture data, it would appear that the major growth inhibitor is distinguishable from protease inhibitor (AUSPRUNK ET AL., 1978). In support of this criticism further evidence exists. Aprotinin, a preparation of the Kunitzbovine protease inhibitor, has been reported to be the major protease inhibitor in bovine cortilage and aorta (RIFKIN and CROWE, 1977). However, its inability to prevent either corneal neovascularization or oedema in corneas cauterized with silver nitrate, has indicated that aprotinin is not the effective molecule in bovine aorta extract (EISENSTEIN ET AL., 1979). Further work has shown that delayed administration of fractions of bovine aorta extract is effective and inhibits both oedema and neovascularization (EISENSTEIN ET AL., 1979). This would suggest that the inhibition of oedema and vascularization by bovine aorta extract is not entirely caused by interference with the initial stimulus to neovascularization, generated by the injury. As white blood cells, a proximate stimulus for neovascularization in the cornea (KLINTWORTH, 1977), are present in large numbers 48 hours after injury (EISENSTEIN ET AL., 1979), an inhibitor such as bovine aorta extract would have medical applications. Indeed bovine aorta extracts in the form of eye drops were shown to enhance regression of newly formed vessels with no deleterious ocular side effects (EISENSTEIN ET AL., 1979).

Smith (1961) proposed the hypothesis that most cells normally inhibit corneal vascularization in some way and that their massive destruction in extensive corneal injury results in a physical or biochemical

change in the stability of the system with subsequent vascularization. Rather tenuous support was given by the observations that mast cells have been noted in the corneae of vascularized eyes (SMITH, 1961; COLLIN, 1973) but not in the corneae of normal or wounded eyes WEIMAR, 1958; SMELSER and SILVER, 1963; GROF ET AL., 1964). Mast cells are often found near blood vessels in the resting state (TAKEDA, 1958; HIBBS ET AL., 1960; IWAMOTO and SMELSER, 1965) and after chemical trauma tend to reappear at first in a perivascular location (SANYAL, 1959), which may be due to the fact that perivascular elements have the ability to undergo metaplasia and form mast cells.

More recently a new theory regarding the vaso-stimulating factor and its site of production has been proposed. Eliason (1978) interpreted from his experiments on leucopenic rabbits, that a vasostimulating substance was present within the first 48 hours after injury. This he reported, was prior to the invasion of occasional leucocytes, an observation which disagrees with Collin (1973), who recorded that neutrophil invasion began 36 minutes after injury. Eliason (1978) suggested from this that the most probable metabilically active source, which could produce a vasostimulating substance within the early time period required, would be the epithelium. The epithelium as a source is consistent with the site of all the various causes of vascularization (FROMER and KLINTWORTH, 1975 (a); COGAN, 1962). Researchers have isolated an angiogenic factor from cutaneous epithelium, one function of which appears to be control of the underlying dermal vascular system (WOLF and HARRISON, 1973; WOLF and HUBLER, 1975; NISHIOKA and RYAN, 1972; RYAN, 1970). Further work has described the vascular ingrowth beneath a glued-on contact lens as being

associated with epithelial ingrowth (DOHLMAN ET AL.,1970; KAUFMAN and GASSET, 1969), and the epithelium has been implicated in providing a stimulus to activate Keratocytes following an injury (WEIMAR, 1959, 1960; DUNNINGTON and WEIMAR, 1958). Finally, in recent reports vascularization was induced in the rabbit cornea by both fibroblast growth factor (FGF) (GOSPODAROWICZ ET AL., 1979) and epidermal growth factor (EGF) (GOSPODAROWICZ ET AL., 1979; WATERBURY ET AL., 1981). Earlier work had demonstrated that FGF was mitogenic for bovine and human endothelial cells (GOSPODAROWICZ ET AL., 1976, 1977, 1978), whereas EGF was not. However, EGF has been shown to be a potent mitogen for the corneal epithelium (SAVAGE and COHEN, 1972, 1973; FRATI ET AL., 1972). Topical administration of EGF to corneas denuded of epithelium resulted in rapid re-epithelialization of the denuded area with increased prominance of limbal blood vessels (SAVAGE and COHEN,1972). From these reports (SAVAGE and COHEN, 1972, 1973; FRATI ET AL., 1972; GOSPODAROWICZ ET AL., 1979) it could be inferred that the neovascularization was secondary to the corneal epithelial hyperplasia, where the epithelium was the source of the neovasculogenic factor.

The tears also contain angiogenic products: enzymes (VAN HAERINGEN and GLASIUS, 1974 (a)), immunoglobulins (McCLELLAN ET AL., 1973) and histamine (ABELSON ET AL., 1977). It has been suggested that histamine is capable of stimulating vessel growth (OFFRET and CHAUVET, 1950 (b); ZAUBERMAN ET AL., 1969). However, observations of vascularization in contact lens wearers (DIXON and BRON, 1973; DIXON, 1964; DIXON and LAWACZECK, 1963) and in patients with nutritional deficiencies (SYDENSTRICKER ET AL., 1946; HOCK ET AL., 1945; BESSEY and WOLBACH, 1939; FOLLIS ET AL., 1941), imply that tears are not the

main source of V.S.F.. This may be due to the inhibition of tear components from reaching the stroma or the limbal blood vessels. Collin (1973) further supported this by suggesting that the concentration of the mediator in the tear film would be insufficient to provoke limbal blood vessel changes.

The presence of melanocytes in the basal layer of the epithelium has been observed both in human and animal corneae with superficial vascularization (REDSLOB, 1922; HENKIND, 1964, 1965; DALLOS, 1932; MICHAELSON, 1952; ZIMMERMAN, 1965; HENKIND and JAY, 1966; COWAN, 1964; McCRACKEN and KLINTWORTH, 1976). The melanocytes were observed to migrate into the cornea preceded by the ingrowth of vessels (HENKIND, 1967) and did not migrate more axially than the vessel ingrowth (HENKIND, 1965; MANN, 1944; MICHAELSON, 1952; McCRACKEN and KLINTWORTH, 1976). In one isolated condition in dogs (pigmentary keratitis) melanocyte invasion of the corneal epithelium, overlying areas of corneal vascularization, has been shown to be the partial stimulus (BELLHORN and HENKIND, 1966). Whether the melanocytes enter the cornea because of an active migration, or whether they are positively carried into the cornea because of a sliding epithelial movement from the corneo-scleral limbus is still unknown.

Studies on rabbit corneal blood vessel growth claimed that there is a latent period prior to growth of approximately one to two days (COGAN, 1949 (a); ASHTON ET AL., 1951; LISTER and GREAVES, 1951; ASHTON and COOK, 1953; ZAUBERMAN ET AL., 1969; LANGHAM, 1960). A wide range of times taken for blood vessels to appear in the rabbit cornea was noted between authors, the range extending from three to seven days (MAURICE ET AL., 1966; MATUMOTO, 1957; COGAN, 1949 (a); ZIGMAN ET AL., 1964; OBENBERGER, 1969; LAZAR ET AL., 1968; BROWN

and HOOK, 1971). The aforementioned figures for a latent period are not consistant with those of the rate of rabbit corneal vessel growth, where Ashton and Cook (1953) noted growth of 1 mm in three days and Yamagami (1970) noted growth of 1 mm in two days with a maximum rate of 0.5mm per day. Investigating the discrepancy Collin (1973) observed the limbal vascular response prior to corneal vascularization. He found that emigration of neutrophils began at 36 minutes after corneal injury, which was a central thermal wound designed not to directly affect the limbal blood vessels as previous methods did. Leakage of Trypan blue was discernable at about one hour after injury, and at the three hour stage hyperaemia was noted. The first observation of limbal blood vessel growth was eighteen hours after injury, the growth rate of which complied with the previously reported data (MAURICE ET AL., 1966; LANGHAM, 1960; YAMAGAMI, 1970). As the increased permeability of limbal blood vessels lasted for at least 24 hours the respect was dissimilar in this respect to the Type 1 pattern of increased permeability (WILHELM, 1968), where the permeability would be expected to fall after 0.5 hour. He discussed previous reports that collagenase, known to be a chemotactic for neutrophils (WARD, 1971), has been produced in the cornea after injury to both the epithelium and the stroma (ITOI ET AL., 1969; SLANSKY, 1970; BROWN and WELLER, 1970; BROWN and HOOK, 1971) and concluded that these facts may have particular significance to the corneal response to injury.

Imre (1966, 1969) postulated that endogenous lactic acid played an important role in vascularization. It has been well documented that in many cases hypoxia can promote the development of new vessels (CHAMPY and LOUVEL, 1938; SANDERS, 1961; WILLIAMS, 1959; BESSEY and

WOLBACH, 1939; JOHNSON and ECKARDT, 1940), and in such anaerobic conditions glycogen is mobilised and converted to lactic acid (HERRMANN and HICKMAN, 1948 (b); SMELSER, 1952; SMELSER and OZANICS, 1952, 1953; SMELSER and CHEN, 1955; LANGHAM, 1952, 1954, 1960; UNIACKE ET AL., 1972), therefore, there is a build up of the lactic acid pool of the cornea in anoxic conditions. Also, as previously mentioned, it was reported that lactic acid concentrations increased in the cornea adjacent to the corneo-scleral limbus before neovascularization occurred (LEVENE ET AL., 1963; CSERNOVA, 1968). These observations (HERRMANN and HICKMAN, 1948 (b); SMELSER, 1952; LEVENE ET AL., 1963; CSERNOVA, 1968) would seem to support Imre's hypothesis. Further work (IMRE, 1964; DEEM ET AL., 1974; CUNHA-VAZ, 1978) has described retinal neovascularization occuring after intravitreal injections of lactic acid. Raised lactic acid levels in the vitreous were noted concomitantly with retinal neovascularization (IMRE and PALFALVY, 1977). Likewise raised lactic acid levels in the aqueous humour were also noted in cases of rubeosis iridis (IMRE, 1977). In a more recent study (IMRE and BÖGI, 1980) intra corneal injections of lactic acid induced vascularization, which was only modified by a suspension of indomethacin suspension, indicating that maybe in that case prostaglandins were not of decisive importance. In addition, neovascularization has been described as a complication in soft contact lens wearers (LEIBOWITZ and ROSENTHAL, 1971; DOHLMAN ET AL., 1973; DOHLMAN, 1974; DIXON and BRON, 1973; RUBEN, 1975; SCHECTER ET AL., 1975; WEINBERG, 1977) and though this has not been directly correlated to an increase in lactic acid levels, such increases have been observed in rabbits after periods of continuous soft contact lens wear (DREIFUS ET AL., 1970; RUBEN and CARRUTHERS, 1972) and beneath hard contact lenses

after periods of wear (SMELSER and CHEN, 1955; MORLEY and McCULLOCH, 1961). Though this hypothesis (IMRE, 1964, 1966, 1969, 1977; IMRE and BÖGI, 1980) is quite feasible there is as yet no proof that lactic acid itself is the vaso-stimulating factor.

However, it can only be concluded in summarising this work that in the absence of invading leucocytes, an injured cornea is capable of producing, through a metabolically active source, an angiogenic factor from its own elements.

2.1 iv) Neovascularization in contact lens wear

The first published report of vascularization of the cornea, in wearers of scleral lenses, was probably in 1929 (LAUBER, 1929). Rosenthal (1961) described the appearance of mild superficial neovascularization in patients that had worn hard contact lenses for several years. The neovascularization was more frequently found in the superior corneal quadrant and was attributed to increased pressure of the upper lid upon the superior portion of the contact lens. Corneal contact lenses were also observed to cause frequent limbal congestion, with the occasional occurrence of slight proliferation into the superficial cornea from the limbus (DIXON and LAWACZEK, 1963). Deep corneal vascularization developed in aphakic patients wearing hard contact lenses (DIXON and LAWACZECK, 1963; MAUDELBAUM 1964; GUMPELMAYER, 1972) which rapidly receded on the removal of the contact lens and the administration of local steroids. Further reports of vascularization in young adults with both healthy (DIXON, 1967) and unhealthy corneae (DIXON and BRON, 1973) were found to be attributable to the wearing of hard contact lenses.

Corneal vascularization may also be a potentially serious complication of soft contact lens wear (LEIBOWITZ and ROSENTHAL, 1971; DOHLMAN ET AL., 1973: DOHLMAN, 1974; DIXON and BRON, 1973; RUBEN, 1975: SCHECTER ET AL., 1975; WEINBERG, 1977). Fluorescein angiography, as described by Bron and Easty (1970), was the method that Dixon and Bron (1973) used to document the progression of corneal vascularization in both hard and soft contact lens wearing patients. This method demonstrated precisely where the vascular changes were occurring. In all cases monitored there were vascular changes related to contact lens

wear (DIXON and BRON, 1973). The application of soft contact lenses in the extended wear concept has increased the need for more stringent clinical aftercare procedures. As a result the observations of subtle as well as more defined limbal blood vessel changes have been more frequently documented. The results of such observations include varying gradations in limbal response. Limbal congestion has been monitored in both normal (BROWN and LOBASCHER, 1975; HODD, 1975; DeCARLE, 1972; LARKE and HIRJI, 1979; OSTLUND ET AL., 1979; HOLDEN and ZANTOS, 1979) and aphakic patients (OSTLUND ET AL., 1979) and in several cases has been described as a common occurrence. Corneal vascularization in extended wear is not a rare phenomenon and has been reported in normal patients (ZANTOS and HOLDEN, 1978; LUMBROSO ET AL., 1975; BINDER, 1979; OSTLUND ET AL., 1979; ATHANASSIADIS and RUBEN, 1979), aphakic patients (KERSLEY ET AL., 1977; ZANTOS and HOLDEN, 1978; NESBURN, 1978; OSTLUND ET AL., 1979; STARK ET AL., 1979; COWDEN, 1979; KAUFMAN, 1979; BINDER and WOODWARD, 1980), patients with bullous keratopathy (BLACK and KEARNS, 1974), and also patients who have had penetrating keratoplastic surgery (LEMP, 1980). The results, of treatment in such cases have been similar to those in the hard contact lens patients mentioned previously. Current topical corticosteroids have stopped soft lens induced neovascularization (NESBURN, 1978) and regression of the blood vessels has also been observed after termination of soft lens wear (SCHECTER ET AL., 1975). However, the evidence that has been presented over the recent years would seem to indicate that until the ideal soft lens for both daily and extended wear is universally available, the practitioner may well have to rely on the ability of limbal blood vessels to regress with and without topical corticosteriods in a small but significant number of patients.

Section 2.2 Corneal Epithelial Dysfunction

2.2 (i) Introduction

The life activities of the cell demand both compounds of high-energy potential, which can release energy quickly for performing cell work, and a reduction pool for synthesis of the compounds necessary for life, in addition to the building molecules for synthesis. The nutrients required for normal cell function are oxygen, and energy supply (usually in the form of glucose or stored glycogen) and an amino acid supply. Lack of oxygen and carbohydrate results in breakdown of cellular integrity and deturgescence. Under such conditions the cornea has been shown to react in the same way (de ROETTH, 1950; DUANE, 1949 (b); SMELSER, 1952; DAVSON, 1955; SCHWARTZ ET AL., 1954; SMELSER and OZANICS, 1952; SMELSER and CHEN, 1955; LANGHAM and TAYLOR, 1956; HARRIS and NORDQUIST, 1955; HARRIS, 1957; RILEY, 1969 (b)).

Section 2.2(ii) Factors Contributing to dysfunction of the corneal Epithelium

Glucose is the main source of energy utilized in the maintenance of corneal hydration (HERRMANN and HICKMAN, 1948 (b); RILEY, 1969, (a)). If the normal glucose supply is stopped, then the glycogen (TURSS ET AL., 1970, 1971; THOFT and FRIEND, 1972) and lactic acid carbohydrate reserves will fall. Gradually the energy supply to the hydration control mechanisms will be reduced (HERRMANN and HICKMAN, 1948 (b); LANGHAM, 1954; De ROETTH, 1951; MISHIMA and KUDO, 1967). It is not completely understood, however, why the lactic acid production rate inreases under these conditions (TURSS ET AL., 1970; SCHÜTTE ET AL., 1972 (a), (b)).

It has been shown that when corneal epithelial anoxia is induced (by reducing the oxygen supply to the epithelium) the only energy producing mechanism that can function is anaerobic glycolysis, otherwise known as the Embden - Meyerhof Pathway (EMP) (MAURICE and RILEY, 1970; RILEY 1969 (a); THOFT and FRIEND, 1972). The epithelium compensates to some degree by a significant increase in the rate of glycolysis, the Pasteur effect (De ROETTH, 1950, 1951; HERRMANN and HICKMAN, 1948 (a), (b); FISCHER, 1940), which must supply all the energy required by the epithelium under anoxic conditions. The increased rate of glycolysis causes an increase in the rate of glucose consumption (THOFT and FRIEND, 1972; MAURICE, 1969), which may, however, be inhibited as the supply of glucose in itself requires energy (HALE and MAURICE, 1969). The glucose concentration in the epithelium rapidly drops to a level at which it must be supplemented by the stored glycogen to maintain normal metabolic processes. The glycogen which is mobilised

to Glucose-6-phosphate, is converted to lactic via the EMP. (HERRMANN and HICKMAN, 1948 (b); SMELSER, 1952; SMELZER and OZANICS, 1952, 1953; SMELSER and CHEN, 1955; LANGHAM, 1952, 1954, 1960; UNIACKE and HILL, 1972). The lactic acid pool of the epithelium increases partly due to the increased rate of glycolysis, and partly because it cannot be used as an energy reserve in anoxia since it can only be metabolised by the aerobic TCA (Tricarboxylic acid cycle). Oxidative phosphorylation cannot be maintained in anoxic conditions, the result of which is a decrease in the ATP/ADP (Adenozine triphosphate/ Adenosine diphosphate) ratio (REIM ET AL., 1966; REIM and LICHTE, 1965).

Under conditions of anoxia the cells of the corneal epithelium swell due to dysfunction of the hydration maintenance mechanism. The dehydrating mechanisms are insufficiently supplied by the energy released from glycolysis (PHILPOT, 1955; RILEY, 1969 (a); MANDELL and POLSE, 1969, 1971; POLSE and MANDELL, 1970 (a), (b); UNIACKE and HILL, 1972; UNIACKE ET AL., 1971, 1972), as it only provides approximately 35% of the normal energy production of the cornea (LANGHAM, 1960).

The enzymes involved with the metabolism of glucose are also affected by anoxia. There is a short term increase in LDH (lactic dehydrogenase) activity throughout the corneal epithelium, followed by a slight decrease in activity in the basal layer of the epithelium (KING ET AL., 1971; UNIACKE ET AL., 1972). It has been suggested by these authors that the short term increase in LDH is coupled with the increased rate of anaerobic glycolysis allowing rapid conversion of pyruvate to lactic acid. SDH (Succinic dehydrogenase), which is one of the major

enzymes of the TCA cycle (RENGSTORFF and HILL, 1974; RENGSTORFF ET AL., 1974), shows decreased activity with moderate anoxia due to the interference with cellular metabolism (KAUFMAN and HILL, 1960). In conditions of severe anoxia however, the SDH activity increases. By drawing comparisons with other tissues in a state of severe anoxia, this could be due to an accumulation of SDH (WEIMAR and HARAGUCHI, 1966). The level of LDH activity (LOWTHER and HILL, 1973, 1974; DIKSTEIN and MAURICE, 1972), as well as the activity of the remaining constituents involved in the metabolism of the corneal epithelium, rapidly return to normal when the anoxic stress is removed.

Carbon dioxide can be produced at two points in the aerobic metabolic pathways; from the aerobic glycolysis of glucose by the HMS (hexose monophosphate shunt) pathway and as the end product of the TCA cycle (KINOSHITA, 1962). The measured carbon dioxide flux at the epithelial surface comprises carbon dioxide moving from the Aqueous Humour to the tears down the diffusion gradient, the profile of which has been calculated by Fatt and Bieber (1968), and the carbon dioxide produced from glucose metabolism. In anoxia, when the aerobic pathways are unable to function, carbon dioxide is no longer produced within the cornea and therefore does not contribute to the epithelial flux.

Section 2.2 (iii) Soft contact lenses and the inhibition of substrate supply

The effects of diminished glucose and oxygen supply to the corneal epithelium have been discussed. The evidence for the possible metabolic insult caused in the corneal epithelium by the presence of a soft contact lens will now be considered.

The soft contact lens conforms closely to the contours of the corneal epithelial surface (HILL and CUCKLANZ, 1967; FATT, 1972 (a), (b); HOLDEN and ZANTOS, 1981). Beneath the soft contact lens the cornea may receive it's oxygen supply by one of three possible routes: transmission of oxygen through the lens substance (HILL and CUCKLANZ, 1967: HILL, 1977), by tear exchange beneath the lens via the tear pump mechanism, or by a combination of these routes (HILL and JEPPE, 1975). The supply of oxygen through the lens material has been shown to be affected by the oxygen permeability of the material (DK), where D is the oxygen diffusion coefficient of the lens and K the oxygen solubility) (HILL and CUCKLANZ, 1967; HILL, 1977) and by the thickness of the lens (L) (FATT ET AL., 1969; FATT and ST. HELEN, 1971; HILL, 1977; HILL and JEPPE, 1975; DECKER ET AL., 1978). A small degree of tear exchange under a hydrogel contact lens has been reported (CARTER, 1972), but the contribution of oxygen from this has been shown to be small (FATT and LIN, 1976; POLSE, 1979). Tomlinson and Soni (1980) have shown that the tear pump mechanism of a soft contact lens is not markedly affected by the peripheral curve design. Kikkawa (1978, 1979) has theoretically described the tear pump action of a soft contact lens and concluded that the ideal mechanism of tear circulation would be achieved by a central negative pressure, generated by the elastic pump of the soft contact lens. This would cause a

significant tear flow all around the lens edge toward the centre. Evidence has been provided, by measurements on oxygen debt, to support Kikkawa's theory that the tear pump may operate under certain fitting conditions. The optimum fit for maximal oxygen tension at the corneal anterior surface was found to correspond to a lens fitting slightly flatter than the corneal curvature (PARRISH and LARKE, 1981). When fitted tightly, Fatt et al. (1969) have shown that insufficient oxygen is passing through the lens to maintain the oxygen requirement of the cornea. This would seem to indicate the need for some mechanical oxygen supply by movement of tears beneath the lens, hence supporting the theory of a soft lens tear pump. In addition other authors have also noted by different techniques that the oxygen supply through various soft contact lenses is insufficient (HILL and CUCKLANZ, 1967; HILL and AUGSBURGER, 1971; PETERSON and FATT, 1973). This has been further supported by animal work which has shown an increase in corneal lactic acid concentration after soft contact lens wear (DREIFUS, 1970).

Oedema, a result of cellular dysfunction has also been studied as a variable dependent on the base curve of the soft contact lens. Mandell (1978) originally stated that central oedema was not dependent on the fit of the lens, but later this was contradicted. Observations showed that when the soft lens base curve was changed the degree of corneal oedema was affected (TOMLINSON ET AL., 1981), as well as the appearance of limbal constriction (an additional sign associated with a tight fitting soft contact lens (MANDELL, 1979)). However, there is still some controversy over the existance of an elastic tear pump beneath a soft contact lens, that can contribute a significant amount

of oxygen to the oxygen tension at the anterior corneal epithelial surface (POLSE, 1979, 1981). To improve the supply of oxygen to the cornea various changes in the manufacture of soft contact lenses have been made. In addition to the production of thinner soft lenses (DECKER ET AL., 1978; MERTZ, 1978; POLSE, 1981), lenses have been made from higher water content materials (FATT, 1978; CORDREY, 1977) and existing soft contact lenses have been fenestrated (BOYD, 1972; JOSEPHSON, 1978 (a), (b); SELLERS, 1979; GARNER and CAITHNESS, 1981), though the mechanism by which the latter method apparently reduces corneal physiological distress is unknown (GARNER and CAITHNESS, 1981). Soft contact lens induced anoxia causes changes in the metabolites and enzyme activities of the corneal cells. The result is an increase in the hydration and corneal thickness. Therefore, the successful contact lens must not allow the oxygen tension to drop below the critical value at the lens corneal interface (FATT and ST. HELEN, 1971; FATT ET AL., 1969).

In the closed eye situation the oxygen flux through the soft contact lens is reduced. This is because the oxygen tension on the outer surface of the lens falls from 155 mm Hg to 55 mm Hg, reducing the oxygen gradient across the lens. It may also be deduced that the lowered oxygen tension at the epithelial surface beneath the soft contact lens is reduced even further, possibly to such an extent that corneal dysfunction could ensue. This statement has been validated by the observations of several investigators (MANDELL and POLSE, 1970; LEIBOWITZ ET AL., 1973; HARRIS ET AL., 1975; POLSE ET AL., 1976; SARVER and STAROBA, 1978; HARRIS ET AL., 1981) who have shown that significant corneal thickening develops when soft contact lenses are

worn under closed eye conditions. Further experiments on the rabbit cornea (which has an oxygen demand similar to that in man (FATT, 1977)) demonstrated that Hema lenses (of 0.15mm and 0.06mm centre thickness) having a water content of 38.6%, produced a virtually maximum hypoxic equivalent percentage (EOP) (ROSCOE and HILL, 1980). The EOP value is defined as that particular oxygen level on a 0 to 20.9% (air) scale, which if maintained in a goggle over the cornea, would produce the same demand as did the experimental condition (HILL and JEPPE, 1975). These results would suggest an extended wear lens of this type would eventually cause significant stress on the physiological tolerances of the average cornea, which is dependent on the level of anoxia at the epithelial surface induced by the contact lens (FARRIS and DONN, 1972; POLSE ET AL., 1975; MANDELL, 1976). Changes in tear fluid constituents have been noted in soft contact lens wear, including a fall in tear protein concentration (HAGGERTY, 1979), which have been attributed to an increase in lacrimation.

Increased lacrimation can also produce isotonic tears (UNIACKE and HILL, 1970; TERRY and HILL, 1977), which may cause a limited increase in corneal hydration (SMELSER, 1952; MANDELL ET AL., 1970; MILLER, 1973). Carney and Hill (1975, 1976) have detected a small transient change in tear pH, while other workers (RUBEN and CARRUTHERS, 1972), used hydrophilic lenses as collecting medium, showed that tear lactate levels increased after soft contact lens wear. Similar results, using the same method, were obtained after periods of anoxia (WIGHAM, 1978). This would provide further evidence linking the wear of soft contact lenses to oxygen deprivation.

The extended wear contact lens must also meet additional requirements to those of the daily wear soft contact lens. An adequate supply of oxygen must pass through the lens to the corneal epithelium in both the open and closed eye situation. If the oxygen supply is allowed to fall below the critical oxygen tension, which has been measured to be 10 to 20mm Hg (POLSE and MANDELL, 1970 (b)), the cornea cannot consume oxygen at its normal rate (FATT ET AL., 1969). To ensure that the oxygen tension at the contact lens corneal interface does not fall below 15mm Hg (taken as the critical oxygen tension level), it has been calculated that a hydrogel contact lens of maximum thickness 0.25mm would be required with a dissolved coefficient of at least 5.75×10^{-11} $cm^3 cm^2 sec^{-1} cm^{-3}$ mm Hg^{-1} (FATT and ST. HELEN, 1971; HIRJI, 1978). Comparing this with data from additional work (Ng, 1974) the equilibrium water contact of a hydrogel material at 34° C must be 72% to comply with the conditions necessary for extended wear. It must be stressed here however, that even if the oxygen supply is just over 2% EOP (approximately 15 mm Hg), there may be no clinically detectable changes in corneal oedema. By comparison with the level of critical oxygen tension previously mentioned, this may indicate the presence of underlying subtle anoxic changes, even though the use of glycogen reserves have been detected at the level of 5% EOP (approximately 38 mm Hg) (POLSE and MANDELL, 1970; UNIACKE ET AL., 1972).

CHAPTER 3

Aspects of Long term ocular response to extended wear Sauflon T.M. 85 Lenses

Section 3.1 Introduction

The concept of extended wear, though initially viewed with a certain degree of scepticism, has been accepted by both patient and practitioner as a particularly convenient form of contact lens wear. Though there has been some success with extended wear in aphakia and in therapeutic application (ZANTOS and HOLDEN, 1978; JACKSON and AQUAVELLA, 1976; STARK ET AL., 1979; KERSLEY ET AL., 1977; SCHECTER ET AL., 1975; BLACK and KEARNS, 1974; HARNSTEIN, 1979; KAUFMAN, 1979; OSTLUND ET AL., 1979; NESBURN, 1978; HODD, 1977; PHILLIPS, 1979; RYDBERG, 1975; KERSLEY, 1977; FREEMAN and CHANDLER, 1979; KOETTING, 1974; CITRON and DYER, 1976; HIGHMAN, 1976; BINDER, 1979 (a), (b); LEMP, 1980; BINDER and WOODWARD, 1980; ING, 1981), the use of the extended wear contact lens for the cosmetic patient has not been without untoward reactions (De CARLE, 1972). Some of the problems that have been associated with extended wear include the build up of contact lens deposits (DOHLMAN ET AL., 1973; DOUGHMAN ET AL., 1975; BINDER and WORTHEN, 1977; LEVY, 1976; HIRJI, 1978; BINDER and WOODWARD, 1980; BINDER, 1979 (a)), superficial punctate Keratitis (CLAHR, 1973; BINDER, 1979 (a); BINDER and WOODWARD, 1980), limbal vascular congestion with some neovascularization (BROWN and LOBASCHER, 1975; HODD, 1975; DeCARLE, 1972; HIRJI, 1978; LARKE and HIRJI, 1979; OSTLUND ET AL., 1979; HOLDEN and ZANTOS, 1979; ZANTOS and HOLDEN, 1978; LUMBROSO ET AL., 1975; BINDER, 1979 (a);

ATHANASSIADIS and RUBEN, 1979; SLATT and STEIN, 1979; HIGHMAN, 1976; BINDER and WOODWARD, 1980; LEMP, 1980), circumcorneal opacification (ZANTOS and HOLDEN, 1978), corneal oedema (SLATT and STEIN, 1979; CLAHR, 1973; HIGHMAN, 1976), corneal striae (HIGHMAN, 1976) corneal stromal infiltrates (BINDER, 1979 (b)) and the acute red eye response which has been regarded as a sign of intolerance (BINDER, 1979 (a); ATHANASSIADIS and RUBEN, 1979; HOLDEN and ZANTOS, 1979). High success rates have not been the norm with extended wear (HODD, 1977) but it has been felt that provided patients could be carefully selected, then the extended wear concept could be a viable option for the cosmetic contact lens wearer (HODD, 1977; BINDER and WORTHEN, 1977; HIRJI, 1978). In addition, it has been claimed that when patient motivation is high and it is imperative that the extended wear contact lens is successful, the results obtained have been excellent without any complications (LUND ET AL., 1978; NILSSON and RENGSTORFF, 1979).

Section 3.2 Extended wear and vasostimulation, a sign of physiological distress

Corneal vascularization has frequently been reported in extended wear patients (ZANTOS and HOLDEN, 1977; BINDER, 1979 (a); OSTLUND ET AL., 1979; ATHANASSIADIS and RUBEN, 1979; KERSLEY ET AL., 1977; NESBURN, 1978; KAUFMAN, 1979; BINDER and WOODWARD, 1980; BLACK and KEARNS, 1974; DOHLMAN ET AL., 1973; DOHLMAN, 1974; WEINBERG, 1977; LEMP, 1980), but has not been monitored qualitatively or quantitatively in a carefully controlled experimental study. Previous workers have reported cases of corneal vascularization in hard contact lens wearers (DIXON and LAWACZECK, 1963; MANDELBAUM, 1964; DIXON, 1967; RIDLEY, 1964; GUMPELMAYER, 1971, 1972), however, only one study (DIXON and BRON, 1973) documented the progression of corneal vascularization in a small number of cases of both hard and hydrophilic contact lens wearers. The method that Dixon and Bron (1973) used was fluorescein angiography, as previously described by Bron and Easty (1970), which clearly demonstrated the extent of the vascular changes and enabled the observer to detect the local causative factor, which was often found to be the upper edge of the contact lens pressing on the limbus. In all the cases monitored by Dixon and Bron (1973) there were corneal vascular changes related to contact lens wear. One common finding of the previously mentioned studies, which stresses the importance of stringent after-care, was that often the patients with vascularization were asymptomless and the vascularization was detected during a routine examination. In a previous report, it was noted that after periods of hard lens wear there was an increase in the lactate level measured beneath the contact lens (SMELSER and CHEN, 1955;

MORLEY and McCULLOCH, 1961) while further reports from rabbit work described an increase in the corneal lactic acid level after periods of continuous soft lens wear (DREIFUS ET AL., 1970; RUBEN and CARRUTHERS, 1972). Furthermore lactic acid was proposed by Imre (1964, 1966, 1969) to play a significant role in neovascularization. Hypoxia, with a consequent increase in lactates, was also suggested to be a vasostimulant (BESSEY and WOLBACH, 1939; JOHNSON and ECKARDT, 1940) and may be an additional factor to consider in extended wear, where adequate oxygen supply to the cornea in both the open and closed eye situation is an all important factor. To date, the vasostimulating factor in the cornea has not been determined. However, it would seem reasonable to postulate that inhibition of the normal metabolic processes in the cornea may increase the chances of its production.

Scanning electron microscopic, (S.E.M.) studies on rabbits wearing soft lenses continuously for 24 hours revealed no damage to the surface of the epithelium (HAMANO ET AL., 1977). In contrast Francois et al. (1976, 1977, 1980) reported several changes in the corneal epithelium of the rabbit after 48 hours of continuous soft lens wear. In these S.E.M. studies (FRANCOIS, 1976, 1977, 1980) there was an increase in both mottled and dark cells, which were considered to constitute a preliminary phase of cell desquamation, suggested as a defense reaction of the corneal epithelium (FRANCOIS ET AL., 1976, 1977, 1980), a more marked exfoliation of the superficial cells (YOSHIDA, 1972; FRANCOIS ET AL., 1976, 1977, 1978, 1980), the disappearance of the intercellular reticulin positive glycoproteins, hence altering the anterior corneal mosaic (FRANCOIS ET AL., 1980), a modification of the

keratinisation, with the appearance of areas of hypokeratinisation and others of hyperkeratinization and with the detachment of keratin filaments from the cellular surface (FRANCOIS ET AL., 1980), an increase in keratohyalin granules with the deep epithelial cells and an irregular distribution of biosynthesis activities in the nuclei of the deep cells, which may be a result of the superficial cellular destruction (FRANCOIS ET AL., 1980). Although experimental continuous wear may differ from extended wear in the clinical situation (POLACK, 1976), the previously mentioned observations (FRANCOIS ET AL., 1976, 1977, 1978, 1980) could be present in the cornea of the extended lens wearer and by virtue of their abnormality may contribute to blood vessel growth.

A recent study on the short term (20 weeks) response to extended wear Sauflon T.M. 85 contact lenses reported one possible case of corneal vascularization in a normal young and healthy patient (HIRJI, 1978). From this one isolated case (HIRJI, 1978) it may be postulated that cosmetic extended wear over a prolonged period of time may yield a significanly higher number of patients with corneal vascular changes. In view of this finding (HIRJI, 1978) and others (ZANTOS and HOLDEN, 1978; LUMBROSO ET AL., 1975; BINDER, 1979 (a); OSTLUND ET AL., 1979; ATHANASSIADIS and RUBEN, 1979), it was felt that detailed observation of the limbal vasculature in the long term wear of extended wear lenses was necessary

Section 3.3 Proposed Nature of the Study

From the work which was previously discussed (sections 3.1 and 3.2) it would appear that only one comparative controlled study (HIRJI, 1978) was carried out to determine the short term effects of extended wear lenses (SAUFLON T.M. 85), when applied cosmetically. During this study, however, limbal blood vessel changes were not observed or monitored in any detail. In the light of the reported complications of prolonged use of extended wear lenses in normal, health eyes (ZANTOS and HOLDEN, 1977; OSTLUND ET AL., 1979; LUMBROSO ET AL., 1975; HIGHMAN, 1976; HIRJI, 1978), usually presented from "case histories" or from groups of patients with a wide variety of ocular profiles, it was decided to observe the long term ocular repsonse to extended wear in a carefully constructed and controlled clinical study. The main aim of the study was to observe and monitor both qualitative and quantitative changes in the limbal blood vessel plexus. In addition, it was decided to record various other factors which are discussed later (section 3.6).

3.3 (i) Experimental Design

Of the many types of experimental designs that have been devised for clinical studies the following three were considered: the matched pair or paired organ type; the cross-over type; and the group comparative type (MAXWELL, 1968; COX, 1958).

In the paired organ study patient numbers may be reduced because of the absence of interindividual variations. However, it would be assumed that no sympathetic response occurred in the eye without the contact lens. In patients wearing a contact lens in one eye only, it was observed that signs of a sympathetic oedematous response occurred in the controlateral eye (TOMLINSON ET AL., 1981). This design would therefore be unsuitable for this study.

The cross-over study assumes that no carry-over effects occur (COX, 1958). This cannot be assumed in contact lens wear where, for example, a patient may be exposed to extended wear for one week followed by daily wear for one week. The patient may not have completely relapsed after the first treatment and some conditioning may be present giving rise to a carried-over effect. As there is a possibility that extended wear may cause permanent changes in ocular parameters, this type of design would be inapplicable.

In conclusion, the group comparative study would be the most suitable type, as it was considered to induce the least bias (COX, 1958). It was therefore used to form the basis of the design of the intended study on the long term ocular response to extended wear Sauflon T.M.85 contact lenses.

The monitoring of the limbal vascular response to the extended wear of Sauflon T.M. 85 contact lenses, was envisaged to be the principle area under investigation. Limbal blood vessel changes observed by previous workers (DIXON and BRON, 1973) were only carried out on a limited number of patients wearing contact lenses for various indications. Therefore from this work (DIXON and BRON,1973) it was not possible to predict how many patients per group were required to give significant results.

However, considering one of the subsiduary parameters under observation, the apparent invivo corneal thickness, results of the preliminary work suggested that fifteen patients for each set of observations were required for a detectable difference between means of 0.0057 mm ($p = 0.05$) (DAVIS, 1967). The final number chosen for each group must be determined by the experimental design constraints. These include the ethical considerations, in particular, the possibility that during long term wear of extended wear lenses ocular damage may occur, and therefore, the group size would be kept to a minimum. Also unforseeable reasons may well cause an unpredictable number of patients to leave the study before its termination. In a previous study on extended wear of Sauflon T.M. 85 (HIRJI, 1978) a wastage factor of 50% was allowed, but the actual patient wastage, at the end of its 20 week duration, was only 10%. This intended study, envisaged to last 18 months, was allowed a 40% wastage rate to ensure statistically significant results.

On this basis each group in the study was expected to comprise 25 suitable volunteer subjects.

The duration of the study (18 months) was mainly controlled by the total research time available, which was three years. During the first 9 months selection and fitting of patients and the optimization of techniques were completed. The final 9 months would comprise the analysis and conclusion of the study and the possibility of refitting patients with daily wear soft contact lenses.

Previous studies described a significant diurnal change in both apparent corneal thickness (7%) (GERSTMAN, 1972; HIRJI, 1978) and in corneal sensitivity (MILLODOT, 1972). In view of this work (GERSTMAN, 1972; HIRJI, 1978; MILLODOT, 1972) it was decided to adopt a Latin Square appointment system (LARKE, 1969), rather than the alternative, where data would be collected at a limited time of the day which would impose limitations on the number of patients that could be examined. Using this system (LARKE, 1969) data was collected from the patients at appointment times distributed evenly thoughout the day (Table 3.3). Thus the construction of an appointment schedule for every patient was possible, where the patient was requested to attend each possible appointment time at least twice during the study, which ensured that the mean measurement time for each group of patients and the distribution of the examination times were similar. Theoretically this system (LARKE, 1969) cancels out diurnal variations in all the measured clinical parameters. Previous work has reported no significant variation in the invivo corneal thickness with menstrual cycle (EL HAGE and BEAULNE, 1973; HIRJI, 1978), however, a signficant decrease in corneal sensitivity was recorded during premenstruum (MILLODOT and LAMONT, 1974) in females not on oral contraceptives. Due to the randomization existing between the beginning of the study and stages

in each patient's menstrual cycle, it was anticipated that any introduction of bias would be eliminated. Previous studies on the invivo human corneal thickness to determine differences between the right and left eyes, and between the sexes revealed no statistically signficant differences for these factors (MARTOLA and BAUM, 1968; TOMLINSON, 1972; HANSEN, 1971; MAURICE and GIARDINI, 1951(a)), therefore both male and female volunteers were considered for the proposed study. The invivo thickness of the normal human cornea was found to be statistically unaffected by age, however, the peripheral cornea showed a reduction in thickness after the fifth decade (MARTOLA and BAUM, 1968). For this reason (MARTOLA and BAUM, 1968) an upper age limit of 36 years was imposed on the study.

TABLE 3.3.

Appointment time distribution

Data point	9.30 am	10.30 am	11.30 am	2.30 pm	3.30 pm	4.30 pm	
1	A_1	B_1	C_1	A_2	B_2	C_2	(i)
2	C_2	A_1	B_1	C_1	A_2	B_2	
3	B_2	C_2	A_1	B_1	C_1	A_2	
4	A_2	B_2	C_2	A_1	B_1	C_1	
5	C_1	A_2	B_2	C_2	A_1	B_1	
6	B_1	C_1	A_2	B_2	C_2	A_1	
7	A_1	B_1	C_1	A_2	B_2	C_2	
8	C_2	A_1	B_1	C_1	A_2	B_2	
9	B_2	C_2	A_1	B_1	C_1	A_2	
10	A_2	B_2	C_2	A_1	B_1	C_1	
11	C_1	A_2	B_2	C_2	A_1	B_1	

C_3	A_3	B_3	A_4	B_4	C_4	(ii)
B_5	C_5	A_5	B_6	C_6	A_6	(iii)

Contact lens wear was commenced every other day, visit 1 having sequences (i), (ii), (iii), (i)... consecutively, and subsequent appointments following the pattern scheduled above.

3:3 (ii) Patient Selection

To inform potential subjects of the envisaged study posters (Appendix 3.3 (ii)(a)) were distributed within the University of Aston in Birmingham and the City of Birmingham Polytechnic. Each volunteer was screened, using a previously determined acceptance profile (HIRJI, 1978) (Appendix 3.3 (ii) (b)) with the following modifications: the upper age limit was increased to 36 years, the lower remaining at 18 years of age. The patients considered were both male and female. The myopia of the contact lens volunteer had to lie within a range of -1.00D to -8.00D in either eye. The spectacle refraction of the control volunteer had to be within -8.00D to +4.00D. The apparent central corneal thickness had to be between 0.47 to 0.62mm and the central keratometry readings had to be not less than 6.95 or greater than 8.54mm. After completion of the screening programme, each suitable patient was subjected to a thorough ocular examination. If any further ocular defects were detected during this examination, the patient was rejected. Students who specifically volunteered to act as control subjects were paid a nominal fee per visit during the study. However, many of these controls had either a very low spectacle prescription or were emmetropic. The patients who specifically volunteered to act as experimental subjects had spectacle prescriptions which were, in the majority, constantly worn. This imbalance in the patient profiles, it may be argued, had introduced bias. However, the primary aim of the study was to observe limbal blood vessel changes with extended wear, the only reports suggesting a possible connection between refraction and corneal vascularization were outside the scope of this project (for example aphakic patients). To determine an

equivalent distribution of all parameter values in each group, therefore, reducing bias, the baseline data for the three groups was analysed prior to the study. With regard to corneal thickness and ocular refraction, there was found to be no correlation (LAVERGNE and KELECOM, 1962; EHLERS and HANSON, 1976). There was no reports of a connection between ocular refraction and corneal sensitivity. However, iris colour was found to be related to both corneal thickness (EHLERS and HANSON, 1971) and corneal sensitivity (MILLODOT, 1975 (b), 1976 (b)). The latter was considered to be due to some higher mechanism of the sensory subserving the sensitivity of the cornea and not due to some inherent difference in the corneas (MILLODOT, 1975 (b), 1976 (b)). It may be assumed that the randomness of iris colour among the patients in each group of subjects would eliminate any introduction of bias. The possibility of variations in ocular parameters between races restricted the study to Caucasians. It was previously determined in an extended wear study (HIRJI, 1978) that for patients within the selection profile, the ocular parameters monitored in that study came from a normally distributed population. Therefore, the type of population distribution had to be ascertained only for additional blood vessel measurements.

Section 3.4 Factors recorded and techniques used

3.4 (i) Visual Acuity (Habitual)

This was evaluated on an internally illuminated Landolt 'C' chart with a constant external illumination (with no supplementary refraction).

3.4 (ii) Stability of vision (Habitual)

This was ranked at five levels as previously described by Hirji (1978). '1' denoted continuously stable vision, '2' represented slightly unstable vision on some occasions, '3' described slightly unstable vision on most occasions, '4' represented moderately unstable vision, '5' denoted very unstable vision. This data was collected from a questionnaire which all contact lens wearing patients were requested to complete (Appendix 3.4(ii))

3.4 (iii)Keratometry

Central Keratometry readings were obtained at three monthly intervals using the Gambs Keratometer, as previous studies reported corneal steepening during extended contact lens wear (SLATT and STEIN, 1979; HIGHMAN, 1976; BINDER and WORTHEN, 1977) and daily soft lens wear (BONNET and EL HAGE, 1968; HARRIS ET AL., 1975; HILL, 1975; GROSVENOR, 1975; BARNETT and RENGSTORFF, 1977). Topographical Keratometry was not carried out as recent work (HIRJI, 1978), described no significant corneal shape change over a period of twenty weeks of extended wear with Sauflon T.M.85 lenses.

3.4 (iv) Pachometry

It was suggested that pachometry may not be a sensitive enough technique to detect subtle low levels of corneal distress (HIRJI, 1978). However, when the oxygen tension at the contact lens - corneal interface was reduced to the critical level of 15mm Hg, changes in corneal thickness were detectable (POLSE and MANDELL, 1970 (a)) and indeed several other workers have noted an increase in corneal thickness during extended wear of soft contact lenses (ZANTOS and HOLDEN, 1978; SORENSEN and CORYDON, 1979). Therefore pachometry was a viable technique for detecting moderate degrees of corneal metabolic distress (POLSE and MANDELL, 1970 (a)).

Both central and topographical pachometry was carried out on all patients using the commercially available Haag-Streit pachometer, based on Jaeger's principle (1952), with the addition of a fixation device recently developed by Hirji (1978). This fixation device (HIRJI, 1978) enabled topographic pachometry readings to be taken at mid peripheral (15^{o}) and peripheral (30^{o}) positions in the superior, inferior, nasal and temporal regions of the cornea. "Blind" readings were obtained by the use of an analogue to digital converter and paper tape printer (HIRJI, 1978). Calibration was achieved by the method advocated by Mandell and Polse (1969), which was found to have an intrinsic error of less than 1% (MANDELL and POLSE, 1969). In a previous extended wear study (HIRJI, 1978) it was shown that any corneal thickness changes noted were equally reflected throughout the corneal topography. However, as the corneal thickness measurements were only recorded at 4 weekly intervals, early changes during the first month of wear may not have been detected. From these observations (HIRJI, 1978), it

was decided to measure central pachometry at two day intervals after the first day of contact lens wear, then at weekly intervals up to the first month when topographic pachometry readings were taken. At further data collection points topographic pachometry was repeated as illustrated in Table 3.5 (b).

3.4 (v) Aesthesiometry

Previous work reported a fall in corneal sensitivity with wear of extended wear lenses (HIRJI, 1978). Also, it was shown that corneal sensitivity is closely related to corneal physiological embarrassment (MILLODOT, 1971, 1974, 1975 (a), 1976 (a)), from which it was suggested that corneal sensitivity may be a valuable parameter to record as it may indicate subtle levels of corneal metabolic distress (HIRJI, 1978) which might be undetected by pachometry.

Corneal sensitivity was determined by the method advocated, and described in detail, by Millodot (MILLODOT, 1973, 1978). The Cochet-Bonnet anaesthesiometer (COCHET and BONNET, 1960) was attached to a micromanipulater and placed on a Nikon T.M. slit lamp. The sensitivity was measured at the 6 o'clock position, using the 0.12mm nylon monofilament, because of reduced patient apprehension (BONNET and MILLODOT, 1965) and also because it was shown that sensitivity reduced by contact lens wear is similar in extent for both central and peripheral readings (MILLODOT, 1975 (a)). Care was taken to observe and control the humidity of the atmosphere to between 50 and 60% because it was shown that the monofilament is affected by humidity and therefore may introduce an unknown bias into the readings (MILLODOT and LARSON, 1967). Data collection points for the recording of sensitivity are illustrated

in Table 3.5(b).

3.4 (vi) Oedema (biomicroscopical detection)

Oedema, an observed phenomenon in extended wear, (SLATT and STEIN, 1979; CLAHR, 1973; HIGHMAN, 1976; HIRJI, 1978), was recorded and ranked using a previously determined classification (HIRJI, 1978) comprising nine levels ranging severity from "physiological" for that patient to "gross oedema generalised over more than 50% of the cornea" (Appendix 3.4 (vi)).

3.4 (vii) Corneal Striae.

Corneal striae (SARVER, 1971, 1973) which were observed in the corneae of soft lens wearing patients, was attributed to corneal oedema (KERNS, 1974; KATZ, 1976; POLSE ET AL., 1975; WECHSLER, 1974; MANDELL, 1976). Mandell (1976) noted that vertical striae were first observed when the cornea swelled by about 7%, and further suggested that when vertical striae appear, they could be indicative of corneal physiological distress. Utilizing the slit lamp biomicroscope the incidence of corneal striae was recorded, but not classified into degrees of severity, as only a level of incidence in extended wear contact lens wearers was required.

3.4(viii) Vital Staining (biomicroscopical detection)

This was recorded after 1 drop of Rose Bengal 1% and Fluorescein sodium 2% was instilled, as advocated by Norn (1972), at baseline and at data points 8 to 15 (Table 3.5 (b)). The type, depth and area of stain in which the cornea was involved was classified by

a previously described method (HIRJI, 1978) (Appendix 3.4(viii)). Factors 6 and 7 were aided by the graticule (E18) in the slit lamp eye piece.

3.4 (ix) Corneal Limbal Injection

3.4 (ix)(a) Injection (biomicroscopical detection)

Where the injection was defined as the dilation of the existing blood vessel plexus, it was ranked at 4 levels of severity ranging from "none" to severe hyperaemia with lacrimation (HIRJI, 1978) (Appendix 3.4 (ix) (a)).

3.4 (ix) (b) Injection indicated by Apparent Lumen Width (photographic detection)

Where the injection was detected by a significant increase in the apparent diameter of five chosen blood vessels, the measurements of apparent blood vessel diameter were recorded by the following procedure.

Each patient was examined closely, using the Nikon T.M. photo-slit lamp, for a distinctive feature or pattern of vessels at the termporal or nasal limbus in one eye. This feature was then recorded by sketching (Appendix 3.4 (ix)(a)). Though it was often reported that vascular changes in contact lens wearers occurs at the superior limbus, it was decided to photograph the nasal or temporal limbus. This was because ocular fixation, even in the trained patient, was not steady enough for photography at high magnification (x35) when the upper eyelid had to be raised. Therefore, the photographs obtained were of a consistantly lower standard. In addition, it was felt that an increased degree of randomness was incorporated, where photographs were taken not only nasally or temporally, but also between 7 and

10 o'clock either side of the horizontal midline of the limbus.

Limbal photographs were taken with a slit beam of 1 to 1.5mm width which illuminated the limbal blood vessels by both direct and retro-illumination, which from previous test runs was found to be the best method for providing maximal detail of the vessel lumen. To photograph the nasal limbus, for example, the patient was directed to a suitable target which was viewed temporally (Plate 3.4 (ix) (i)). The beam was placed at approximately 30° to the observation system on the nasal side and finely adjusted until the optimum illumination of the blood vessels under observation was obtained. A green filter was used in 50% of the photographs because it appeared to aid focussing during photography. Previous test films indicated that one out of three transparencies was of a high enough standard to enable blood vessel measurement, and furthermore those obtained with white light and with green filter were comparable. As there was an adequate supply of film, it was decided to take three photographs with both white and green light to safeguard against any unforseen difficulties. Furthermore, repeated measurements of identical blood vessels, taken from photographic negatives obtained with both white and green light, on the same day, revealed no statistically significant differences(Appendix 3.4(ix)(b)(i)). For each patient, successive photographs were taken at virtually idential locations. This was accomplished by aligning two prominent and easily recognisable features, within the limbal plexus being photographed, with two positions on the graticule (E18) scale, one on the horizontal axis and one on the vertical axis. Alignment was achieved by fine movements of the patients fixation and the position of the slit lamp and illumination system.

The Nikon T.M. photo-slit lamp available for this study, was used in conjunction with a new photographic technique, devised by Holden etal. (1978). In this sytem (HOLDEN ET AL., 1978; ZANTOS and PYE, 1979), the camera lens and body was placed behind one of the slit lamp eye pieces by an appropriate adaptor tube (Plate 3.4(ix)(ii)), whereby high magnification photographs (approximately x7 on the film) were obtained by virtue of the additional magnification contributed by the eye piece. The observer in this technique (HOLDEN ET AL., 1978; ZANTOS and PYE, 1979) can comfortably and simultaneously perform (monocular) biomicroscopy and photography by viewing through the camera viewfinder. By the conventional method (SPIVAK, 1977; ZANTOS ET AL., 1980) the observer must also view through the camera viewfinder to ensure accurate positioning and focussing of the object. This method (SPIVAK, 1977; ZANTOS ET AL., 1980) introduces two problems, one because of the rather inaccessible positioning of the camera on top of the photo-slit lamp to which it is connected by a phototube, hence making observation awkward, and the other because the image viewed by this method is upside down. The additional advantage the new adaption (HOLDEN ET AL., 1978) has over the conventional methods (SPIVAK, 1977), already mentioned, is the additional magnification obtained at the camera film plane, which enables fine ocular detail to be recorded. The Nikon T.M. photo-slit lamp was therefore fitted with a suitable adaptor tube (HOLDEN ET AL., 1978). The camera used was the Olymous OM 1 with a 50mm lens, a photomicrography focussing screen with a clear central circle (with cross hairs) and a cable release, to reduce the possibility of camera movement, all of which complied with the photographic equipment suggestions by Holden et al. (1978). The film used was Kodachrome 64, chosen because it was shown to provide the best

available resolution at the film speed required for this type of photography (HOLDEN ET AL., 1978).

In addition to the aforementioned photographic techniques, fluorescein angiography was used very successfully by Dixon and Bron (1973), to demonstrate vascularization in contact lens wearers. This technique (DIXON and BRON, 1973) was dismissed on ethical grounds as its previous application was on patients wearing contact lenses for various reasons who were fitted in a hospital environment. It was felt that fluorescein angiography could not be justified on young healthy patients wearing extended wear lenses only for cosmetic reasons (CREWS, 1978). In addition, it was observed that the calibre of retinal vessels appeared greater in fluorescein photographs than in white light photographs (ALLEN ET AL., 1966; SHIKANO and SHIMIZU, 1968; HODGE ET AL., 1969). Although on average increase of 13% in the readings was reported (HODGE ET AL., 1969), there was no mention of a uniform or non-uniform effect in all the vessels. From these observations (ALLEN ET AL., 1966; SHIKANO and SHIMIZU, 1968; HODGE ET AL., 1969) it could not be assumed that the increase reported was equal in all vessels and indeed in all patients, which would indicate that fluorescein angiography in itself may cause apparent variations in the diameter of the limbal blood vessels, as well as those caused by extended contact lens wear.

Blood vessel width measurement of both retinal and limbal vessels is accompanied by various problems. The accuracy of various methods of retinal blood vessel measurement was reported (HODGE ET AL., 1969). The results from this study (HODGE ET AL., 1969) reported that a

slightly higher accuracy was obtained with a screw micrometer eye-piece incorporated with a microscope than with the method of measuring the projected image on a screen with dial calipers. More recently (BRACHER ET AL., 1979) it was reported that the projection method (HODGE ET AL., 1969) was found to be far less fatiguing than the screw micrometer eyepiece method (HODGE ET AL. 1969), a factor which was carefully considered in view of the large number of readings envisaged. Furthermore, though Bracher et al. (1979) preferred a modified form of projection technique, they were unable to show any significant improvement in accuracy over the previously described projection technique (HODGE ET AL., 1969).

The limbus was photographed at baseline and then every three months during contact lens wear. When the photographic film was developed the best slide for each date appointment was selected and set aside, regardless of the colour of the illumination, as this was found to be insignificant (Plate 3.4 (ix) (iii). For each patient, the five clearest blood vessels common to all the successive photographic transparencies were noted. The baseline transparency was then traced onto graph paper using the Zeiss microfilm reader (Plate 3.4 (ix) (iv)). and for each selected blood vessel a reference point was designated (fig 3.4 (ix)(b) (i)). The distance from the reference point to the position of measurement of the blood vessel lumen diameter was recorded and referred to at successive readings, thus enabling relocation of the same position along the lumen. It was shown in a recent study (BRACHER ET AL., 1979) that vessel width was best described when measured at three sites instead of one, because of physiological width fluctuations. However, as limbal blood vessels

FIGURE 3.4 ix) (b) (i)

Numbers 1 to 5 indicate the positions at which blood vessel diameters were measured, and the letters, A,B,C,D and E, indicate the corresponding reference points.

F is equal to 13.8 cm, the vertical range for each reference point, within which the apparent limbal depth for that reference point would be measured.

The markers labelled 0 and 100 correspond to the extremities of the graticule (E18).

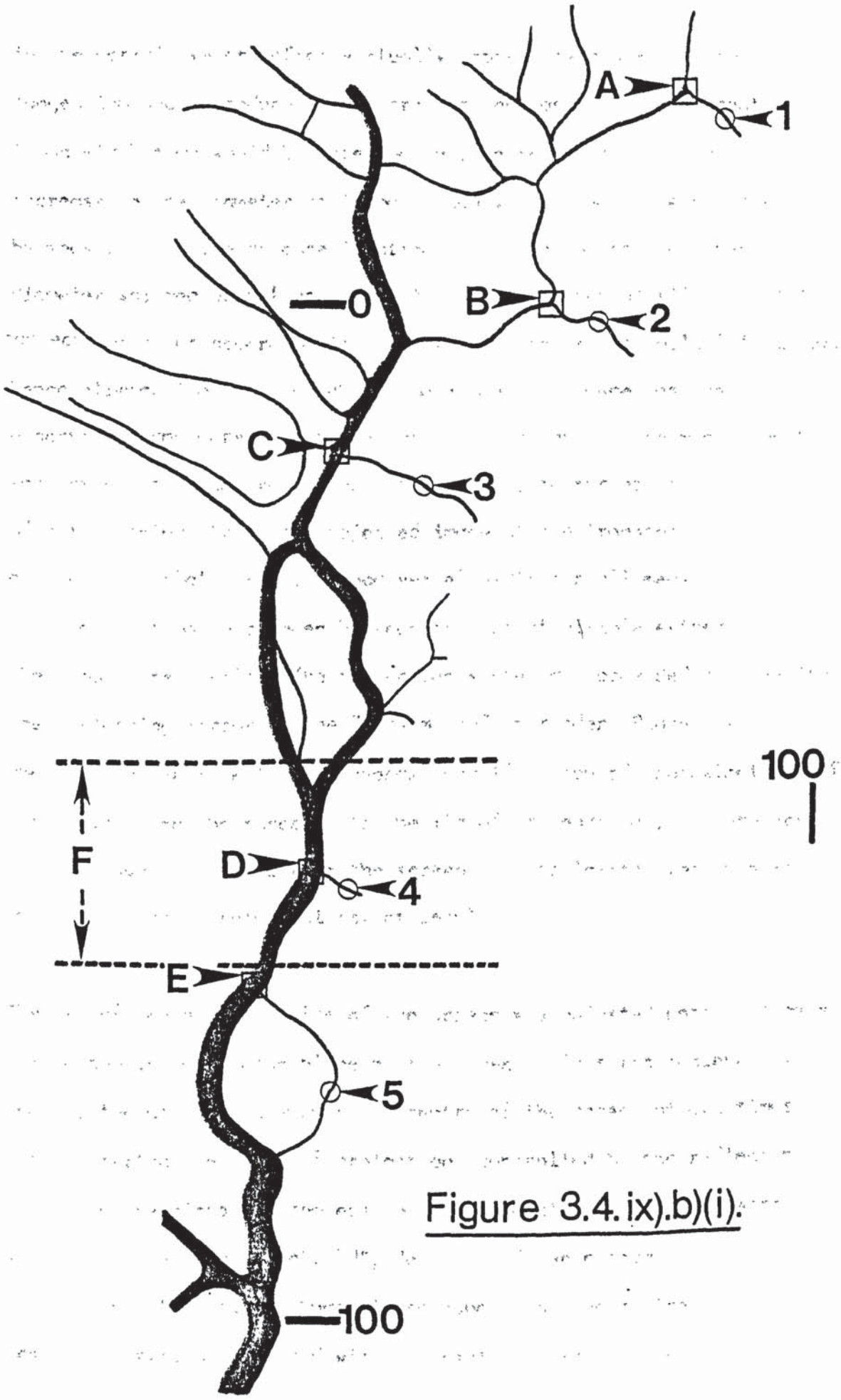


Figure 3.4. ix).b)(i).

in the normal eye are often virtually empty, any degree of limbal congestion would produce a much greater increase in the apparent lumen width than would be expexted in a retinal vessel. Such an increase in the diameter of limbal blood vessels would be detected by measuring at one or more locations. Each apparent blood vessel diameter was measured five times (Appendix 3.4 (ix) (b) (ii)), not consecutively but according to the system described in Table 3.4 (ix)(b), hence eliminating bias, which may have been introduced as the observer became more experienced at the technique. Each measurement was taken, using the Matui Vernier Calliper, measuring to a tenth of a millimeter, from the projected image of the transparency on a matt white, flat screen. Blood vessel width for all measurements at each location, was taken between the widest visible extremities of the blood vessel wall. The projection system was provided by lowering the reflecting mirror in the Zeiss microfilm reader (Plate 3.4 (ix) (v), and using a x28 objective an overall magnification of approximately x69 was achieved on the screen. As the microfilm reader did not produce uniform magnification across the screen, the following procedure was adopted to ensure repeatability of results.

The projection at the centre of the screen was adjusted until its axis was perpendicular to the plane of the screen. This was achieved by keeping the graticule image on the centre of the screen at all times while altering the angle of projection (controlled by the reflecting mirror in the microfilm reader) until the lengths "a" and "b" were equal and also lengths "c", "d", "e", and "f" were equal (fig 3.4 (ix)(b) (ii)). Under these conditions the centre of the projection system coincided with the centre of the screen and

TABLE 3.4 ix) (b) Showing the order in which successive photographic blood vessel readings were taken.

Measurement Sessions	PATIENT NUMBERS				
	1 - 15	16 - 30	31 - 45	46 - 60	61 - 75
First	X	1	2	3	4
Second	4	X	1	2	3
Third	3	4	X	1	2
Fourth	2	3	4	X	1
Fifth	1	2	3	4	X

"X" denotes commencement of readings.

1, 2, 3 and 4 denote subsequent readings at the same measurement session.

distortion was reduced to a minimum.

Diagramatic Representation of the Projection

Aligning technique

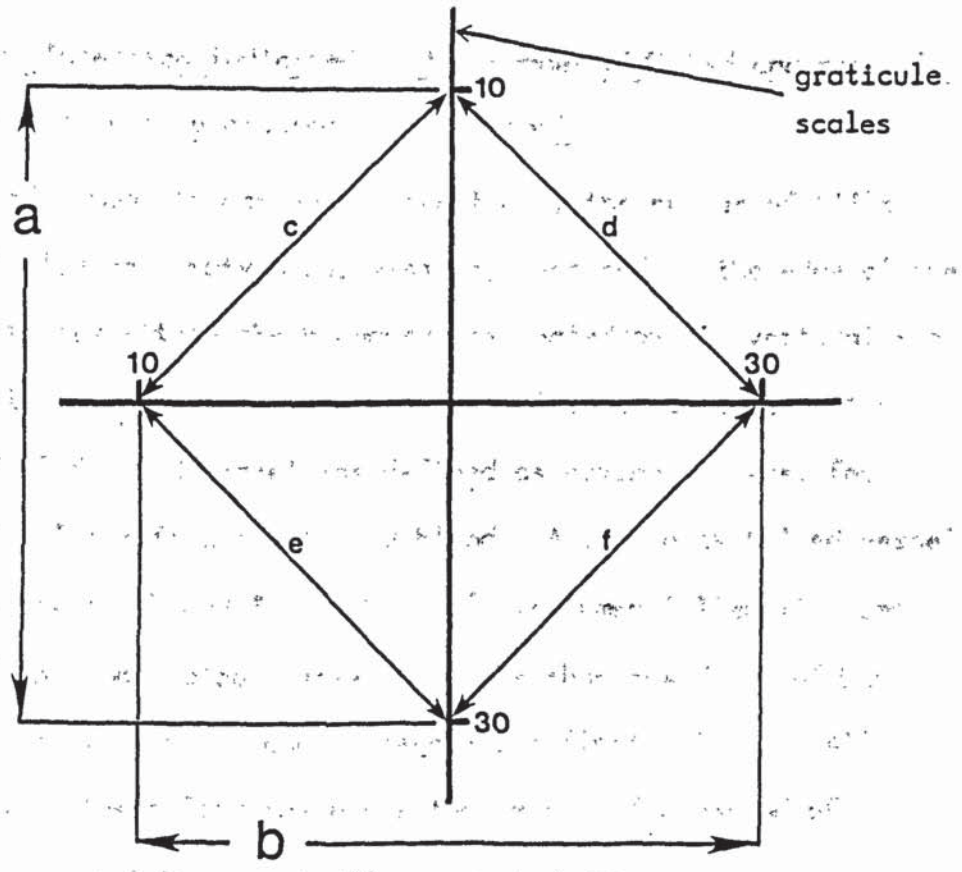


Fig. 3.4 (ix) (b) (ii)

To calibrate projection at successive measuring sessions, a piece of white card was taken and the images produced by the "30" and "10" points for both vertical and horizontal scales, were marked upon it. To recalibrate, the projection system was adjusted until the central

projected image coincided with the predetermined image size upon the white card. In addition, all measurements were taken at shoulder/eye level within a depth of 30cm. marked upon the screen. It was anticipated that any further small variations caused laterally would be eliminated by the variability of measurement locations, and by virtue of the control group.

3.4 (ix) (c) Injection indicated by the number of filled and partially filled blood vessels (photographic detection)

The degree of limbal injection was denoted by the number of filled, partially filled and empty blood vessels, measured at the edge of the corneal periphery within the boundary designated by the vertical scale of the graticule, or within an equivalent distance to that of the scale. A filled blood vessel was defined as having at least four fifths of its lumen filled with red blood. A partially filled vessel had between one fifth and four fifths of its lumen filled with red blood, while an empty blood vessel had less than one fifth of its volume occupied with red blood (Appendix 3.4 (ix)(b) (ii). All recordings were taken from the projected image. The method of projection was the same as the one previously mentioned.

3.4 (x) Corneal Vascularization

3.4(x) (a) Vascularization measured by a ranking system (biomicroscopical detection)

Vascularization was defined as the growth of new blood vessels into the cornea and ranked at four levels of severity ranging from "none" to "severe vascularization which had encroached to within 2mm of the corneal apex" (HIRJI, 1978) (Appendix 3.4 (ix)(a)). The second grade of severity was divided into three sections; superior, inferior and nasal/ temporal, which was recorded in the computer as being part of an effective classification comprising six grades.

3.4 (x) (b) Vascularization, indicated by the number of unlooped vessels (biomicroscopical detection)

This was defined by the number of unlooped vessels that were present at the limbus observed at high magnification (x35) (Appendix 3.4(ix)(a)).

3.4 (x) (c) Apparent Vascularization (biomicroscopical detection)

Where the apparent vascularization was defined as a significant increase in the apparent limbal depth measured superiorly, inferiorly, nasally and temporally with the aid of the graticule (E18), from Graticules Ltd., which was placed within one of the eye-pieces. Readings were taken to the nearest five divisions on the graticule (i.e.0.25mm). The measurements were taken either horizontally, for the nasal and temporal limbus, or vertically, for the superior and inferior limbus, from the outermost visible limit of the palisades of Vogt to the innermost tip of the vessel, or vessels, extending into the cornea (Appendix 3.4 (ix)(a)). This technique was difficult because of the enhanced ocular movements present at higher magnifications, but reducing the magnification below x16 also reduced the size of the image observed to an impractical level, hence x16 was chosen as the optimum magnification.

3.4 (x) (d) Apparent Vascularization (photographic detection)

Where apparent vascularization was defined by an increase in the apparent limbal depth measured by projection (as described previously) from photographic records of the limbus (Appendix 3.4 (ix)(b) (ii)). The readings were taken from the five previously determined reference points in a horizontal plane to the most distal tip of the adjacent blood vessels. Five readings of each measurement were taken, but

not consecutively, for reasons discussed before. To ensure that an average distribution of apparent limbal depths was being obtained, the average of the vertical distances, between reference points for 25% of the patients was obtained (Appendix 3.4 (x) (d)). This figure (13.8cm) was used to described the vertical zone above and below the horizontal line, from each reference point, within which apparent limbal depth measurements would be taken (Fig 3.4 (ix) (b) (i)).

3.4 (xi) Tarsal Conjunctival examination (biomicroscopical)

An adverse reaction of the tarsal conjunctiva, which was suggested to be a manifestation of delayed-type basophil hypersensitivity (COLLIN and ALLANSMITH, 1977; ALLANSMITH ET AL., 1977; COLLIN, 1980) was noted in both daily soft lens wearers (SPRING, 1974; CUMMING and KARAGEOZIAN 1975; BERNSTEIN and LEMP, 1975; HORNBROOK, 1976; ALLANSMITH ET AL., 1977, 1978; MACKIE and WRIGHT, 1978; GREINER ET AL., 1978; HENRIQUES and ALLANSMITH, 1979) and extended wear contact lens wearers (HIRJI, 1978). The signs and symptoms of this response to contact lens wear, which was termed giant papillary conjunctivitis (G.P.C.) (ALLANSMITH ET AL., 1977), include the formation of giant papillae, mucous and discomfort. These signs were also associated with vernal conjunctivitis and indeed histological sections from vernal conjunctivitis and G.P.C. sufferers showed remarkable similarities (ALLANSMITH ET AL., 1977; COLLIN and ALLANSMITH, 1977; COLLIN, 1980).

In view of these previous findings the tarsal conjunctiva was examined using the method and classification advocated by Allansmith et al(1977) (Appendix 3.4 (xi)).

The tarsal conjunctiva was classified as follows:-

i. Satin appearance, where the tarsal conjunctiva was devoid of papillae and had a smooth surface.

ii. Uniform papillary appearance, in which small (4 to 8 per mm) microscopically elevated papillae were detected over zones 1, 2 and 3 (see Appendix 3.4 xi)).

iii. Non-Uniform papillary appearance, in which some of the papillae were 0.4 to 0.8 mm in diameter resulting in a non-uniform appearance.

iv. Giant papillary appearance, where papillae 1 mm in diameter or greater were present in zones 1, 2 or 3.

v. Severity of Giant papillae, categorized into five grades ranging from "none" to "occupying 100% of zones 1, 2 and 3".

Additional information was recorded when necessary under "vi" and "vii" on the record sheets (Appendix 3.4 (xi)), for example development of concretions.

3.4 (xii) Contact Lens over-refraction: determined by the cross cyl technique using standard circular targets with the contact lens in situ where applicable.

3.4 (xiii) Spectacle prescription: determined by the cross-cyl technique, using standard circular targets.

3.4 (xiv) Contact lens condition: was categorised into five sections as previously described by Hirji (1978), (Appendix 3.4 (xiv)).

3.4 (xv) Contact lens deposits

In view of previous observations (HIRJI, 1978) where the presence of

contact lens deposits was noted in 28.9% of patients after only four weeks of Sauflon T.M. 85 extended wear, it was felt necessary to record characteristics of the deposits formed. However, Fatt et al. (1977) demonstrated that significant levels of deposition did not affect the oxygen transmissibility, and only when the deposits were very extensive, such that the level of discomfort and visual acuity would be totally unacceptable, was the oxygen transmissibility detected to fall to an insufficiently low level (FATT ET AL., 1977), an observation which was further supported by Benjamin and Hill (1980).

3.4 (xv) (a) Contact Lens deposit colour (biomicroscopical observation)

The colour was categorised into five sections as previously described by Hirji (1978) (Appendix 3.4 (xiv)).

3.4 (xv) (b) Appearance of Contact Lens deposits (biomicroscopical observation)

The deposits were observed utilizing white light at a constant magnification (x35). The following categories were applied (HIRJI, 1978):

i. Crystalline: defined as a deposit that appeared to have a definite repeatable geometric form, in principle "needle like" deposits.

ii. Film like haze: defined as coatings of a thin layer without any discrete areas of deposits.

iii. Granular: defined as the presence of fine even sized granules within an area of deposit on the lens surface.

iv. Speckles: defined as the presence of small opaque "dots", widely scattered, of uneven size, over the contact lens surface (Appendix 3.4 (xiv)).

3.4 (xvi) Further observations (biomicroscopical detection)

Careful examination of the cornea and adnexa using the slit lamp at high magnification (x35), was carried out at each appointment to detect any developing anomalous changes.

In addition, aspects not already recorded were obtained from a questionnaire form (HIRJI, 1978) (Appendix 3.4 (ii)), which was filled in by all patients. Further information was also recorded to enable the author to assess and record various clinical problems.

An extract from a typical patient record may be found in Appendix 3.4 xvi).

Section 3.5 Clinical and data appointment schedule

To simplify and to help the understanding of the data collection system the following Tables were drawn up: Table 3.5 (a) illustrates when the patients were seen, the visit number allotted to each appointment and the reason(s) for the appointment; Table: 3.5 (b) illustrates the frequency at which individual factors were recorded. Each patient was given a personal list of appointments (Appendix 3.5) which indicated the time and type of appointment which conformed to the schedule listed in Table 3.5 (a).

TABLE 3.5 (a)

Clinical and Data Appointment Plan

Appointment	Visit No.	Group 'A'	Group 'B'	Group 'C'
Baseline	1	D	D	D
Day 2	2	D	D	D
Day 4	3	D	D	D
Day 6	4	D	D	D
Day 8	5	D	D	D
Week 2	6	D	D	D
Week 3	7	D	D	D
1 Month	8	D/CA	D/CA/CL	D
2 Month	9	D/CA	D/CA/CL	D
3 Month	10	D/CA	D/CA/CL	D
6 Month	11	D/CA	D/CA/CL	D
9 Month	12	D/CA	D/CA/CL	D
12 Month	13	D/CA	D/CA/CL	D
15 Month	14	D/CA	D/CA/CL	D
18 Month	15	D/CA	D/CA/CL	D

Key. D - data collection
CA - clinical after-care
CL - contact lens cleaning

Note:- Contact lens wearers (ie Groups 'A' and 'B') attended at 4 weekly intervals between the data collection points 10 to 15, for routine clinical aftercare. In addition group "B" had their lenses cleaned.

TABLE 3.5 (b) Data Collection

Data \ Data point	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Visual acuity	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Visual stability								X	X	X	X	X	X	X	X
Spectacle refraction	X							X	X	X	X	X	X	X	X
Over refraction	X							X	X	X	X	X	X	X	X
Central pachometry	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Topographical pachometry	X									X	X	X	X	X	X
Keratometry	X									X	X	X	X	X	X
Tarsal conjunctiva	X							X	X	X	X	X	X	X	X
Oedema	X							X	X	X	X	X	X	X	X
Staining	X							X	X	X	X	X	X	X	X
Blood vessel data	X									X	X	X	X	X	X
Contact lens condition and deposits	X							X	X	X	X	X	X	X	X

Where "X" denotes data collection

Section 3.6 Extended Wear Procedure

3.6 i) Sauflon T.M. 85, the extended wear lens

Sauflon T.M. hydrogels were produced from copolymerising methyl-methacrylate and N-vinyl pyrrolidone. Sauflon T.M. 85 is a dimensionally stable hydrogel derived from the same comonomers as other Sauflon T.M. materials, but because of different initial monomer ratios it has an equilibrium water content of approximately 80% in normal saline at room termperature (20°) (CORDREY, 1977). The equilibrium water content when placed on the eye in the open (34°) and closed eye (37°c) situation is 78.6% and 77.7% respectively (LARKE, 1978). The measured value of dissolved oxygen permeability (DK) for Sauflon T.M. 85 is 48.6 x 10^{-11} cm^2 cm^3 sec^{-1} cm^{-3} mm Hg^{-1} at 20°C (FATT and MORRIS, 1977), and the predicted value from its equilibrium water content at 34° was shown to be approximately 78 x 10^{-11} cm^2 cm^3 sec^{-1} cm^{-3} mm Hg^{-1} (NG, 1974). From temperature coefficients, it was predicted that an increase of 5°C produced an increase of 10% in the measured dissolved oxygen permeability coefficient (DK) (FATT and MORRIS, 1977) from which a DK value of 65 x 10^{-11} cm^2 cm^3 sec^{-1} cm^{-3} mm Hg^{-1} was predicted for the closed eye (37°C) situation. However, it was previously suggested (NG, 1974) that the relationship was more complicated, and the dependent relationship of water content and permeability on temperature was fully documented (NG, 1974).

Fatt and St. Helen (1971) derived several equations to monitor and predict the movement of dissolved gases through a membrane. It was shown that the movement per unit area of dissolved gas (Q_2 O_2) through

a membrane was proportional to the concentration gradient across its two surfaces ($P_{ANTERIOR\ (A)} - P_{POSTERIOR\ (B)}$) and inversely proportional to the thickness of the membrane (L). Therefore

$$Q_2\ O_2 = D\ \frac{(P_A - P_B)}{L} \quad \text{----------(1)}$$

(Where D is the diffusion coefficient)

From Henry's Law (GLASSTONE, 1960), the concentration of dissolved oxygen (O_2) is proportional to its partial pressure in a solvent (PO_2).

Therefore $(O_2) = kPO_2$ ----------(2)

Where K is a solubility coefficient.

Substituting equation (2) into equation (1)

$$Q_2\ O_2 = \frac{DK}{L}\ (PO_{2A} - PO_{2B}) \quad \text{----------(3)}$$

(FATT and ST HELEN, 1971). Fatt and St. Helen (1971) further reported that the cornea utilized oxygen under a tightly fitted oxygen permeable hydrogel contact lens and described the oxygen consumption across the epithelial surface as

$$Q_3\ O_2 = aPx\beta \quad \text{----------(4)}$$

Where a and β were empirical constants and Px was the oxygen tension at the epithelial lens interface ($a = 0.24 \times 10^{-6} cm^3 cm^{-2} sec^{-1} (mm\ Hg)^{-\frac{1}{2}}$, $\beta = 0.5$).

When the corneal oxygen consumption rate is equal to the available oxygen at the corneal-contact lens interface, $Q_3\ O_2$ in equation (4) is equal to $Q_2\ O_2$ in equation (3) (FATT and ST. HELEN, 1971). Substituting equation (4) into equation (3) -

$$aPx\beta = \frac{DK}{L}\ (PO_{2A} - PO_{2B}) \quad \text{----------(5)}$$

Solving equation (5), for DK (Coefficient of dissolved oxygen permeability) for conditions of sleep, the desireable values of oxygen tension at the contact lens - corneal interface can be obtained, therefore, allowing definition of the theoretical steady state physiological requirements of intended extended wear contact lenses.

$$DK = \frac{aPx\beta \quad (L)}{40} \qquad \text{----------(6)}$$

$$= 57.5 \times 10^{-11} cm^3 cm^2 sec^{-1} cm^{-3} mm\ Hg^{-1}$$

(Where $PO_{2B} = Px = 15mm$ Hg, $PO_{2A} = 55$ mm Hg, $L = 0.025$ cm)

Therefore, to ensure that a minimum oxygen tension at the contact lens-corneal interface is 15mm Hg a contact lens of maximum thickness 0.25mm would be required to be made from a hydrogel with a dissolved oxygen coefficient of at least $57.5 \times 10^{-11} cm^3 cm^2 sec^{-1} cm^{-3} mm\ Hg^{-1}$.

The units of (DK) (FATT and ST. HELEN, 1971) compared to the units of (Pd) (YASUDA ET AL., 1966; NG, 1974), were noted to be 100 times smaller that (Pd) units. Considering this factor from NG (1974), who correlated the log of dissolved oxygen permeability coefficients of various hydrated materials with their water content at 25°C and 34°C, the (Pd) value of $575 \times 10^{-10} cm^3 mm\ sec^{-1} cm^{-2} cm\ Hg^{-1}$ implied that a hydrogel material of at least 72% equilibrium water content at 34°C should be used. From the figures previously mentioned (LARKE, 1978; NG, 1974; FATT and MORRIS, 1977) Sauflon T.M. 85 would appear to meet the theoretical demands of ensuring a minimum oxygen tension of 15mm Hg at the corneal - contact lens interface during sleep and thus can be accepted, theoretically, for extended wear up to a thickness of 0.25mm (HIRJI, 1978). (The maximum hydrated thickness guaranteed by the Manufacturers (Contact Lenses Manufacturing) for lathe cut Sauflon T.M. 85

is 0.25mm)

3.6 ii) Patient Grouping

The experimental volunteers were divided into three groups. Group 'A' wore Sauflon T.M. 85 lenses without removal, except at clinical after-care appointments, and without recourse to proprietary cleaning agents. The lenses were replaced with new ones when contact lens deposits had accumulated to an unacceptable level. The second group of experimental patients, group 'B', wore Sauflon T.M. 85 lenses which were removed at 4 - weekly intervals and cleaned with Monoclens C40 (Contact Lens Manufacturing), as recommended by the manufacturers. The third group of patients, group 'C', comprised controls who wore spectacles when required.

3.6 iii) The fitting of Sauflon T.M. 85 extended wear lenses

The optimum lens - cornea relationship for Sauflon T.M. 85 was determined by previous workers (HODD, 1976; HIRJI, 1978) and found to coincide with the lens having a back centre optic radius 0.50 mm flatter than the flattest Keratometry reading. It was also suggested that fitting a soft lens slightly flatter than the flattest Keratometry reading provides maximal oxygen tension at the anterior corneal surface (PARRISH and LARKE, 1981). Each patient was therefore fitted with contact lenses 0.25 to 0.50mm $\pm$ 0.1mm flatter than the flattest K reading, in accordance with the predetermined optimum fit for Sauflon T.M. 85 (HODD, 1976; HIRJI, 1978). All contact lens wearing patients were required to wear the "best fit" contact lenses for an overnight trial. The lens suitability was determined the following day by clinical examination. The occurance of any untoward

reaction at this stage resulted in rejection of the patient from the study. Once the "best fit" lenses were obtained for each patient, the lenses were marked, autoclaved and stored until required at the beginning of the intended study. The patients were instructed on emergency removal of the lenses, should such a situation arise during the course of the study.

3.6 iv) Schedule for extended wear

Both the experimental contact lens wearing groups were to wear their lenses continuously for a period of 18 months. The Sauflon T.M. 85 lenses would only be removed at selected data collection and clinical evaluation appointments (Tables 3.5 (a),(b)), when vital stains were instilled for corneal assessment. When the contact lenses were cleaned or replaced continuance of contact lens wear was resumed within 24 hours. When this was not possible data collection points were rearranged such that the original duration of contact lens wear that was intended between data points was adhered to.

3.6 v) Contact lens cleaning regime

The patients in group 'B' had their lenses cleaned at 4 weekly intervals with Monoclens C40. The lenses were placed in vials in a solution of 0.3 gm Monoclens T.M. powder to 5 ml of physiological saline then boiled in an ascepticisor for at least 10 minutes, where they were allowed to remain for at least 2 hours. The vials were allowed to cool and the lenses were transferred into vials half filled with Monoclens C40 T.M. solution, in which they were left to soak for at least 4 hours. The lenses were then thoroughly rinsed several times in physiological saline and then asepticised, after which the pH in the

vial was checked. If the pH was outside the range of 7.0 to 7.2, the lenses were re-rinsed and asepticised and the pH checked.

Section 3.7 Termination of the Study

At the eighteenth week of the study a patient in group "B" presented with micro-epithelial cysts. After this observation just prior to the six month appointment, six further subjects were examined and showed the presence of similar bodies. Consequently all other contact lens wearing subjects were carefully examined. Only one patient did not initially present with micro-epithelial cysts.

Although the presence of the cysts was not considered to be particularly serious, in view of the high incidence, the study was abandoned and lens wear was stopped at the six month data point. The incidence, severity and rate of recovery of the micro-epithelial cysts were observed and recorded (Chapter 6).

Section 3.8 Data Recording and Manipulation

Data taken from the patients was recorded immediately on standard data recording sheets (Appendix 3.4(xvi)). These were gathered in sequence for each patient, and the data was copied from them onto Fortran Coding Forms, supplied by the University Computer Centre. The data was typed onto cards and the cards verified by the University card punching service, and then read from these cards into a file in the computer.

Although time consuming and tedious, this process was simple and enabled the large volume of data to be input into computer filestore with the minimum number of steps, and thus minimised copying errors.

The analysis was performed on subordinate files created from the main data file by means of an editor. These files may be found in appendices 3.8 (b-e), each being preceded by an explanatory key. A macro command was written to call the ICL George 3 editor and instruct it to copy selected portions of the main file onto the subordinate files. By using this macro, any modifications to the master file could be passed onto the subordinate files simply and accurately. Superfluous outdated files were erased after a period of two days.

Once the files had been established in the ICL 1904s, a standard University macro was used to transfer them to a Harris 500 computer for analysis. The analysis was performed interactively on the Harris 500 because it offered the fastest job turnaround of the facilities available at Aston University.

Photographic blood vessel data obtained using the projection technique

was recorded on standard sheets as the readings were taken (Appendix 3.8 (f)). When all the sets of readings were complete, means and standard deviations of each set were calculated using a Texas Instruments SR 51 II calculator. A file was then opened in the ICL 1904s and these means and standard deviations were input manually using an online terminal. This file was subsequently transferred to the Harris 500 for analysis.

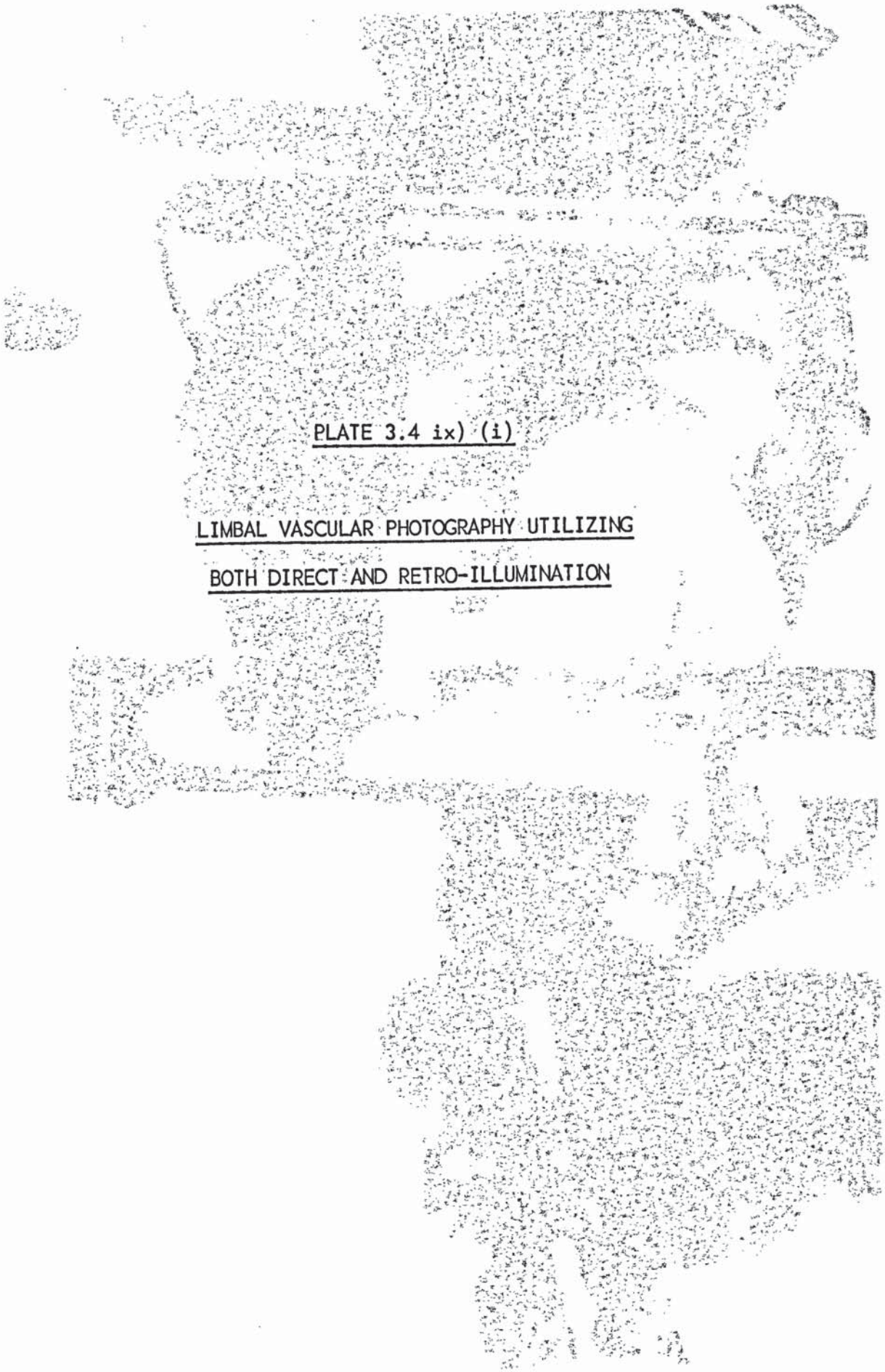


PLATE 3.4 ix) (i)

LIMBAL VASCULAR PHOTOGRAPHY UTILIZING BOTH DIRECT AND RETRO-ILLUMINATION

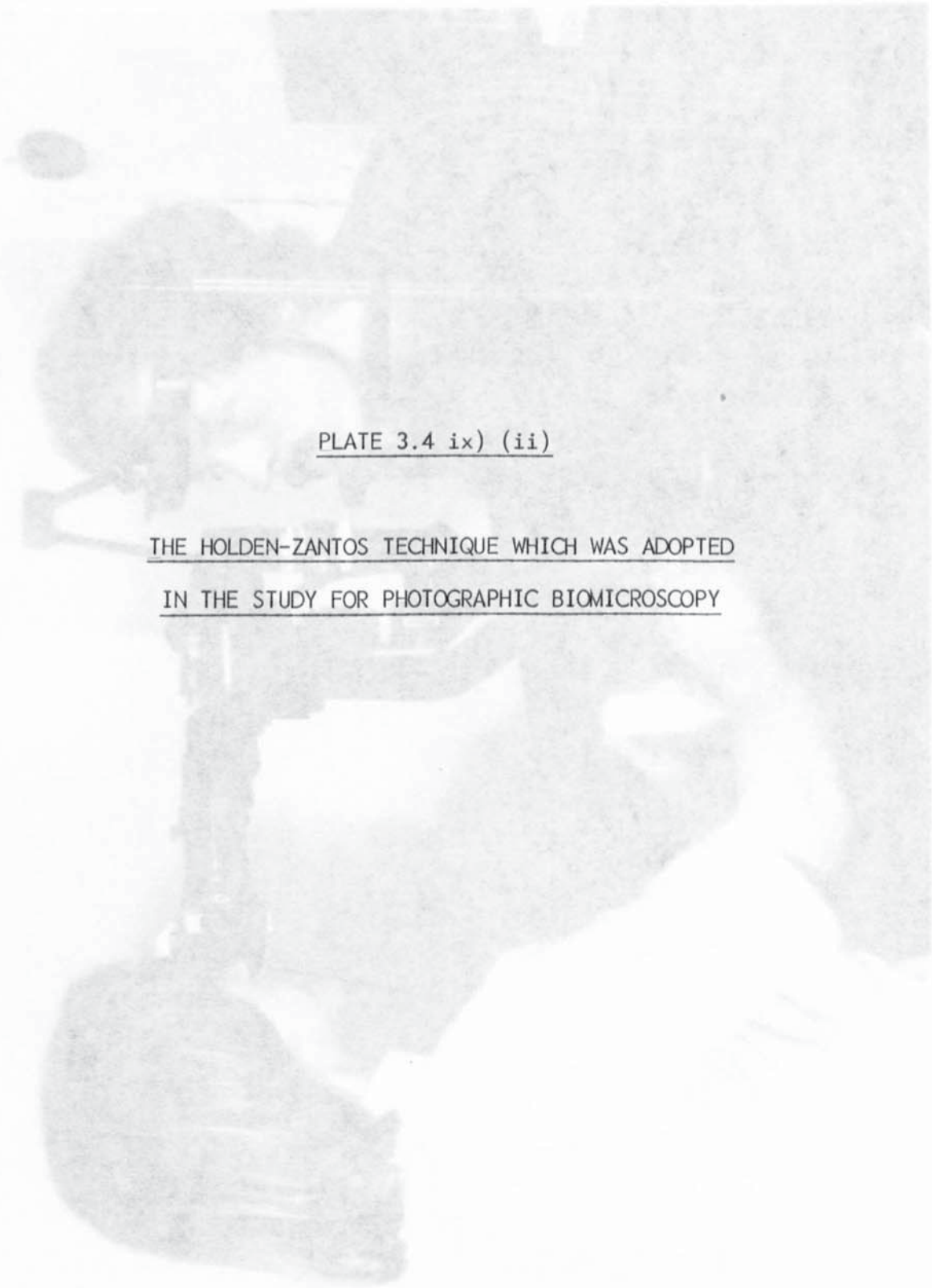


PLATE 3.4 ix) (ii)

THE HOLDEN-ZANTOS TECHNIQUE WHICH WAS ADOPTED

IN THE STUDY FOR PHOTOGRAPHIC BIOMICROSCOPY

PLATE 3.4 ix) (iii)

TWO EXAMPLES OF LIMBAL BLOOD VESSEL PHOTOMICROGRAPHS

The first set of photomicrographs, selected from the control group (patient Medlock), show the same area of the limbus at:

a) Baseline

b) Three month appointment

c) Six month appointment

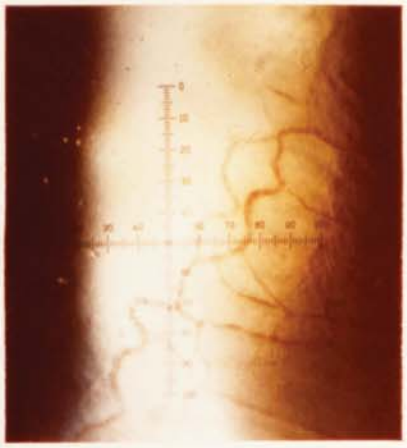
The second set, selected from the lens wearing patients (Booth, solution user), show the same area of a lens wearer's limbus at:

d) Baseline

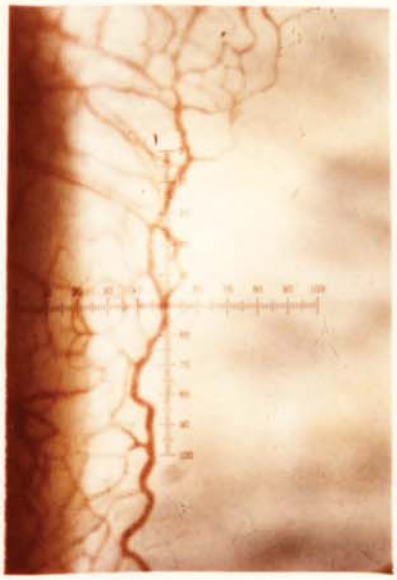
e) Three month appointment

f) Six month appointment

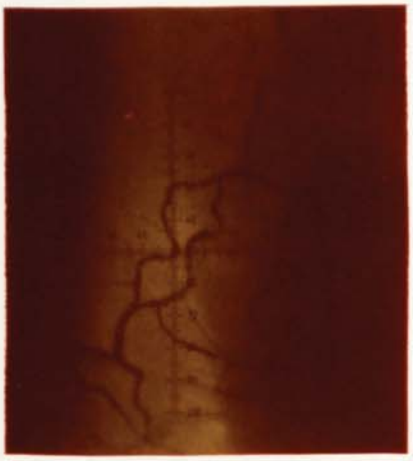
Note, in the case of Booth, the contrast between baseline and three months and baseline and six months, for limbal blood vessel engorgement and apparent limbal depth.



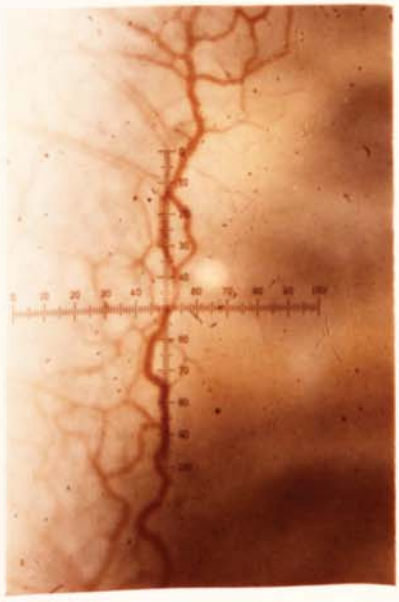
(a)



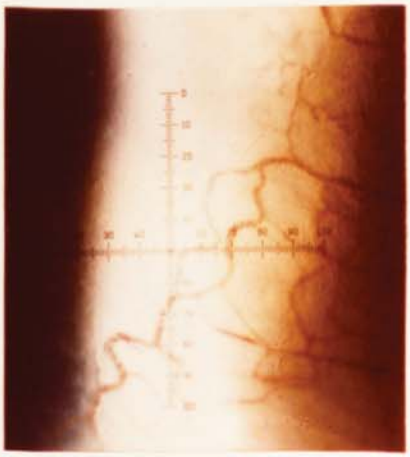
(d)



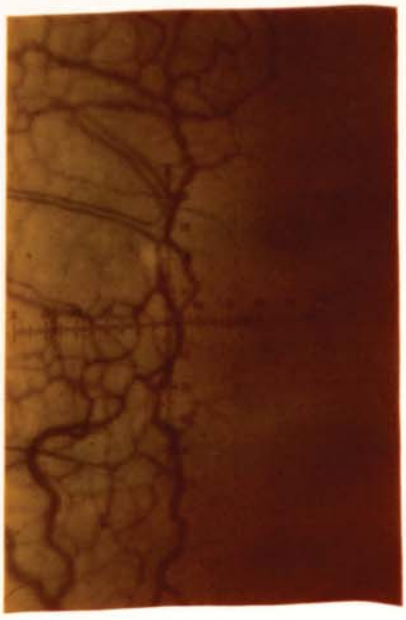
(b)



(e)



(c)



(f)

PLATE 3.4 ix) (iii)

PLATE 3.4 ix) (iv)

THE TRACING OF SELECTED TRANSPARENCIES

UTILIZING THE ZEISS MICROFILM READER

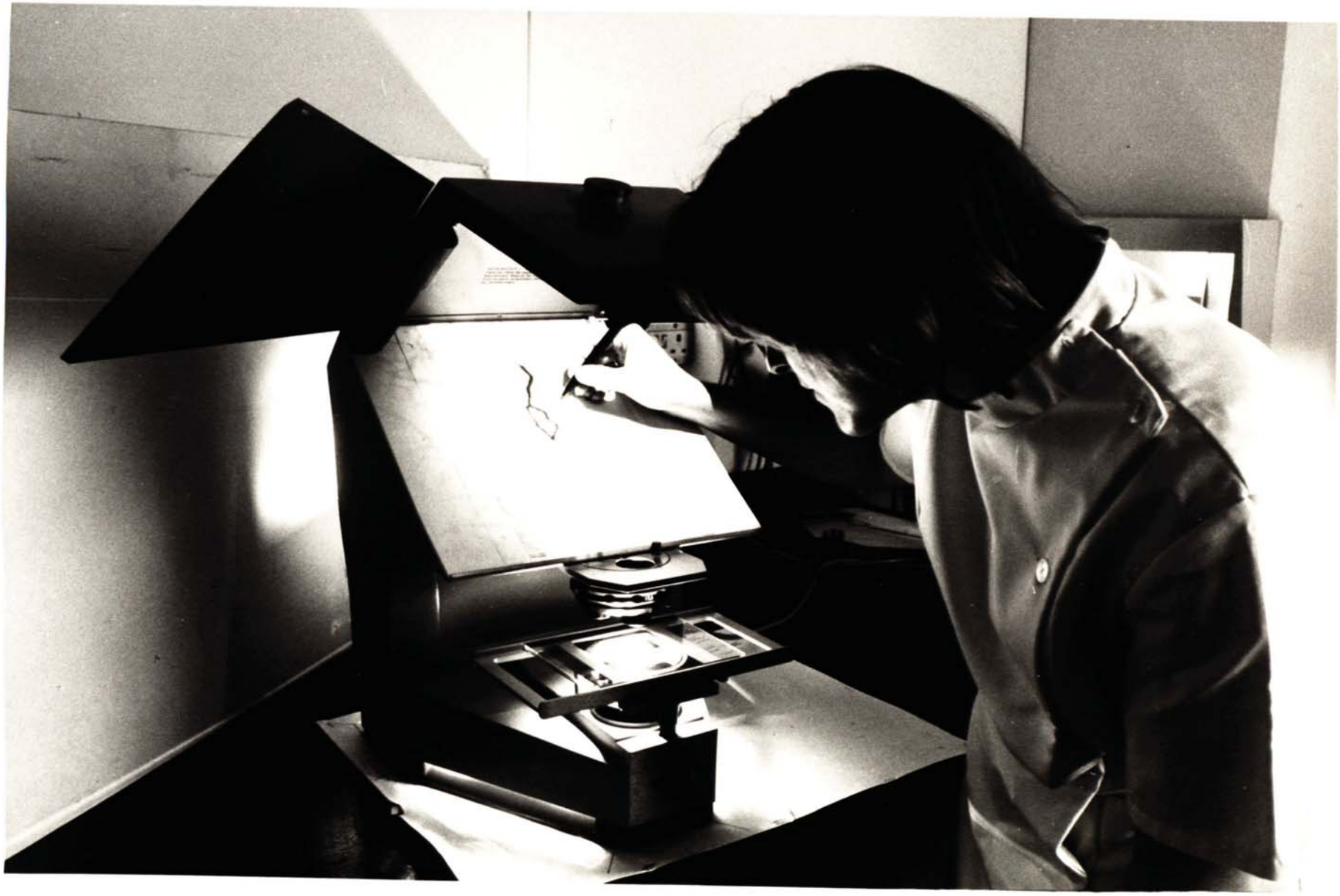
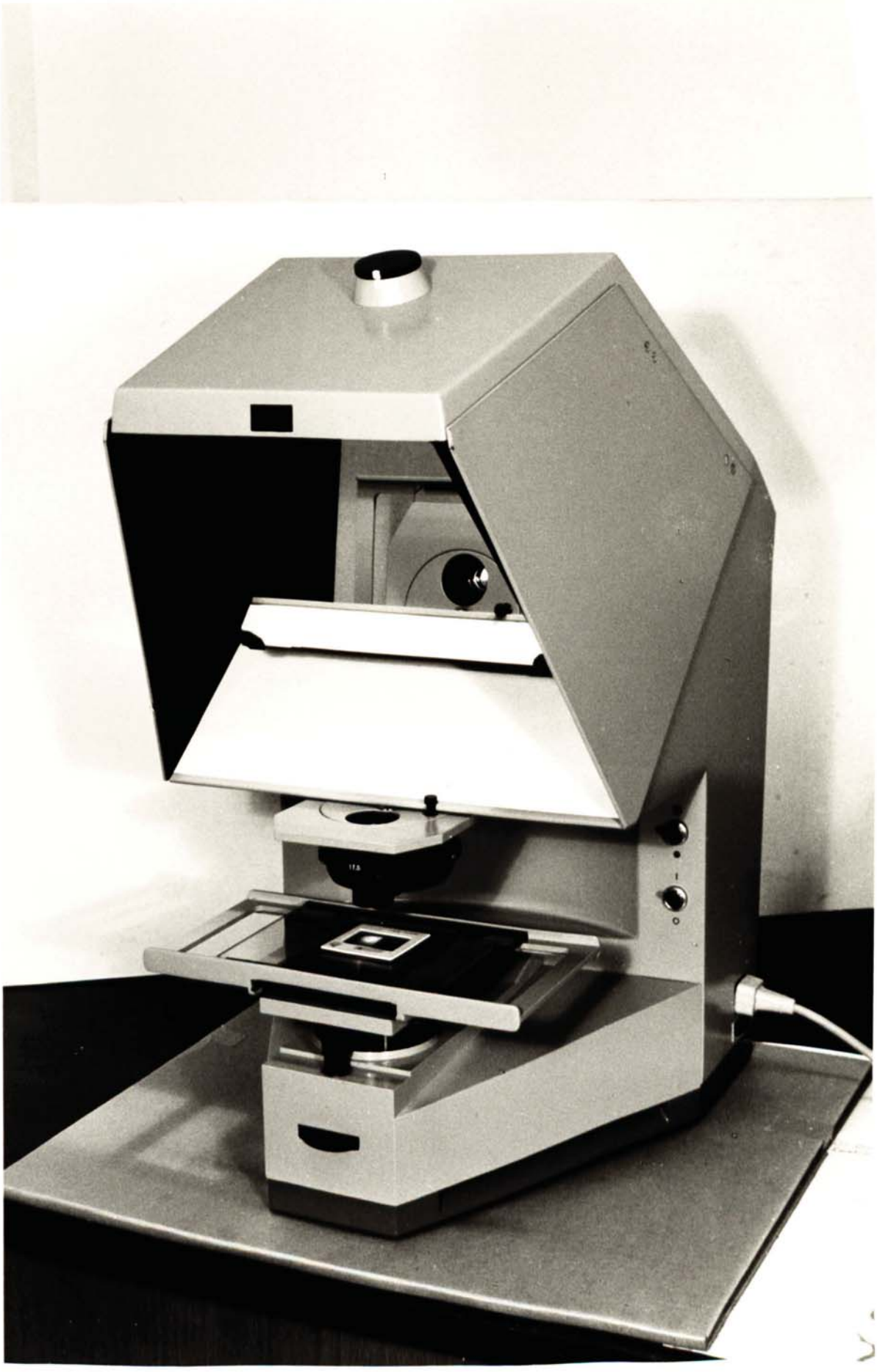


PLATE 3.4 ix) (v)

THE ZEISS MICROFILM READER

The reflecting mirror was lowered to enable projection onto a matt white screen approximately 1.5 meters away.



CHAPTER 4

Results

Section 4.1 Introduction

During a previous study (HIRJI, 1978) it was ascertained that for patients drawn from a similar selection profile, the ocular parameters recorded came from a normal distribution. Therefore, in this present study most of the data collected, except for the additional limbal blood vessel measurements, was assumed to come from a normal distribution. Due to premature termination of the study and the resultant reduction in data points it was felt that two way analysis of variance, using the SPSS (Statistical Package for the Social Sciences) (NIE et al, 1975) subprogram "Anova", based on a regression model, was more appropriate for the majority of factors recorded than using a regression analysis. For data collected with non-sequential, qualitative classifications contingency tables were calculated using the SPSS subprogram "Crosstabs". Unfortunately four patients who were all in the non-solution using group withdrew from the study within the first month, and one patient in the solution using group failed to attend after the three month visit. For these reasons and also because of nonattendance of other patients at several data points, group sizes were reduced to 18 or 16 depending on the data recorded. Further reduction of group sizes was caused by instrumental failure, resulting in lost data.

Section 4.2 Visual Acuity (Habitual)

Visual acuity was analysed using the SPSS sub program "Anova" which calculates two way analysis of variance based on a regression model. Changes in visual acuity during the short-term (visits, 1, 2, 3, 4, and 5), intermediate term (visits 1, 5, 6, 7 and 8) and long-term (visits 1, 8, 9, 10 and 11) were all analysed separately. As the sub program "Anova" calculated an error estimate partially based on inter-individual variations, it's value was artificially high. To calculate a new error estimate the following formula was used

$$\text{Standard Deviation} = \frac{b - a}{\sqrt{12}}$$

(DAVIES and GOLDSMITH, 1972)

Where (b - a) is the difference between two scale divisions, which for visual acuity was equal to 1

Therefore: $\text{Standard Deviation} = \frac{1}{\sqrt{12}} = 0.28868$

Error estimate = $0.28868^2 = 0.08333$

This formula assumes that for every recording the correct scale division is selected. As many patients were often between 6/4 and 6/5 it was felt that a factor of 50% should be added to the error estimate to allow for patient error, patient memory and any other factors which may have been present.

The Final Error Estimate = 0.1250

Where DF = Infinity.

The following hypotheses were tested:

1. H_o: Visual Acuity in independent of time.

   H_1: Visual Acuity is not independent of time.

2. H_o: Visual Acuity is independent of group.

   H_1: Visual Acuity is not independent of group.

Table 4.2 (a)

i. Analysis of Variance Table for Short-Term Visual Acuity by Group, "with" Visit

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Visit	0.752	1	0.752	6.016	0.025
Group	16.075	2	8.037	64.296	<0.0001
Explained	16.827	3	5.609	44.872	<0.0001
Residual	60.635	236	0.257		
Error Estimate		∞	0.125	1	
Total	77.462	239	0.324		

Therefore: 1. Accept H_o

2. Accept H_1

ii. Analysis of Variance Table for Intermediate-Term Visual Acuity by Group, "with" Visit

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Visit	5.753	1	5.753	46.024	<0.0001
Group	18.175	2	9.087	72.696	<0.0001
Explained	23.928	3	7.976	63.808	<0.0001
Residual	127.034	236	0.538		
Error Estimate		∞	0.125	1	
Total	150.962	239	0.632		

Therefore: 1. Accept H_1

2. Accept H_1

Table 4.2 (a) continued

iii. Analysis of Variance Table for Long-term Visual Acuity by Group, "with" Visit

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Visit	3.424	1	3.424	27.392	0.0001
Group	17.033	2	8.517	68.136	0.0001
Explained	20.458	3	6.819	54.552	0.0001
Residual	165.276	236	0.700		
Error Estimate		∞	0.125	1	
Total	185.733	239	0.777		

Therefore: 1. Accept H_1

2. Accept H_1

From the results of the analysis it would appear that throughout the duration of the study the contact lens wearing groups have a lower standard of visual acuity than the control group. However, as the control group did not deviate from 6/4 and the control groups always presented with a mean value of less than 6/6, this lower standard of visual acuity could still be considered as satisfactory. Visual acuity did not change with time for the control group but it did for the contact lens wearing groups. During the short term there was an indication that the lens wearer's visual acuity reduced. In the intermediate and long term there was a reduction of visual acuity from baseline which was signficant. The lowest values for visual acuity in the control groups appeared at the three and four week appointments

(visits 7 and 8), after which there was a slight improvement, however, before termination of the project this did not return to baseline value.

Section 4.3 Stablility of Vision (Habitual)

For stability of vision and all other factors recorded on the questionnaire form except satisfactory distance and near vision, the SPSS subprogram "Anova" was used based on the regression model. For satisfactory distance and near vision contingency tables were calculated using the SPSS subprogram "Cross-tabs".

As the subprogram "Anova" calculated a residual which took into account patient to patient variations, a new error estimate for stability of vision (and other values on the questionnaire) was calculated using the previously described method (DAVIES and GOLDSMITH, 1972):

$$\text{Therefore: } SD = \frac{1}{\sqrt{12}} = 0.28868$$

This assumes that all patients will designate correctly their subjective response lying within ½ a division either side of each point of the scale. However, to allow for patient error the standard deviation was increased from 0.29 to 0.40 (ASTON, 1981). Therefore, the new error estimate was given by:

$$SD^2 = 0.40^2 = 0.16$$

This new error estimate (0.16) therefore, replaced the residual calculated by the SPSS subprogram "Anova".

Using the "Anova" subprogram the following hypotheses were tested:

1. H_o: The recorded factor is independent of time.

   H_1: The recorded factor is not independent of time.

2. H_o: The recorded factor is independent of group.

   H_1: The recorded factor is not independent of group.

Table 4.3 (a)

i. Analysis of Variance Table for "Stability of Vision" by Group "with" Visit

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Visit	0.139	1	0.139	0.869	N.S.
Group	0.694	1	0.694	4.338	0.05
Explained	0.833	2	0.417	2.606	0.10
Residual	32.056	141	0.227		
Error Estimate		∞	0.160	1	
Total	32.889	143	0.230		

Therefore: 1. Accept H_o

2. Accept H_o

ii. Analysis of Variance Table for "Ocular Discharge" by Group, "with" Visit

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Visit	1.901	1	1.901	11.881	<0.001
Group	2.507	1	2.507	15.669	<0.001
Explained	4.408	2	2.204	13.775	<0.001
Residual	60.585	141	0.430		
Error Estimate		∞	0.160	1	
Total	64.993	143	0.454		

Therefore: 1. Accept H_1

2. Accept H_1

Table 4.3 (b)

i. Analysis of Variance Table for "Ocular Discomfort" by Group, "with" Visit

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F.
Visit	0.113	1	0.113	0.706	N.S.
Group	1.174	1	1.174	7.338	0.01
Explained	1.286	2	0.643	4.019	0.05
Residual	47.151	141	0.334		
Error Estimate		∞	0.160	1	
Total	48.437	143	0.339		

Therefore: 1. Accept H_o

2. Accept H_1

ii. Analysis of Variance Tables for "Haloes" by Group "with" Visit

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F.
Visit	0.050	1	0.050	0.313	N.S.
Group	0.444	1	0.444	2.775	N.S.
Explained	0.494	2	0.247	1.544	N.S.
Residual	25.506	141	0.181		
Error Estimate		∞	0.16	1	
Total	26.000	143	0.182		

Therefore: 1. Accept H_o

2. Accept H_o

Table 4.3 (c)

i. Analysis of Variance Table for "Burning Sensation" by Group, "with" Visit

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F.
Visit	0.113	1	0.113	0.706	N.S.
Group	0.007	1	0.007	0.044	N.S.
Explained	0.119	2	0.060	0.375	N.S.
Residual	13.318	141	0.094		
Error Estimate		∞	0.160	1	
Total	13.437	143	0.094		

Therefore: 1. Accept H_o
2. Accept H_o

ii. Analysis of Variance Table for "Photophobia" by Group "with" Visit

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F.
Visit	0.089	1	0.089	0.556	N.S.
Group	0.694	1	0.694	4.338	0.05
Explained	0.783	2	0.392	2.45	N.S.
Residual	58.967	141	0.418		
Error Estimate		∞	0.160	1	
Total	59.750	143	0.418		

Therefore: 1. Accept H_o
2. Accept H_o

From the results of the analyses it would appear that though there was no indication of a change in stability of vision with time there was an indication of a lower stability of vision in the non-solution using group. This may have been due to the increased level of contact lens deposition in this group, which formed more rapidly with the lack of cleaning. The non-solution using group also presented with greater ocular discomfort, photophobia and ocular discharge. No significant change with time was found for ocular discomfort and photophobia, but a significant decrease in ocular discharge during the course of the study was reported, by both contact lens wearing groups.

By calculating contingency tables the following hypothses were tested

H_o: Vision is independent of time.

H_1: Vision is not independent of time.

Table 4.3 (d)

Crosstabulation of Near Vision by Visit

i. Solution Users

COUNT / ROW % / COLUMN % / TOTAL %		8	9	10	11	ROW TOTAL
NEAR VISION RE	0	1 100.0 5.6 1.4	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 1.4
	1	17 23.9 94.4 23.6	18 25.4 100.0 25.0	18 25.4 100.0 25.0	18 25.4 100.0 25.0	71 98.6
COLUMN TOTAL		18 25.0	18 25.0	18 25.0	18 25.0	72 100.0

RAW CHI SQUARE = 3.04225. DF = 3. SIGNIFICANCE = 0.3852

Therefore: Accept H_o

ii. Non-solution Users

COUNT / ROW % / COLUMN % / TOTAL %		8	9	10	11	ROW TOTAL
NEAR VISION RE	0	3 60.0 16.7 4.2	1 20.0 5.6 1.4	0 0.0 0.0 0.0	1 20.0 5.6 1.4	5 6.9
	1	15 22.4 83.3 20.8	17 25.4 94.4 23.6	18 26.9 100.0 25.0	17 25.4 94.4 23.6	67 93.1
COLUMN TOTAL		18 25.0	18 25.0	18 25.0	18 25.0	72 100.0

RAW CHI SQUARE = 4.08358. DF = 3. SIGNIFICANCE = 0.2526

Therefore: Accept H_o

Table 4.3 (e)

Crosstabulation of Distance Vision by Visit

i. Solution Users

COUNT / ROW % / COLUMN % / TOTAL %		8	9	10	11	ROW TOTAL
DISTANCE VISION R.E.	0	1 100.0 5.6 1.4	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 1.4
	1	17 23.9 94.4 23.6	18 25.4 100.0 25.0	18 25.4 100.0 25.0	18 25.4 100.0 25.0	71 98.6
COLUMN TOTAL		18 25.0	18 25.0	18 25.0	18 25.0	72 100.0

RAW CHI SQUARE = 3.04225. DF = 3. SIGNIFICANCE = 0.3852

Therefore: Accept H_o

ii. Non-Solution Users

COUNT / ROW % / COLUMN % / TOTAL %		8	9	10	11	ROW TOTAL
DISTANCE VISION R.E.	0	1 33.3 5.6 1.4	2 66.7 11.1 2.8	0 0.0 0.0 0.0	0 0.0 0.0 0.0	3 4.2
	1	17 24.6 94.4 23.6	16 23.2 88.9 22.2	18 26.1 100.0 25.0	18 26.1 100.0 25.0	69 95.8
COLUMN TOTAL		18 25.0	18 25.0	18 25.0	18 25.0	72 100.0

RAW CHI SQUARE = 3.82609. DF = 3. SIGNIFICANCE = 0.2809

Therefore: Accept H_o

In addition the following hypotheses were tested:

H_o: Vision is independent of group type.

H_1: Vision is not independent of group type.

The results obtained are summarised in the following table.

Table 4.3 (f)

Summary Table of Crosstabulations of Distance and Near Vision by Group for:

	Vision	Raw Chi Square	DF	Significance	Conclusion
a) Visit = 8	Dist.	0.00000	1	1.0000	Accept H_o
	Near	1.12500	1	0.2888	Accept H_o
b) Visit = 9	Dist	0.00000	1	1.0000	Accept H_o
	Near	1.02857	1	0.3105	Accept H_o
c) Visit = 10	Dist	-	-	1.0000	Accept H_o
	Near	-	-	1.0000	Accept H_o
d) Visit = 11	Dist	-	-	1.0000	Accept H_o
	Near	1.02857	1	0.3105	Accept H_o

From these results it would appear that there was no statistically significant change in either distance or near vision with time and also that there was no difference between the two contact lens wearing groups.

Section 4.4 Keratometry

The results of minimum and maximum radii of curvature were analysed using the subprogram "Anova" based on the regression model. For the same reasons as described in previous sections, a new error estimate was obtained from the average of the two-way interactions, taken from the two separate analyses.

Due to instrumental failure the sample size in each group was reduced to nine. The following hypotheses were tested:

1. H_o: Corneal radius of curvature is independent of time.
   H_1: Corneal radius of curvature is not independent of time.

2. H_o: Corneal radius of curvature is independent of group type.
   H_1: Corneal radius of curvature is not independent of group type.

Table 4.4. (a)

i. Analysis of Variance Table for Maximum Keratometry

Radius by Group, "with" Visit

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Visit	0.001	1	0.001	0.1538	N.S.
Group	0.178	2	0.089	13.6923	0.005
Explained	0.179	3	0.060	9.2308	0.010
Residual	2.757	77	0.036		
Error Estimate		8	0.0065	1	
Total	2.936	80	0.037		

Therefore: 1. Accept H_o

2. Accept H_1

ii. Analysis of Variance Table for Minimum Keratometry

Radius by Group, "with" Visit

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Visit	0.072	1	0.072	11.077	0.025
Group	0.039	2	0.020	3.077	0.100
Explained	0.111	3	0.037	5.692	0.025
Residual	4.553	77	0.059		
Error Estimate		8	0.0065	1	
Total	4.664	80	0.058		

Therefore: 1. Accept H_o

2. Accept H_o

The Rank-Sum test, for two populations (HAYSLETT, 1974), was used to analyse the variation of keratometry axes between visits.

The following hypothesis was tested.

H_o: The controls and the contact lens wearers come from the same population, i.e. they have the same median.

H_1: The controls and contact lens wearers do not come from the same population, i.e. they do not have the same median.

1. Controls and Solution Users

Differences in Keratometry Axes between successive Visits for Controls and Solution Users (Table 4.4. (b))

Maximum K Axes				Minimum K Axes			
Visit 10 -1		Visit 11 - 10		Visit 10 - 1		Visit 11 - 10	
C	B	C	B	C	B	C	B
5	5	15	0	15	10	15	0
0	5	5	5	5	5	20	5
0	5	5	5	10	25	10	0
15	10	0	10	5	5	5	0
15	0	5	10	10	5	10	10
15	10	15	10	15	10	10	10

Where C and B denote the groups (Group C = Controls, Group B = Solution users)

a) Maximum Keratometry Axes

i) For Visits 10 - 1.

Combing the two samples and arranging the results in order from smallest to largest we have

0, 0, 0, 5, 5, 5, 5, 10, 10, 15, 15, 15

Where the underlining indicates values from the solution using group. Replacing the observations by their ranks, with equal observations being replaced by the mean of the ranks that they occupy, we have

2, 2, 2, 5.5, 5.5, 5.5, 5.5, 8.5, 8.5, 11, 11, 11,

The sum of the underlined ranks, R (i.e. solution using group), is 35.5.

For two sample sizes of 6 and $\alpha = 0.05$

the critical range is $\leqq 26$ and $\geqq 52$.

Therefore, Accept H_o.

ii) For Visits 11 - 10

By ranking the combined observations we have:

1.5, 1.5, 5, 5, 5, 5, 5, 9, 9, 9, 11.5, 11.5

Sum of underlined ranks, R (i.e. solution using group), is 38.5

Therefore, Accept H_o.

b) Minimum Keratometry Axes

1) For Visits 10 - 1

Ranking of the combined observations gives

1.5, 1.5, 4, 4, 4, 7.5, 7.5, 7.5, 7.5, 10.5, 10.5. 12

The sum of the underlined ranks, R (i.e. solution using group) is 39.0.

Therefore, Accept H_o.

ii) For Visits 11 - 10

Ranking of the combined observations gives

2, 2, 2, 4.5, 4.5, 8, 8, 8, 8, 8, 11, 12

The sum of the underlined ranks, R (i.e. solution using group), is 26.5

Therefore, Accept H_o.

2. Controls and Non-Solution Users

Differences in Keratometry Axes between Successive Visits for Non-Solution Users (Table 4.4. (c))

Maximum K Axes		Minimum K Axes	
Visit 10 - 1	Visit 11 - 10	Visit 10 - 1	Visit 11 - 10
5	5	0	5
5	25	5	0
0	5	0	10
25	15	5	20
20	5	5	10
15	10	25	15
0	0	0	5

Applying the rank sum test for two populations (controls and non-solution users)

The following results were obtained

a) Maximum K Axes	R	Conclusion
i) Visits 10 - 1	37	Accept H_o
ii) Visits 11 - 10	40	Accept H_o
b) Minimum K Axes		
i) Visits 10 - 1	54	Accept H_o
ii) Visits 11 - 10	47	Accept H_o

Note: the critical range of the random variable R at the 5% level is $\leqq 30$ and $\geqq 54$.

Therefore, from these results it would appear that the change in Keratometry axes with time, in the contact lens wearing groups, did not differ significantly from the corresponding changes in the control group.

To increase the sample size the changes only between the first and last visits could be considered. However, due to the presence of several near spherical corneae (where both K readings differ by a maximum of 0.05mm) the advantage of the increase in sample size would be counteracted by the increased inaccuracy in determining the axes during readings of these corneae. Therefore, it was felt that further calculations would be of little value.

Section 4.5 Pachometry

4.5 i) Central Pachometry

Changes in central pachometry occuring during the short-term (visits 1, 2, 3, 4 and 5), intermediate-term (visits 1, 5, 6, 7 and 8) and long-term (visits 1, 8, 9, 10 and 11) stages of the study were analysed separately. For each analysis the subprogram "Anova", based on the regression model, was used to calculate two-way analysis of variance. Due to the artificially high value of the error estimate (because of reasons discussed in previous sections), a new error estimate was calculated from the average of the two-way interactions given in each of the analyses.

Prior to the above analyses data from the control group was analysed using the SPSS subprogram "Regression" for short-term, intermediate term and long term changes. From the results of these analyses it was concluded that for the controls there was no evidence of any linear change in central pachometry with time, throughout the duration of the study.

Then for all three groups the following hypotheses were tested:

1. H_o: Central Pachometry is independent of time.
   H_1: Central Pachometry is not independent of time.
2. H_o: Central Pachometry is independent of group.
   H_1: Central Pachometry is not independent of group.

Table 4.5. (i) (a)

Analysis of Variance Tables for Central Pachometry

by Group, "with" Visit

i. Short-term Changes (Visits 1, 2, 3, 4 and 5)

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Visit	0.005	1	0.005	16.667	0.001
Group	0.016	2	0.008	26.667	0.0005
Explained	0.020	3	0.007	23.333	0.0005
Residual	0.245	236	0.001		
Error Estimate		24	0.0003	1	
Total	0.265	239	0.001		

Therefore: 1. Accept H_1

2. Accept H_1

ii. Intermediate-term Changes (Visits 1, 5, 6, 7 and 8)

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Visit	0.001	1	0.001	3.333	0.10
Group	0.008	2	0.004	13.333	0.001
Explained	0.009	3	0.003	10.0	0.005
Residual	0.259	236	0.001		
Error Estimate		24	0.0003	1	
Total	0.268	239	0.001		

Therefore: 1. Accept H_o

2. Accept H_1

Table 4.5 (i) (a) continued

Analysis of Variance Table for Central Pachometry

by Group, "with" Visit

iii. Long-term Changes (Visits 1, 8, 9, 10 and 11)

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Visit	0.000012	1	0.000012	0.040	N.S.
Group	0.005	2	0.003	10.000	0.005
Explained	0.006	3	0.002	6.666	0.005
Residual	0.263	236	0.001		
Error Estimate		24	0.0003	1	
Total	0.269	239	0.001		

Therefore: 1. Accept H_o

2. Accept H_1

Throughout the duration of the study the solution using group presented with the smallest value of central corneal thickness, while the non-solution using group presented with the largest value of central corneal thickness. During the short term period of the study (Fig 4.5 (i) (a)) a significant increase in corneal thickness was detected, the maximum values being reached at the end of the first week of extended wear. The analysis of intermediate term changes (Fig 4.5 (i) (b)) did not indicate a significant change in corneal thickness, but analysis of visits 5 to 8 inclusive did show a significant decrease in central corneal thickness at the 1% level. At visit 8 (i.e. 4 weeks of contact lens wear) the central corneal thickness of the non-solution using group had returned to it's original level, while the solution using group, still with a slightly thicker central cornea than at

baseline, did not return to it's original corneal thickness until the six month data check. Analysis of the long term changes in central corneal thickness (Fig 4.5 (i) (c)) indicated that there was no change with time. An overall thinning of the cornea found by a previous worker (HIRJI, 1978) who was observing changes caused by Sauflon$^{T.M.}$ 85 lenses, was not reflected in this study.

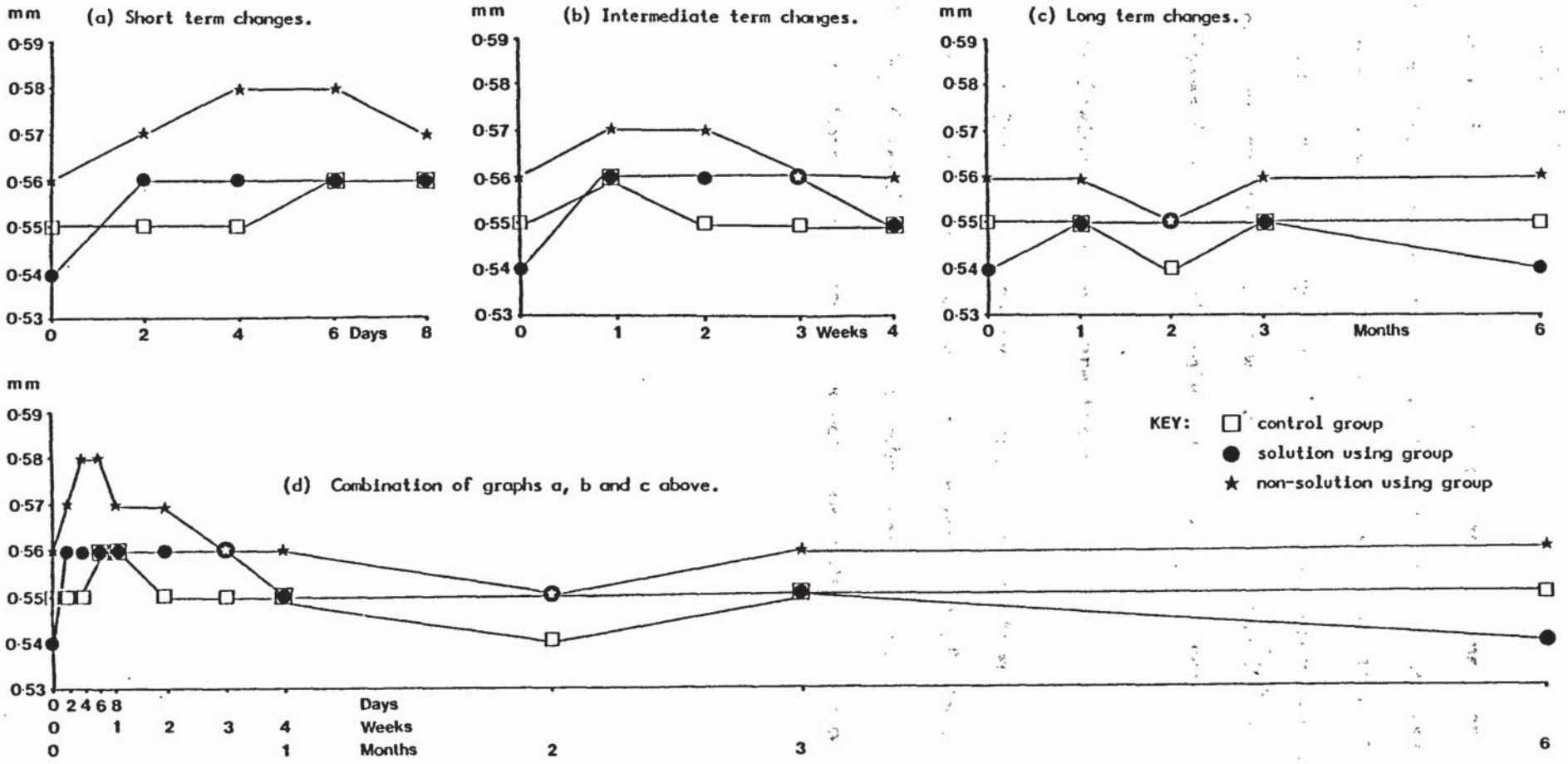


FIGURE 4.5(i) Central pachometry changes with duration of extended contact lens wear.

4.5 ii) Topographical Pachometry

Topographical pachometry was measured at baseline, three months and six months. The "Anova" subprogram was used to analyse the data. To provide an error estimate (because of the artificially high error estimate calculated by the subprogram) the average value of the four two-way interactions was obtained from the 30° pachometry analyses (i.e. temporal, inferior, nasal and superior).

The following hypotheses were tested:

1. H_o: Corneal pachometry is independent of time.
   H_1: Corneal pachometry is not independent of time.
2. H_o: Corneal pachometry is independent of group.
   H_1: Corneal pachometry is not independent of group.

Table 4.5 (ii) (a)

Analysis of Variance Tables for Topographical Pachometry

by Group, "with" Visit

i. Temporal 30°

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Visit	0.001	1	0.001	0.541	N.S.
Group	0.021	2	0.010	7.336	0.001
Explained	0.022	3	0.007	5.071	0.05
Residual	0.223	158	0.001		
Error Estimate		16	0.001	1	
Total	0.245	161	0.002		

Therefore: 1. Accept H_o

2. Accept H_1

ii. Inferior 30°

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Visit	0.005	1	0.005	4.556	0.05
Group	0.009	2	0.005	4.500	0.05
Explained	0.014	3	0.005	4.999	0.05
Residual	0.362	158	0.002		
Error Estimate		16	0.001	1	
Total	0.376	161	0.002		

Therefore: 1. Accept H_o

2. Accept H_o

Table 4.5 (ii) (a) continued

Analysis of Variance Tables for Topographic Pachometry

by Group "with" Visit

iii. Nasal 30°

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Visit	0.005	1	0.005	5.000	0.05
Group	0.005	2	0.003	2.50	0.100
Explained	0.010	3	0.003	3.333	0.05
Residual	0.321	158	0.002		
Error Estimate		16	0.001	1	
Total	0.331	161	0.002		

Therefore: 1. Accept H_o

2. Accept H_o

iv. Superior 30°

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Visit	0.001	1	0.001	2.000	0.10
Group	0.023	2	0.011	22.000	0.0005
Explained	0.023	3	0.008	16.000	0.001
Residual	0.254	158	0.002		
Error Estimate		16	0.0005	1	
Total	0.277	161	0.002		

Therefore: 1. Accept H_o

2. Accept H_1

Table 4.5(ii) (b)

Analyses of Variance Tables of Topographical Pachometry

by Group "with" Visit

i. Temporal 15°

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Visit	0.00017	1	0.00017	0.168	NS
Group	0.007	2	0.003	2.669	0.10
Explained	0.007	3	0.002	1.836	NS
Residual	0.204	158	0.001		
Error Estimate		16	0.001	1	
Total	0.211	161	0.001		

Therefore: 1. Accept H_o

2. Accept H_o

ii. Inferior 15°

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Visit	0.00001	1	0.00001	0.010	NS
Group	0.001	2	0.0005	0.500	NS
Explained	0.001	3	0.0003	0.300	NS
Residual	0.251	158	0.002		
Error Estimate		16	0.001	1	
Total	0.252	161	0.002		

Therefore: 1. Accept H_o

2. Accept H_o

Table 4.5 (ii) (b) continued

Analysis of Variance Tables for Topographical Pachometry

by Group, "with" Visit

iii. Nasal 15°

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Visit	0.000	1	0.000	0.000	N.S.
Group	0.007	2	0.004	2.471	0.100
Explained	0.007	3	0.002	1.647	N.S.
Residual	0.235	158	0.001		
Error Estimate		4	0.001	1	
Total	0.242	161	0.002		

Therefore: 1. Accept H_o

2. Accept H_o

iv. Superior 15°

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Visit	0.001	1	0.001	1.572	N.S.
Group	0.005	2	0.0025	5.000	0.05
Explained	0.006	3	0.002	4.000	0.05
Residual	0.190	158	0.001		
Error Estimate		4	0.0005	1	
Total	0.196	161	0.001		

Therefore: 1. Accept H_o

2. Accept H_o

Reflecting the results of central corneal thickness, the non-solution using group tended to have greater values of corneal thickness throughout the cornea, which were most significantly different at the 30° superior position.

The results indicated a possible corneal thinning with time at the nasal and inferior 30° positions, but this was not reflected at any of the other positions. Therefore no significant change in the thickness of the cornea can be inferred from these results.

Section 4.6 Aesthesiometry

The subprogram "Anova" was used to analyse results of aesthesiometry. As the subprogram "Anova" would have calculated an error estimate, partially based on inter-individual variations, a new error estimate was calculated from the formula:

$$\text{standard deviation} = \frac{b - a}{\sqrt{12}}$$

(DAVIES and GOLDSMITH, 1972).

As the scale for corneal sensitivity is not uniform the standard deviation was calculated for the minimum and maximum difference between scale readings. The variances were then averaged giving the new error estimate (where DF = infinity). This error assumes that in all cases the correct scale is chosen for each value recorded. To allow for errors in selecting the correct scale division in border-line cases, a factor of 5% was added to the error estimate.

Therefore for the minimum scale interval:

$$\text{Standard deviation} = \frac{0.08}{\sqrt{12}} = 0.0231$$

and for the maximum scale interval:

$$\text{Standard deviation} = \frac{0.80}{\sqrt{12}} = 0.2309$$

$$\text{Error estimate} = \frac{0.0231^2 + 0.2309^2}{2}$$

$$= 0.0269$$

Increasing by 5%

Error Estimate = 0.0282

The following hypotheses were tested:

1. H_o: Corneal aesthesia is independent of time.

   H_1: Corneal aesthesia is not independent of time.

2. H_o: Corneal aesthesia is independent of group.

   H_1: Corneal aesthesia is not independent of group.

Table 4.6

Analysis of Variance Table for Corneal Aesthesia

by Group "with" Visit

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Visit	0.336	1	0.336	11.91	0.001
Group	0.087	2	0.044	1.56	0.250
Explained	0.423	3	0.141	4.82	0.005
Residual	32.212	236	0.136		
Error Estimate			0.0282	1	
Total	32.635	239	0.137		

Therefore: 1. Accept H_1

2. Accept H_o

A significant decrease in corneal sensitivity (Fig 4.6) was found in both contact lens wearing groups. The maximum value of the corneal touch theshold was reached at the six month visit, which supports the findings of an earlier study (HIRJI, 1978). However, the reverse of other findings in the same study were found, where the solution using group presented with the higher increase in corneal touch threshold (24.2%) while the non-solution using group presented with a lower increase (13.44%). Also the degree of increase in the corneal touch threshold was found to be considerably less than the earlier extended wear study (HIRJI, 1978). However, the findings here further support the observation that loss of corneal sensitivity is an expected feature of contact lens wear, and that this loss is considerably less

for the soft lens wearer than the hard lens wearer (KNOLL and WILLIAMS, 1970; LARKE and SABELL, 1971; MILLODOT, 1971, 1975, 1976; HIRJI, 1978).

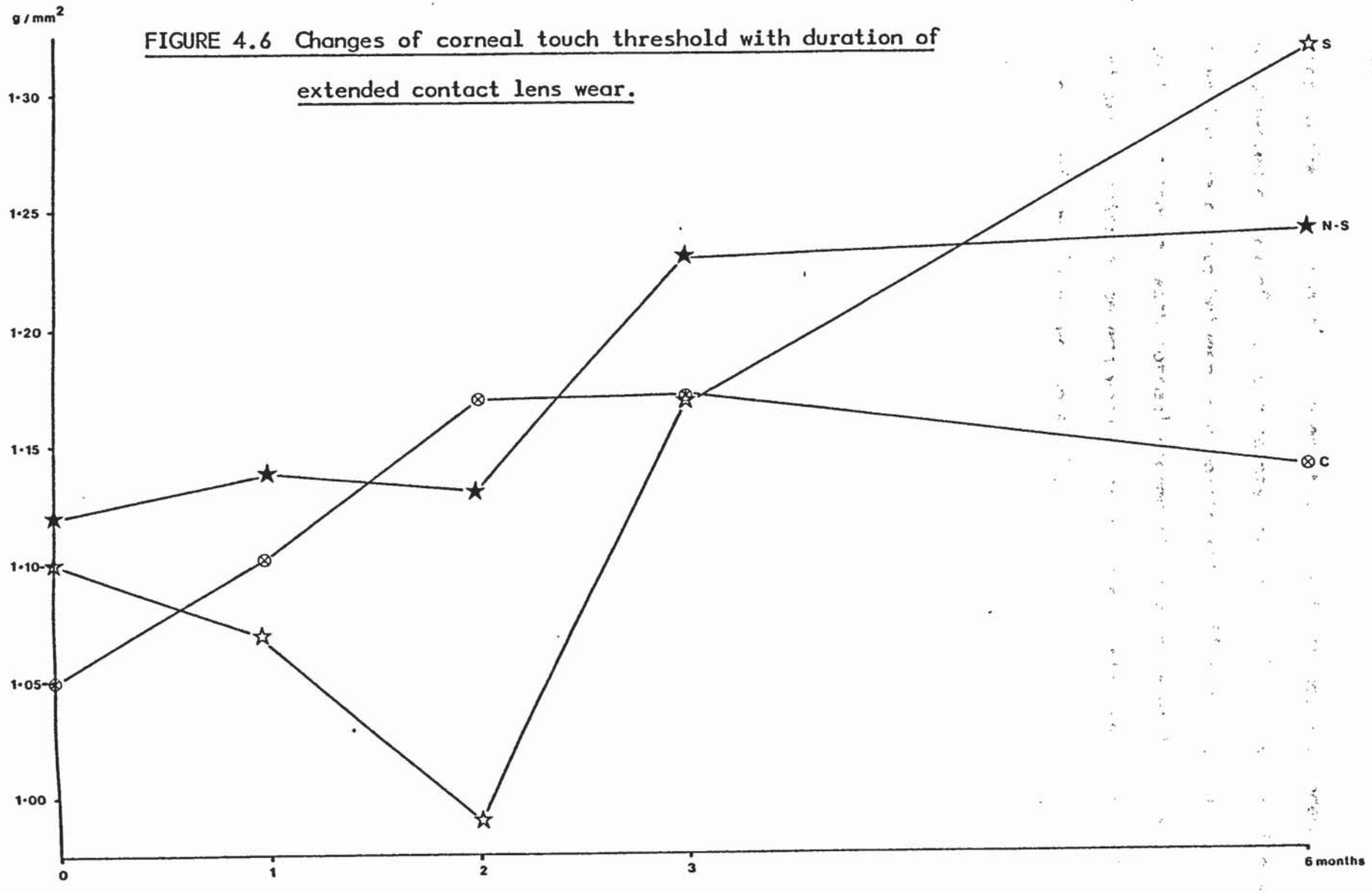


FIGURE 4.6 Changes of corneal touch threshold with duration of extended contact lens wear.

Section 4.7 Oedema

Prior to the detection of micro-epithelial cysts no corneal oedema was observed at any of the data points throughout the study. Patients attending the clinic between data points with differing problems sometimes presented with corneal oedema of varying severity. The most severe cases of oedema were observed in patients presenting with red eye syndrome (see Section 4.17).

Section 4.8. Corneal Striae

The appearance of corneal striae was not observed in any patient throughout the course of the study.

Section 4.9 Vital Staining

The evidence (i.e. type) of staining was analysed using contingency tables.

The following hypotheses for evidence of staining, for both Sodium Fluorescein and Rose Bengal, were tested:

H_o: Evidence of staining is independent of group type.

H_1: Evidence of staining is not independent of group type.

Table 4.9 (a)

Crosstabulations of Evidence of Fluorescein Staining by Group

Visit = 8

Evidence of Fluorescein Staining	COUNT / ROW % / COL % / TOT %	GROUP 1	GROUP 2	GROUP 3	ROW TOTAL
	1	6 40.0 37.5 12.5	7 46.7 43.8 14.6	2 13.3 12.5 4.2	15 31.3
	2	1 50.0 6.3 2.1	0 0.0 0.0 0.0	1 50.0 6.3 2.1	2 4.2
	3	9 29.0 56.3 18.8	9 29.0 56.3 18.8	13 41.9 81.3 27.1	31 64.6
	COLUMN TOTAL	16 33.3	16 33.3	16 33.3	48 100.0

Raw Chi Square = 4.83226. DF = 4. Significance = 0.3049

Therefore: Accept H_o

Visit = 9

Evidence of Fluorescein Staining	COUNT / ROW % / COL % / TOT %	GROUP 1	GROUP 2	GROUP 3	ROW TOTAL
	1	13 65.0 81.3 27.1	7 35.0 43.8 14.6	0 0.0 0.0 0.0	20 41.7
	3	3 10.7 18.8 6.3	9 32.1 56.3 18.8	16 57.1 100.0 33.3	28 58.3
	COLUMN TOTAL	16 33.3	16 33.3	16 33.3	48 100.0

Raw Chi Square = 21.77143. DF = 2. Significance = 0.0000

Therefore: Accept H_1

Table 4.9 (b)

Crosstabulations of Evidence of Fluorescein Staining by Group

Visit = 10

Evidence of Fluorescein Staining	COUNT / ROW % / COL % / TOT %	GROUP 1	GROUP 2	GROUP 3	ROW TOTAL
	1	6 40.0 37.5 12.5	8 53.3 50.0 16.7	1 6.7 6.3 2.1	15 31.3
	3	10 30.3 62.5 20.8	8 24.2 50.0 16.7	15 45.5 93.8 31.3	33 68.8
	COLUMN TOTAL	16 33.3	16 33.3	16 33.3	48 100.0

Raw Chi Square = 7.56364. DF = 2. Significance = 0.0228

Therefore: Accept H_o

Visit = 11

Evidence of Fluorescein Staining	COUNT / ROW % / COL % / TOT %	GROUP 1	GROUP 2	GROUP 3	ROW TOTAL
	1	14 63.6 87.5 29.2	8 36.4 50.0 16.7	0 0.0 0.0 0.0	22 45.8
	3	2 7.7 12.5 4.2	8 30.8 50.0 16.7	16 61.5 100.0 33.3	26 54.2
	COLUMN TOTAL	16 33.3	16 33.3	16 33.3	48 100.0

Raw Chi Square = 24.83916. DF = 2. Significance = 0.0000

Therefore: Accept H_1

Table 4.9 (c)

Crosstabulations of Evidence of Rose Bengal Staining by Group

Visit = 8

Evidence of Rose Bengal Staining	COUNT / ROW % / COL % / TOT %	GROUP 1	GROUP 2	GROUP 3	ROW TOTAL
	1	13 43.3 81.3 27.1	9 30.0 56.3 18.8	8 26.7 50.0 16.7	30 62.5
	3	3 16.7 18.8 6.3	7 38.9 43.8 14.6	8 44.4 50.0 16.7	18 37.5
	COLUMN TOTAL	16 33.3	16 33.3	16 33.3	48 100.0

Raw Chi Square = 3.73333. DF = 2. Signficance = 0.1546

Therefore: Accept H_o

Visit = 9

Evidence of Rose Bengal Staining	COUNT / ROW % / COL % / TOT %	GROUP 1	GROUP 2	GROUP 3	ROW TOTAL
	1	16 45.7 100.0 33.3	10 28.6 62.5 20.8	9 25.7 56.3 18.8	35 72.9
	3	0 0.0 0.0 0.0	6 46.2 37.5 12.5	7 53.8 43.8 14.6	13 27.1
	COLUMN TOTAL	16 33.3	16 33.3	16 33.3	48 100.0

Raw Chi Square = 9.07253. DF = 2. Significance = 0.0107

Therefore: Accept H_1

Table 4.9 (d)

Crosstabulations of Evidence of Rose Bengal Staining by Group

Visit = 10

Evidence of Rose Bengal Staining	COUNT / ROW % / COL % / TOT %	GROUP 1	GROUP 2	GROUP 3	ROW TOTAL
	1	16 45.7 100.0 33.3	13 37.1 81.3 27.1	6 17.1 37.5 12.5	35 72.9
	3	0 0.0 0.0 0.0	3 23.1 18.8 6.3	10 76.9 62.5 20.8	13 27.1
	COLUMN TOTAL	16 33.3	16 33.3	16 33.3	48 100.0

Raw Chi Square = 16.66813. DF = 2 Significance = 0.0002

Therefore: Accept H_1

Visit = 11

Evidence of Rose Bengal Staining	COUNT / ROW % / COL % / TOT %	GROUP 1	GROUP 2	GROUP 3	ROW TOTAL
	1	15 44.1 93.8 31.3	11 32.4 68.8 22.9	8 23.5 50.0 16.7	34 70.8
	2	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 100.0 6.3 2.1	1 2.1
	3	1 7.7 6.3 2.1	5 38.5 31.3 10.4	7 53.8 43.8 14.6	13 27.1
	COLUMN TOTAL	16 33.3	16 33.3	16 33.3	48 100.0

Raw Chi Square = 8.48416. DF = 4. Significance = 0.0754

Therefore: Accept H_o

It would appear from the results that the non-solution using group presented with a higher incidence of punctate staining with Fluorescein sodium than the solution using group, while the control group fluctuated between visits. The incidence of punctate staining with Rose Bengal was similar for both contact lens groups, except at visit 10, and higher than the incidence of staining in the control group. Both contact lens groups, however, presented with a much higher incidence of staining than that previously reported in extended wear of Sauflon T.M. 85 lenses (HIRJI, 1978). By calculating contingency tables for evidence of staining by visit, the following hypotheses were tested for each group:

H_o: Evidence of staining is independent of visit.

H_1: Evidence of staining is not independent of visit.

Table 4.9 (e)

Summary Table of Chi Square Analyses on Crosstabulations of Evidence of Fluorescein Staining by Visit for:

	Chi Square	DF	Significance	Conclusion
a) Group 1	17.15385	6	0.0087	Accept H_1
b) Group 2	0.25098	3	0.9690	Accept H_o
c) Group 3	7.06667	6	0.3147	Accept H_o

Table 4.9 (f)

Summary Table of Chi Square Analyses on Crosstabulations of Evidence of Rose Bengal staining by Visit for:

	Chi Square	DF	Significance	Conclusion
a) Group 1	6.40000	3	0.0937	Accept H_o
b) Group 2	2.48062	3	0.4788	Accept H_o
c) Group 3	4.36290	6	0.6277	Accept H_o

From the results of evidence of staining, crosstabulated against visit, it would appear that the only significant change with time occurred with evidence of fluorescein staining in the control group. This was due to a higher percentage of controls presenting with staining at visits 8 and 10 than at visits 9 and 11. No conclusive reason for this random occurance of staining was apparent at the time of data collection, however an increase in the number of air born particles (possibly due to increased wind conditions), to which the control eyes would have been exposed, may have accounted for this observation (LARKE, 1981).

Fluorescein staining was analysed using the subprogram "Anova". The following hypotheses were tested:

1. H_o: Area/Depth of stain in independent of time.

   H_1: Area/Depth of stain is not independent of time.

2. H_o: Area/Depth of stain is independent of group type.

   H_1: Area/Depth of stain is not independent of group type.

Table 4.9 (g)

i. Analysis of Variance Table of Depth of Fluorescein Stain by Group "with" Visit

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Visit	0.301	1	0.301	3.627	0.10
Group	10.792	2	5.396	65.012	<0.005
Explained	11.093	3	3.698	44.554	<0.005
Residual	35.652	188	0.190		
Error Estimate		∞	0.083	1	
Total	46.745	191	0.245		

Therefore: 1. Accept H_o
2. Accept H_1

ii. Analysis of Variance Table of Area of Fluorescein Stain by Group, "with" Visit

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Visit	0.026	1	0.026	0.313	N.S.
Group	6.635	2	3.318	39.976	<0.005
Explained	6.661	3	2.220	26.747	<0.005
Residual	54.958	188	0.292		
Error Estimate		∞	0.083	1	
Total	61.620	191	0.323		

Therefore: 1. Accept H_o
2. Accept H_1

Table 4.9 (g) continued

iii. Analysis of Variance Table of Area of Rose Bengal Stain by Group, "with" Visit

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Visit	0.037	1	0.037	0.446	N.S.
Group	0.219	2	0.109	1.313	0.10
Explained	0.256.	3	0.085	1.024	0.10
Residual	14.994	188	0.080		
Error Estimate		∞	0.083	1	
Total	15.250	191	0.080		

Therefore: 1. Accept H_o

2. Accept H_o

No significant change in either depth or area of staining was detected with time. The non-solution using group showed an increased degree of fluorescein staining over the two other groups, both in area and depth, but no significant difference between the groups for Rose Bengal stain was found.

Increased deposition of contact lens deposits in the non-solution using group may have accounted for the larger areas of fluorescein stain, the presence of the deposits increasing the likelihood of minor mechanical abrasions. This could be a further indication of the importance to corneal integrity of soft lens wearers having a regular contact lens cleaning regime.

Section 4.10 Corneal Limbal Injection

4.10 i) Injection (Biomicroscopical detection)

As injection was classified on a scale of increasing severity, the subprogram "Anova" was used to analyse the results.

The subprogram "Anova" calcuted an error estimate which would have included inter-individual variations, and would have been artificially high. To calculate a more suitable error estimate the previously described technique was used (DAVIES and GOLDSMITH, 1972).

$$\text{Standard Deviation} = \frac{1}{\sqrt{12}} = 0.28868$$

Therefore:

Error Estimate = 0.0833

This assumes that for each reading taken, the scale division chosen was correct. To allow for occasional mistakes, when selecting the appropriate scale, a factor of 10% was added to the error estimate.

Therefore:

Error Estimate = 0.0916

The following hypotheses were tested:

1. H_o: Injection is independent of time.

   H_1: Injection is not independent of time.

2. H_o: Injection is independent of group type.

   H_1: Injection is not independent of group type.

Table 4.10 (i)

Analysis of Variance Table of Limbal Vascular Injection (Biomicroscopical detection) by Group, "with" Visit

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Visit	9.890	1	9.890	107.97	<0.0001
Group	8.037	2	4.019	43.39	<0.0001
Explained	17.927	3	5.976	65.24	<0.0001
Residual	41.851	158	0.265		
Error Estimate		∞	0.0916	1	
Total	59.778	161	0.371		

For the control group no limbal congestion was detected. However, from observing the means of the groups, both solution and non-solution groups presented with a significant increase in vascular injection at the three month visit which reduced in severity, again for both groups, at the six month data point. Further discussion of this observation is to be found in Chapter 5.

4.10 ii) Injection, indicated by Apparent Lumen Width (Photographic Detection)

After a consideration of the type of analyses which would be most appropriate for the measurement of lumen width, it was decided that two methods would be most appropriate. Firstly, to look at the differences between the mean lumen widths at successive visits for each patient, and apply the t - test to detect significant changes; secondly, to calculate analysis of variance for lumen width, based on the regression model, using the subprogram "Anova". Due to a failure of the photographic apparatus during collection of data at the six month visit, the patient numbers within each group were reduced to ten.

The differences between lumen widths for visits 1 and 11 were considered.

The first group of hypotheses tested for the control group were:

H_o: Apparent lumen width is independent of time (i.e. the differences are centred about zero).

H_1: Apparent lumen width is not independent of time (i.e. the differences are not centred about zero).

Using the formula $t = \frac{\bar{x}}{S/\sqrt{10}}$ (HAYSLETT, 1974)

$$t = \frac{0.01657}{0.1116/3.16} = 0.4692$$

From t tables (for 9 DF):

Accept H_o (i.e. there was no significant change with time).

Having established that the control had apparently not changed between the first and last visits the second set of hypotheses to test for both the contact lens groups were:

H_o: The increase in apparent lumen width is not larger in the contact lens groups than in the control group.

H_1: The increase in apparent lumen width is larger in the contact lens groups than in the control group.

It was established that the variances of the lens wearing groups and the control group were the same (ASTON, 1981), and assuming an approximately normal distribution the following formula was applied for each contact lens group with the control group:

1. For the Solution Using Group

Using $$t = \frac{(\bar{x}_1 - \bar{x}_2)}{\sqrt{SP^2\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$ (HAYSLETT, 1974)

Where $\bar{x}_1$ is the mean of the differences in the control group, $\bar{x}_2$ is the mean of the differences in the solution using group, Sp is the pooled standard deviation, and n_1 and n_2 are the numbers of patients in the control group and solution using group respectively.

Therefore:

$$t = \frac{0.1101}{\sqrt{\frac{0.01592}{5}}}$$

$$= 1.769$$

From t tables for 18DF

Accept H_o at a significance level of 5%.

2. For the Non- Solution using Group

Applying the same formula

$$t = \frac{(\bar{x}_1 - \bar{x}_3)}{\sqrt{SP^2\left(\frac{1}{n_2} + \frac{1}{n_3}\right)}}$$

Where $\bar{x}_3$ is the mean of the differences in the non-solution group, and N_3 is the number of patients in the non-solution using group

Therefore:

$$t = \frac{0.1499}{0.05274} = 2.8422$$

From t tables for 18 DF.

Accept H_1 at a significance level of 1%.

From these results it may be assumed that the apparent lumen width of the non-solution using group does increase during the period between the first and the last visits, while for the solution using group, there is an indication of an increase in the lumen width between the first and last visit.

To find out if there was a signficant difference between the two contact lens groups the following hypotheses were tested:

H_o: The contact lens groups come from the same population.

H_1: The contact lens groups do not come from the same population.

Using the previous formula

$$t = \frac{(\bar{x}_2 - \bar{x}_3)}{\sqrt{SP^2\left(\frac{1}{n_2} + \frac{1}{n_3}\right)}}$$

(HAYSLETT, 1974)

$$t = \frac{\bar{x}_2 - \bar{x}_3}{\sqrt{SP^2\left(\frac{1}{n_2} + \frac{1}{n_3}\right)}}$$ (HAYSLETT, 1974)

$$t = \frac{0.04979}{0.003476} = 0.84447$$

From t tables for 18 DF

Accept H_o

Therefore, it may be assumed that the lumen widths for the two contact lens groups change to a similar degree during the period between the first and last visits.

In addition, 99% confidence limits for individuals in each of the three groups were obtained:

1. Controls

Confidence Limits = -0.017 ± 0.361

Therefore, the limits are -0.378 and +0.344. Converting to more meaningful values the limits are -0.0077mm and +0.0070mm

2. Contact lens wearing groups

Having established that there is no statistically significant difference between the changes in apparent lumen width for the two contact lens wearing groups, the confidence limits fo a contact lens wearing individual were obtained. Combining the two contact lens groups:

99% Confidence limits = 0.1065 ± 0.3787

Therefore:

the limits are -0.272 and +0.485

Converting to more meaningful values the limits are

$$\underline{-0.0056 \text{ and } +0.0099\text{mm}}$$

From these values it appears that individuals in the contact lens wearing population would be expected to have a greater degree of limbal vascular injection than individuals in the non-contact lens wearing population. Further discussion of these results may be found in Chapter 5.

It was then decided to analyse the data using the subprogram "Anova" based on the regression model. It was felt that as the sample size within each group was small, analysing the means of these samples would be the most appropriate analysis (ASTON, 1981).

As the subprogram "Anova" would have calculated an error estimate partially based on inter-individual variations it was felt necessary to calculate a new error estimate. For this error estimate one visit from five patients was selected at random. The variances from the five replicates for each of these patients were averaged to give a new error estimate. This value, however, did not include between photograph variations, and to account for this a factor of 25% was added.

The following hypotheses were tested:

1. H_o: Apparent mean lumen width is indepenedent of time.
   H_1: Apparent mean lumen width is not independent of time.

2. H_o: Apparent mean lumen width is independent of group type.
   H_1: Apparent mean lumen width is not independent of group type.

For the three experimental groups and for data collected at all three visits the following results were obtained:

Table 4.10 (ii)

Analysis of Variance Table for Mean Lumen Diameter by Group, "with" Visit

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Visit	0.066	1	0.066	26.40	0.0005
Group	0.116	2	0.058	23.20	0.0005
Explained	0.182	3	0.061	24.40	0.0005
Residual	2.864	86	0.033		
Error Estimate		100	0.0025	1	
Total	3.046	89	0.034		

Therefore: 1. Accept H_1

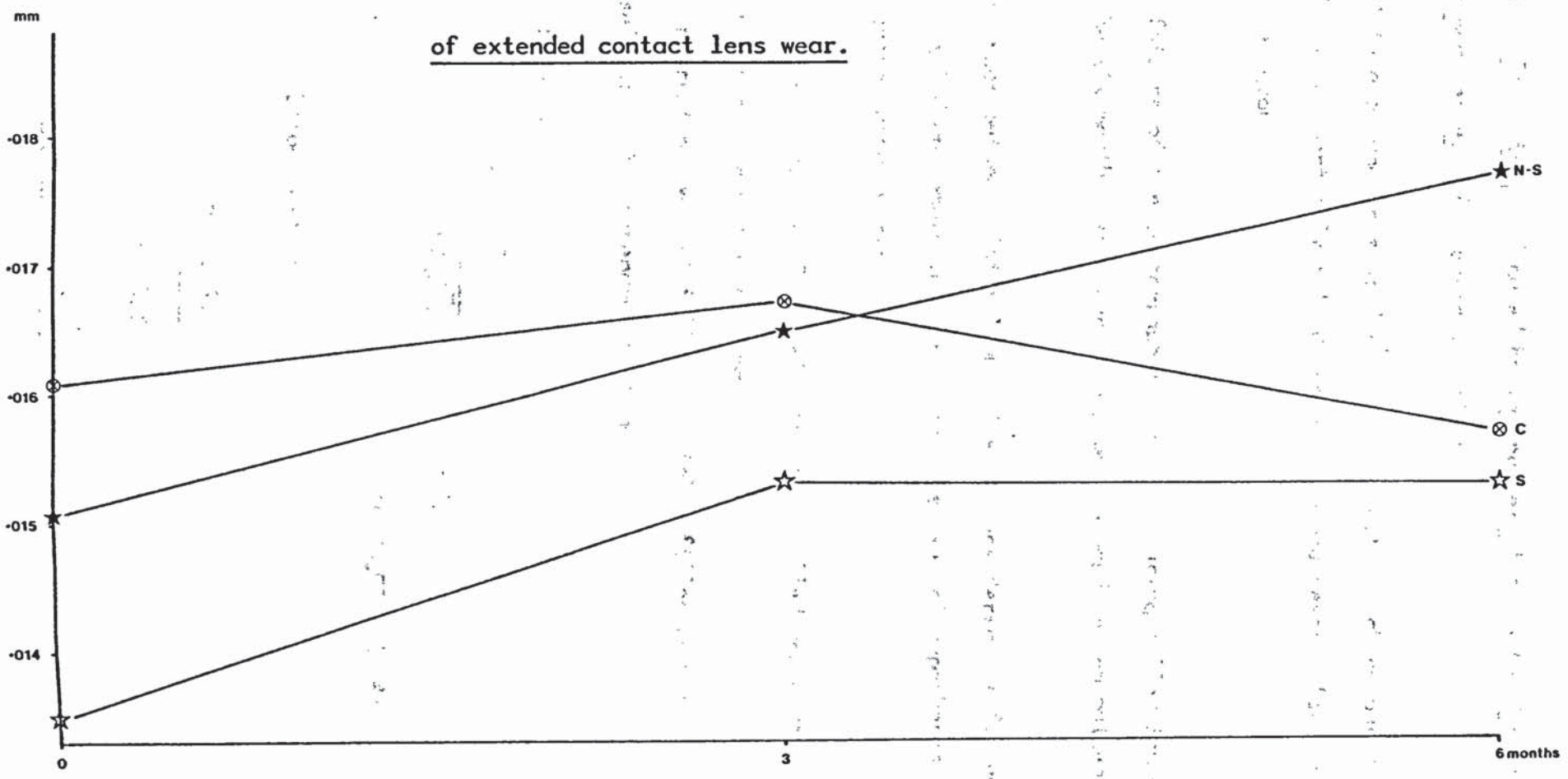
2. Accept H_1

From observations of the group means at visits 1, 10, and 11 the mean lumen width for the control group increased slightly at the three month data point (visit 10) and then decreased by a larger amount at the six month data point (visit 11). The mean lumen width of both contact lens groups increased at the three month check, the solution using group presenting with a greater increase (Fig. 4.10 (ii)).

At the six month data point the mean lumen width for the solution using group had ceased to increase, while the non-solution users presented with a further increase. By repeating use of the sub program "Anova" with all three groups at visits 1 and 10, then 10 and

11, and also by pairing the groups and combining them with the same combinations of visits, the above comments were supported. Possible reasons for the apparent increase in limbal congestion between the three and six month visits for the non-solution using group are discussed in Chapter 5.

FIGURE 4.10 (ii) Changes in the mean lumen diameter of limbal blood vessels with duration of extended contact lens wear.



4.10 iii) Injection, indicated by the number of filled and partially filled blood vessels (Photographic Detection)

The first type of analysis used was the t - test, which compared the means of filled, partially filled and empty blood vessels for each of the three groups.

Due to a failure of the photographic apparatus during collection of data at the six month visit, each group was reduced to ten patients.

The differences between visits 1 and 11 were considered for filled, partially filled and empty vessels. The first set of hypotheses tested for the control group were:

H_o: The apparent numbers of filled, partially filled and empty blood vessels are independent of time.

H_1: The apparent numbers of filled, partially filled and empty blood vessels are not independent of time.

Using the formula

$$t = \frac{\bar{x}}{S/\sqrt{10}}$$

(HAYSLETT, 1974)

1) For filled blood vessels

$$t = \frac{-0.66}{0.7315}$$

$$t = 0.9023$$

From t tables for 9 DF:

Accept H_o

i.e. the number of filled blood vessels in the control group is independent of time.

2) For Partially Filled Blood Vessels

$$t = \frac{-0.84}{0.3873}$$

$$t = 2.1689$$

From t tables for 9DF:

Accept H_o at the 10% significance level

3) For Empty Blood Vessels

$$t = \frac{0.64}{0.4053}$$

$$t = 1.579$$

From t tables for 9DF

Accept H_o.

Having established that the number of filled, partially filled and empty blood vessels had not changed signficantly with time the second set of hypotheses to test for both contact lens groups were:

H_o: The differences in filled, partially filled and empty blood vessels are not greater in the contact lens groups than in the control group.

H_1: The differences in filled, partially filled and empty blood vessels are greater in the contact lens group than in the control group.

1) For the Solution - Using Group

Using the formula:

$$t = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)}{\sqrt{SP^2\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

(HAYSLETT, 1974)

Where $\bar{x}_1$ and $\bar{x}_2$ are the means of the control group and solution - using group respectively, μ_1 and μ_2 are the variances of the controls and solution - users respectively, SP^2 is the pooled variance and n_1 and n_2 the numbers of samples in each group.

a) Filled Blood Vessels

$$t = \frac{-0.66 - (-0.84)}{\sqrt{4.4082\left(\frac{2}{10}\right)}}$$

$$= -0.1917$$

Therefore, from t tables for 19DF

Accept H_o

b) Partially Filled Blood Vessels

From examination of the differences in partially filled vessels between the first and last visits, it was apparent that two patients presented with increases which exceeded the other patients by a factor of approximately six times. As these outliers changed the distribution from the normal it was decided to omit them in these calculations.

Therefore: $t = \frac{-0.84 - 0.55}{\sqrt{1.9716\left(\frac{1}{I0} + \frac{1}{8}\right)}} = \frac{-2.0870}{}$

For 17 DF Accept H_o at the 5% significance level.

c) Empty Blood Vessels

$$t = \frac{0.64 - 0.66}{\sqrt{2.3988\left(\frac{2}{I0}\right)}} = \frac{-0.0289}{}$$

Therefore, from t tables for 19 DF:

Accept H_o.

From these results of the solution using group, it would appear that no significant increase in filled, partially filled or empty blood vessels occurred between the first and last visits. However, for both filled and partially filled vessels there is an indication that the solution using group presented with increases in comparison to the control group. This would result in an increase in the overall number of blood vessels counted in the solution using group. This apparent increase in the total number of blood vessels noted may be due to the original presence of empty blood vessels which could not be detected by visual inspection of the projected image.

2) For the Non-Solution Using Group

Appkying the same formula used for solution users:

a) Filled Blood Vessels

$$t = \frac{-0.66 - 1.12}{\sqrt{5.6233\left(\frac{2}{I0}\right)}}$$

$$= \frac{1.78}{1.0605} = 1.6785$$

Therefore:

From t tables for 19 DF

Accept H_o at the 10% significance level

b) Partially Filled Blood Vessels

Two patients presented with markedly different changes (in the order of six times) from the remaining patients in the group. As this would have changed the distribution from the normal it was decided to omit these two outliers from these calculations.

$$t = \frac{-2.115}{\sqrt{3.4527\left(\frac{1}{10} + \frac{1}{8}\right)}} = -2.3995$$

Therefore:

for 17 DF Accept H_o at the 2.5% significance level.

c) Empty Blood Vessels

$$t = \frac{0.64 - 0.26}{0.22655}$$

$$= 0.7983$$

Therefore, from t tables for 19 DF.

Accept H_o

The non-solution using group did not present with a significant increase in the number of filled, partially filled or empty blood vessels. As with the solution using group, there was an indication of increases in both filled and partially filled vessels in comparison with the control group. These results will be discussed

further in Chapter 5.

The subprogram "Anova" was used to calculate analysis of variance for filled and empty blood vessels. Again, as with the reasoning for lumen width, it was felt that for such small sample sizes within groups analysing the mean value for each group was the most appropriate method (ASTON, 1981). Because the partially filled vessel data did not come from a normal distribution, analysis of variance was not appropriate.

As the subprogram "Anova" had again calculated an error estimate, partially based on inter-individual variations a new error estimate was calculated. For filled and empty blood vessels separate error estimates were obtained. One visit from each of five patients was selected at random. The variances for each of the three above recorded values were obtained for each of the five patients, and averaged to give error estimates. However, these values did not include between photograph variations and to take this into account a factor of 25% was added.

The following hypotheses were tested:

1. H_o: The mean number of filled and empty blood vessels are independent of time.

   H_1: The mean numbers of filled and empty blood vessels are not independent of time.

2. H_o: The mean numbers of filled and empty blood vessels are independent of group type.

H_1: The mean numbers of filled and empty blood vessels are not independent of group type.

Table 4.10 (iii) (a)

i. Analysis of Variance Table for the Mean Number of Filled Blood Vessels by Group "with" Visit.

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Visit	1.176	1	1.176	0.6817	N.S.
Group	57.512	2	28.756	16.670	< 0.001
Explained	58.688	3	19.563	11.341	< 0.001
Residual	275.492	86	3.203		
Error Estimate		20	1.725	1	
Total	334.180	89	3.755		

Therefore: 1. Accept H_o

2. Accept H_1

ii. Analysis of Variance Table for the Mean Number of Empty Blood Vessels by Group, "with" Visit

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Visit	4.056	1	4.056	8.539	0.010
Group	10.891	2	5.445	11.463	< 0.001
Explained	14.947	3	4.982	10.488	< 0.001
Residual	87.597	86	1.019		
Error Estimate		20	0.475	1	
Total	102.544	89	1.152		

Therefore: 1. Accept H_1

2. Accept H_o

From these results there is no significant change in the number of filled blood vessels with time, which supports the previous results using the t - test. There is a significant increase in the number of empty blood vessels for each ofthe three groups with time. Whether this is due to a marginal increase in the quality of photography, hence improving their detection, or indeed due to a true increase in their number is difficult to ascertain. These results are further discussed in Chapter 5.

Section 4.11 Corneal Vascularization

4.11 i) Vascularization, measured by ranking system (biomicroscopical detection)

As the vascularization observed on the slit-lamp was ranked on a scale of increasing severity it was felt that analysis of variance based on the regression model was the most appropriate. However, from observation of the group means at each visit it was apparent that no vascularization was detected during the course of the study.

4.11 ii) Vascularization, indicated by the number of unlooped vessels (biomicroscopical detection)

No unlooped blood vessels were detected throughout the course of the study

4.11 iii) Apparent Vascularization (biomicroscopical detection)

The values of apparent limbal depth obtained using the graticule (E18) placed in the slit lamp objective were analysed using the subprogram "anova" (ASTON, 1981). To obtain a suitable error estimate which would not include patient to patient variations (unlike the "Anova" sub-program error estimate which is partially based on these variations) two repeated readings were taken at each of the four positions (nasal, superior, temporal and inferior). on one patient, repeated at the same time for five successive days (Appendix 4.11 (iii)). The variances for each of the paired readings were obtained and then averaged to give a new error estimate.

The following hypotheses were tested.

1. H_o: Apparent limbal depth is independent of time.

   H_1: Apparent limbal depth is not independent of time.

2. H_o: Apparent limbal depth is independent of group type.

   H_1: Apparent limbal depth is not independent of group type.

Table 4.11 (iii) (a)

i. Analysis of Variance Table of Apparent Limbal Depth, Nasally, by Group, "with" Visit.

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Visit	1.873	1	1.873	0.231	N.S.
Group	161.420	2	80.710	9.934	0.005
Explained	163.293	3	54.431	6.699	0.005
Residual	1669.423	158	10.566		
Error Estimate		20	8.125	1	
Total	1832. 716	161	11.383		

Therefore: 1. Accpet H_o
2. Accept H_1

ii. Analysis of Variance Table of Apparent Limbal Depth Superiorly, by Group, "with" Visit

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Visit	35.983	1	35.983	4.429	0.050
Group	922.531	2	461.265	56.771	< 0.001
Explained	958.513	3	319.504	39.324	< 0.001
Residual	3514.944	158	22.246		
Error Estimate		20	8.125	1	
Total	4473.457	161	27.785		

Therefore: 1. Accept H_o
2. Accept H_1

Table 4.11 (iii) (b)

i. Analysis of Variance Table of Apparent Limbal Depth

Temporally by Group, "with" Visit

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Visit	110.501	1	110.501	13.600	0.001
Group	96.605	2	48.302	5.945	0.010
Explained	207.106	3	69.035	8.497	0.001
Residual	2108.943	158	13.348		
Error Estimate		20	8.125	1	
Total	2316.049	161	14.385		

Therefore: 1. Accept H_1

2. Accept H_1

ii. Analysis of Variance Table of Apparent Limbal Depth

Inferiorly by Group, "with" Visit.

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Visit	43.692	1	43.692	5.377	0.050
Group	513.272	2	256.636	31.586	<0.001
Explained	556.964	3	185.655	22.850	<0.001
Residual	2916.493	158	18.459		
Error Estimate		20	8.125	1	
Total	3473.457	161	21.574		

Therefore: 1. Accept H_o

2. Accept H_1

Firstly it was established, using the subprogram "Regression", that for the control group apparent limbal depth superiorly and inferiorly did not change linearly with time. However, at both nasal and temporal positions there was an indication of an increase in apparent limbal depth.

From the results of analysis of variance there was no significant difference in apparent limbal depth nasally with time. Observation of cell means showed that nasal apparent limbal depth for the solution using group had increased and for the non-solution using group had decreased, at both three month and six month visits. However, superiorly, temporally and inferiorly the apparent limbal depth for both contact lens groups had increased. This is supported by the results of the analysis of variance. Further discussion of these results may be found in Chapter 5.

4.11 iv) Apparent Vascularization (Photographic detection)

Apparent limbal depth was analysed in the same way as apparent lumen width (section 4.10 (ii)), but because of the significance of the results from the t - test, it was felt unnecessary to calculate analysis of variance as well.

The differences between the means of the apparent limbal depths at visits 1 and 11, for each patient, were obtained. Using the t- test the first hypotheses tested for the control group were:

H_o: Apparent limbal depth is independent of time (i.e. the mean is centred about zero)

H_1: Apparent limbal depth is not independent of time (i.e. the mean is not centred about zero).

Prior to calculation it was apparent that two outliers were present in the control samples. As this test assumes a normal distribution the outliers were omitted.

From $t = \dfrac{\bar{x}}{S/\sqrt{10}}$

$$t = \frac{0.8468 \times 3.1622}{1.6033} = \underline{1.2727}$$

From t tables for 7DF

Accept H_o

Therefore, there is no indication of an increase in the apparent limbal depth of the control group with time. The following hypotheses for the contact lens wearing groups were then tested:

H_o: The contact lens groups do not present with an increase in apparent limbal depth which is greater than in the control group.

H_1: The contact lens groups present with an increase in apparent limbal depth which is greater than in the control group.

1. For the Solution Using Group

$$t = \frac{(\bar{x}_1 - \bar{x}_2)}{\sqrt{Sp^2\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}} = \frac{-1.9169}{0.62415} = \underline{-3.0709}$$

From t tables, for 16 DF:

Accept H_1, at the 0.5% significance level, i.e. there was a significant increase in apparent limbal depth with time in the solution using group

compared with the control group.

2. For the Non-Solution Using Group

Two outliers also present in the non-solution using group were omitted from these calculations.

$$t = \frac{(\bar{x}_1 - \bar{x}_3)}{\sqrt{Sp^2 \left(\frac{1}{n_1} + \frac{1}{n_3}\right)}}$$

$$= \frac{-3.2688}{0.7166} = \underline{4.5615}$$

From t tables, for 15 DF:

Accept H_1.

This indicates that there was a significant increase in apparent limbal depth with time in the non-solution using group as compared with the control group.

The following hypotheses were then tested:

H_o: The contact lens wearing groups come from the same population.

H_1: The contact lens wearing groups do not come from the same population.

Using $t = \frac{(\bar{x}_2 - \bar{x}_3)}{\sqrt{Sp^2 \left(\frac{1}{n_2} + \frac{1}{n_3}\right)}}$

$$t = \frac{-1.3519}{0.5229} = \underline{2.5854}$$

Therefore from t tables, for 17 DF:

Accept H_1 at the 1% significance level.

There is an indication, from the means, that the non-solution users have a larger increase in apparent limbal depth than the solution users.

From the above results it may be asserted with confidence that the change in apparent limbal depth in the non-solution using group is indeed greater than the change in the solution using group.

To give an indication of the range of values within which apparent limbal depth may be expected to change for an individual, confidence limits (99% level) were calculated for each group, excluding the two outliers in each of the control and non-solution using groups.

Controls

Confidence limits of individual changes are given by:

$$-0.847 \pm t_7\alpha \times 1.603$$

$$= -0.847 \pm 3.499 \times 1.603$$

$$= -0.847 \pm 5.609$$

Therefore, limits are -6.456 and +4.762

Converting to more meaningful values the limits are:

-0.1318mm and +0.0972mm

Solution Users

Confidence limits of individual changes are given by:

$$1.070 \pm t_9\alpha \times 0.945$$

$$= 1.070 \pm 3.250 \times 0.945$$

$$= 1.070 \pm 3.071$$

Therefore, limits are -2.001 and +4.141

Converting to more meaningful values the limits are:

-0.0408mm and +0.0845mm

Non-solution Users

Confidence limits of individual changes are given by:

$$2.422 \pm t_{7}\alpha \times 1.2401$$

$$= 2.422 \pm 4.339$$

Therefore, limits are -1.917 and +6.761

Converting to more meaningful values the limits are:

-0.0391mm and +0.1380mm

From these results it would appear that the non-solution using group presented with the greatest increase in apparent limbal depth over the period of six months (Fig 4.11 (iv)). The control group, though having the greatest range of limbal depth changes, is more biased towards decreasing changes than either of the two contact lens groups. These results further support previous findings where the two contact lens wearing groups presented with a significant increase in apparent limbal depth, in comparison to the control group. Increases in this instance were found to be more significant in the non-solution using group then in the solution using group.

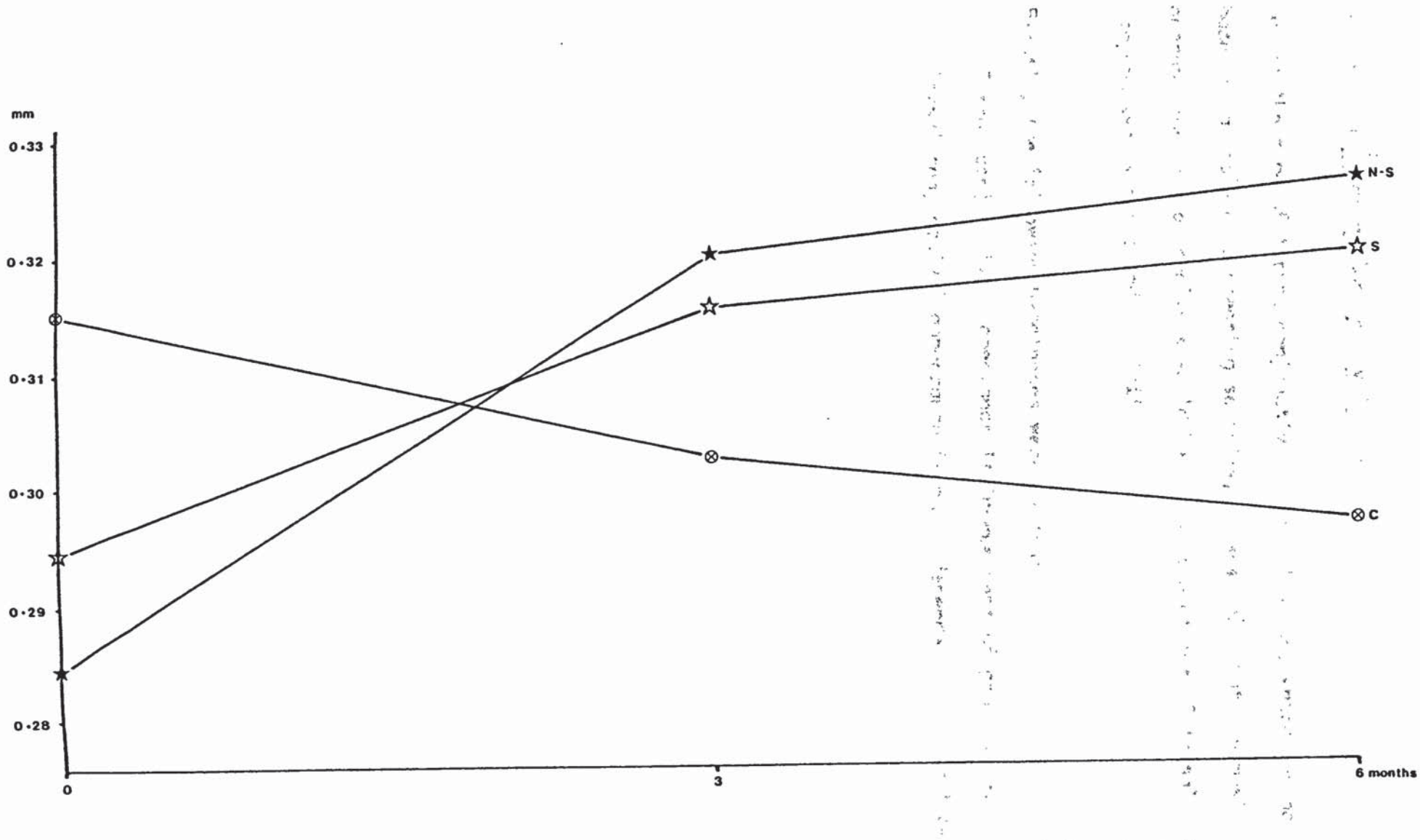


FIGURE 4.11(iv). Changes in the mean apparent limbal depth with duration of extended contact lens wear.

Section 4.12 Tarsal Conjunctival Examination

Due to the type of tarsal conjunctival classification, which was not based on a scale of increasing severity, it was felt that the most appropriate form of analysis would be cross tabulations of tarsal conjunctiva by group and by visit.

Firstly, the following hypotheses were tested:

H_o: Tarsal conjunctival appearance is independent of group type.

H_1: Tarsal conjunctival appearance is not independent of group type.

Table 4.12 (a) i.

Crosstabulations of Tarsal Conjunctiva by Group

Visit = 1

Tarsal Conjunctiva Right	COUNT / ROW % / COL % / TOT %	GROUP 1	GROUP 2	GROUP 3	ROW TOTAL
	1	2 40.0 12.5 4.2	2 40.0 12.5 4.2	1 20.0 6.3 2.1	5 10.4
	2	13 34.2 81.3 27.1	14 36.8 87.5 29.2	11 28.9 68.8 22.9	38 79.2
	3	1 20.0 6.3 2.1	0 0.0 0.0 0.0	4 80.0 25.0 8.3	5 10.4
	COLUMN TOTAL	16 33.3	16 33.3	16 33.3	48 100.0

Raw Chi Square = 5.96842. DF = 4. Significance = 0.2015

Visit = 8

Tarsal Conjunctiva Right	COUNT / ROW % / COL % / TOT %	GROUP 1	GROUP 2	GROUP 3	ROW TOTAL
	1	2 100.0 12.5 4.2	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 4.2
	2	13 31.7 81.3 27.1	16 39.0 100.0 33.3	12 29.3 75.0 25.0	41 85.4
	3	1 20.0 6.3 2.1	0 0.0 0.0 0.0	4 80.0 25.0 8.3	5 10.4
	COLUMN TOTAL	16 33.3	16 33.3	16 33.3	48 100.0

Raw Chi Square = 9.83415. DF = 4. Significance = 0.0433

Table 4.12 (a) ii.

Crosstabulations of Tarsal Conjunctiva by Group

Visit = 9

Tarsal Conjunctiva Right	COUNT / ROW % / COL % / TOT %	GROUP 1	GROUP 2	GROUP 3	ROW TOTAL
	1	1 100.0 6.3 2.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 2.1
	2	13 28.9 81.3 27.1	16 35.6 100.0 33.3	16 35.6 100.0 33.3	45 93.8
	3	1 100.0 6.3 2.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 2.1
	4	1 100.0 6.3 2.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 2.1
	COLUMN TOTAL	16 33.3	16 33.3	16 33.3	48 100.0

Raw Chi Square = 6.40000. DF = 6. Significance = 0.3799.

Visit = 10

Tarsal Conjunctiva Right	COUNT / ROW % / COL % / TOT %	GROUP 1	GROUP 2	GROUP 3	ROW TOTAL
	1	2 100.0 12.5 4.2	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 4.2
	2	14 30.4 87.5 29.2	16 34.8 100.0 33.3	16 34.8 100.0 33.3	46 95.8
	COLUMN TOTAL	16 33.3	16 33.3	16 33.3	48 100.0

Raw Chi Square = 4.17391. DF = 2. Significance = 0.1241

Table 4.12 (a) iii

Crosstabulation of Tarsal Conjunctiva by Group

Visit = 11

Tarsal Conjunctiva Right	COUNT / ROW % / COL % / TOT %	GROUP 1	GROUP 2	GROUP 3	ROW TOTAL
	1	3 100.0 18.8 6.3	0 0.0 0.0 0.0	0 0.0 0.0 0.0	3 6.3
	2	13 29.5 81.3 27.1	16 36.4 100.0 33.3	15 34.1 93.8 31.3	44 91.7
	3	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 100.0 6.3 2.1	1 2.1
	COLUMN TOTAL	16 33.3	16 33.3	16 33.3	48 100.0

Raw Chi Square = 8.31818. DF = 4. Significance = 0.0806.

Therefore, for Visits 1, 8, 9, 10 and 11 Accept H_o.

Secondly the following hypotheses were tested:

H_o: Tarsal Conjunctival appearance was independent of visit.

H_1: Tarsal Conjunctival appearance was not independent of visit.

Table 4.12 (b)

Summary Table of Crosstabulations of Tarsal Conjunctiva by Visit for:

	Raw Chi Square	DF	Significance
a) Group 1	7.06061	12	0.8536
b) Group 2	8.20513	4	0.0843
c) Group 3	14.90476	8	0.0610

For Groups 1, 2, and 3 Accept H_o.

No appearance of giant papillary conjunctivis or indeed any other abnormality of the tarsal conjunctiva was detected.

Section 4.13 Contact Lens Over-refraction

Both the spherical and cylindrical components of the over-refraction were analysed using the SPSS subprogram "Anova".

For both spherical and cylindrical components of the over-refraction the "Anova" subprogram would have calculated the error estimate partially based on inter-individual variations. To obtain a new error estimate, in both cases, the two-way interactions from each analysis were used.

The following hypotheses were tested:

1. H_o: The over-refraction component is independent of time.
   H_1: The over-refraction component is not independent of time.

2. H_o: The over-refraction component is independent of group type.
   H_1: The over-refraction component is not independent of group type.

Table 4.13 (a)

i. Analysis of Variance Table of the Spherical component of the Over-Refraction by Group, "with" Visit

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Visit	0.392	1	0.392	1.136	N.S.
Group	0.066	1	0.066	0.815	N.S.
Explained	0.458	2	0.229	2.827	N.S.
Residual	12.308	157	0.078		
Error Estimate		8	0.081	1	
Total	12.765	159	0.080		

Therefore: 1. Accept H_o
2. Accept H_o

ii. Analysis of Variance Table of the Cylindrical Component of the Over-Refraction by Group, "with" Visit

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Visit	1.509	1	1.508	24.401	<0.001
Group	0.025	1	0.025	0.405	N.S.
Explained	1.533	2	0.767	12.411	0.005
Residual	9.953	157	0.063		
Error Estimate		8	0.0618	1	
Total	11.486	159	0.072		

Therefore: 1. Accept H_1
2. Accept H_o

The changes in cylindrical axes were then analysed using the Rank-sum test for two populations (HAYSLETT, 1974). The following hypotheses were tested:

H_o: The contact lens groups come from the same population, i.e. they have the same median.

H_1: The contact lens group do not come from the same population, i.e. they do not have the same median.

Table 4.13 (b)

Summary Table of the Results of the Rank-Sum test for changes in Over-refraction Cylindrical axes between the following visits

Visits (n_1, n_2)	Z	Conclusion
8 - 9 (10,13)	-2.09	Accept H_o
9 - 10 (11,11)	-0.23	Accept H_o
10 - 11 (11,9)	+0.11	Accept H_o

Note: The critical region for Z, at the 1% level is -2.576 and +2.576.

n_1 = sample size of Group B (Solution Users)

n_2 = sample size of Group A (Non-solution Users).

It was estimated, from repeated refractions of patients within the study, that for cylinders under 1 dioptre an angle change of greater than $7\frac{1}{2}^{\circ}$ was meaningful. Using this estimate as the criterion for

angle changes the numbers of meaningful changes for each group were counted and tabulated below.

Table 4.13 (c)

Table illustrating the number of meaningful changes in over-refraction cylindrical axes between visits.

Visit	1 - 8	8 - 9	9 - 10	10 - 11
Non-solution users n_1/n_2	2/3	8/13	7/11	6/9
Solution users n_1/n_2	3/4	3/10	6/11	7/11

Where n_1 is the number of meaningful axis changes and n_2 is the total number of changes recorded between the same visits (these are not always equal to the total sample size because of the presence of spherical over-refractions).

The increase in the number of meaningful axes changes corresponds quite closely to the increase in the number of cylinders after baseline. Both groups appear to have similar counts of meaningful changes except during the visits 8 to 9 period, when the cylinder axes in the solution using group appear to be more stable.

From the previous table and from calculations of the Rank-Sum test it was apparent that at some visits the number of spherical over-refractions differed quite noticeably from the rest. The numbers of spherical over-refractions at different visits were then analysed by calculating contingency tables. The following hypotheses

were tested:

H_o: The number of spherical over-refractions is independent of visit.

H_1: The number of spherical over-refractions is not independent of visit.

Table 4.13 (d)

Contingency tables of the number of Spherical Over-Refractions by Visit

i. Non-Solution using Group

Expected Count / Actual Count / Difference	Visit 1	8	9	10	11	Row Total
yes SPHERICAL PRESCRIPTION	4.8 11 6.2	4.8 3 1.8	4.8 2 2.8	4.8 3 1.8	4.8 5 0.2	24 12.8
no	11.2 5 6.2	11.2 13 1.8	11.2 14 2.8	11.2 13 1.8	11.2 11 0.2	56 12.8
COLUMN TOTAL	16	16	16	16	16	80.0 25.6

Chi Square = 15.71. DF = 4. Significance = 0.005

Therefore, Accept H_1.

Note: As the Chi square value is so highly signficant, the conclusion can be safely accepted even though the expected value in some cells is slightly less than 5.

ii. Solution-Using Group

Expected Count / Actual Count / Difference	Visit 1	8	9	10	11	Row Total
yes SPHERICAL PRESCRIPTION	4.8 10 5.2	4.8 5 0.2	4.8 4 0.8	4.8 1 3.8	4.8 4 0.8	24.0 10.8
no	11.2 6 5.2	11.2 11 0.2	11.2 12 0.8	11.2 15 3.8	11.2 12 0.8	56.0 10.8
COLUMN TOTAL	16	16	16	16	16	80.0 21.6

Chi Square = 12.74. DF = 4. Significance = 0.025

Therefore, Accept H_o.

From the results of analysis of variance the increase in the cylindrical component of the over-refraction was shown to be signficant. These results are further supported by the results from crosstabulations of spherical over-refractions by visit, which illustrate the significantly higher number of spherical over-refractions at baseline. This may well be due to the incomplete conformity of the contact lens to the cornea within the first hour of wear, hence giving rise to a spherical anterior contact lens surface and an over-refraction without a cylindrical component.

Section 4.14 Spectacle Prescription

Both the spherical and cylindrical components of the spectacle prescription were analysed using the SPSS subprogram "Anova".

The following hypotheses were tested:

1. H_o: The spectacle prescription component is independent of time.

   H_1: The spectacle prescription component is not independent of time.

2. H_o: The spectacle prescription component is independent of group type.

   H_1: The spectacle prescription component is not independent of group type.

The error estimate calculated by the subprogram "Anova" would also have included patient to patient variations, therefore, new error estimates for both spherical and cylindrical components were obtained from the appropriate two-way interactions.

Table 4.14 (a)

i. Analysis of Variance Table of the Spherical Component of the Spectacle Refraction by Group, "with" Visit

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Visit	1.773	1	1.773	3.443	N.S.
Group	508.206	2	254.103	493.404	<0.001
Explained	509.979	3	169.993	330.083	<0.001
Residual	436.362	236	1.849		
Error Estimate		8	0.515	1	
Total	946.341	239	3.960		

ii. Analysis of Variance Table of the Cylindrical Component of the Spectacle Refraction by Group, "with" Visit

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F
Visit	0.008	1	0.008	0.348	N.S.
Group	3.416	2	1.708	74.261	<0.001
Explained	3.424	3	1.141	49.609	<0.001
Residual	18.920	236	0.080		
Error Estimate		8	0.023	1	
Total	22.343	239	0.093		

Changes in spectacle cylindrical axes were analysed in the same way as changes in the Keratometry axes (i.e. Rank-sum test (HAYSLETT, 1974)).

The following hypotheses were tested

H_o: The controls and the contact lens wearers come from the same population, i.e. they have the same median.

H_1: The controls and the contact lens wearers do not come from the same population, i.e. they do not have the same median.

Table 4.14 (b)

Summary Table of the Results of the Rank-Sum test for changes in Spectacle Cylindrical Axes between the following Visits

Visits (n_1, n_2)	Non-Solution Using Group		Solution Using Group	
	R	Conclusion	R	Conclusion
1 - 8 (9,9)	85.5	Accept H_o	76.5	Accept H_o
8 - 9 (8,8)	76.0	Accept H_o	67.0	Accept H_o
9 - 10 (8,8)	88	Accept H_o	84	Accept H_o
10 - 11 (8,8)	72.5	Accept H_o	80	Accept H_o

Note: For sample sizes of $n_1 = n_2 = 9$ the critical range of the random variable R, at the 5% significance level, is ≤ 66 and ≥ 105, and for sample sizes of $n_1 = n_2 = 8$ the critical range of the random variable R, at the 5% significance level, is ≤ 52 and ≥ 84.

From these results there is an indication of a greater change in the cylindrical axes of the two contact lens group than in the axes

of the control group, between visits 9 and 10. Therefore, in order to increase the precision of the test for these results the sample sizes of the two contact lens groups were increased and the test repeated.

Table 4.14 (c)

Summary table of the Rank-Sum test for Spectacle Cylindrical Axes between Visits 9 and 10

Non-Solution Using Group		Solution Using Group	
Z	Conclusion	Z	Conclusion
-2.16	Accept H_o	-2.16	Accept H_o

Note: For sample sizes of $n_1 = 8$ and $n_2 = 12$ the critical region for Z at the 1% significance level is -2.576 and +2.576.

These results therefore verify that for both contact lens groups, between visits 9 and 10, there was only an indication of a greater change in the cylindrical axes than in the control group.

From calculating the Rank-sum test it was apparent that the number of spherical spectacle prescriptions varied from visit to visit. Therefore, contingency tables of spherical spectacle prescription, by visit, were calculated for each group. The following hypotheses were tested:

H_o: The number of spherical spectacle prescriptions is independent of visit.

H_1: The number of spherical spectacle prescriptions is not independent of visit.

Table 4.14 (d)

Contingency Tables of the Number of Spherical Spectacle Prescriptions by Visit

i. Controls

Expected count / Actual count / Difference		Visit 1	8	9	10	11	Row Total
SPHERICAL SPECTACLE PRESCRIPTION	Yes	5.6 3 2.6	5.6 6 0.4	5.6 7 1.4	5.6 7 1.4	5.6 5 0.6	28.0 6.4
	No	10.4 13 2.6	10.4 10 0.4	10.4 9 1.4	10.4 9 1.4	10.4 11 0.6	52.0 6.4
COLUMN TOTAL		16	16	16	16	16	80.0 12.8

Chi Square = 3.08. DF = 4. Significance = 0.25

Therefore, Accept H_o.

ii. Solution Users

Expected count / Actual count / Difference		Visit 1	8	9	10	11	Row Total
SPHERICAL SPECTACLE PRESCRIPTION	Yes	2.6 2 0.6	2.6 1 1.6	2.6 3 0.4	2.6 4 1.4	2.6 3 0.4	13.0 4.4
	No	13.4 14 0.6	13.4 15 1.6	13.4 13 0.4	13.4 12 1.4	13.4 13 0.4	67.0 4.4
COLUMN TOTAL		16	16	16	16	16	80.0 8.8

Chi Square = 2.39. DF = 4. Significance = 0.35.

Therefore, Accept H_o.

Table 4.14 (d) continued

iii.Non-Solution Users

Expected count / Actual count / Difference		Visit 1	8	9	10	11	Row Total
SPHERICAL SPECTACLE PRESCRIPTION	Yes	2.6 3 0.4	2.6 2 0.6	2.6 1 1.6	2.6 4 1.4	2.6 3 0.4	13.0 4.4
	No	13.4 13 0.4	13.4 14 0.6	13.4 15 1.6	13.4 12 1.4	13.4 13 0.4	67.0 4.4
COLUMN TOTAL		16	16	16	16	16	80.0 8.8

Chi Square = 2.39. DF = 4. Significance = 0.35.

Therefore, Accept H_o.

Note: As simple Chi square calculations led to acceptance of the null hypotheses in every case, there was no point in applying corrections.

It would appear from these results that the variation in spherical spectacle prescription between visits for each group is not significant.

Section 4.15 Contact Lens Condition

By calculating crosstabulations of contact lens condition by Group, the following hypotheses were tested:

H_o: Contact lens condition was independent of group type.

H_1: Contact lens condition was not independent of group type.

Table 4.15 (a) i.

Crosstabulations of Contact Lens Condition by Group

Visit = 8

CONTACT LENS CONDITION RIGHT	COUNT / ROW % / COL % / TOT %	Group 2	Group 3	Row Total
	1	14 51.9 93.3 45.2	13 48.1 81.3 41.9	27 87.1
	2	1 33.3 6.7 3.2	2 66.7 12.5 6.5	3 9.7
	4	0 0.0 0.0 0.0	1 100.0 6.3 3.2	1 3.2
	COLUMN TOTAL	15 48.4	16 51.6	31 100.0

Raw Chi Square = 1.33951. DF = 2. Significance = 0.5118.

Therefore: Accept H_o.

Visit = 9

CONTACT LENS CONDITION RIGHT	COUNT / ROW % / COL % / TOT %	Group 2	Group 3	Row Total
	1	15 48.4 93.8 46.9	16 51.6 100.0 50.0	31 96.9
	2	1 100.0 6.3 3.1	0 0.0 0.0 0.0	1 3.1
	COLUMN TOTAL	16 50.0	16 50.0	32 100.0

Raw Chi Square = 1.03226. DF = 1. Significance = 0.3096

Therefore: Accept H_o

Table 4.15 (a) ii.

Crosstabulations of Contact Lens Conditions by Group

Visit = 10

CONTACT LENS CONDITION RIGHT	COUNT / ROW % / COL % / TOT %	Group 2	Group 3	Row Total
	1	15 50.0 93.8 46.9	15 50.0 93.8 46.9	30 93.8
	2	1 100.0 6.3 3.1	0 0.0 0.0 0.0	1 3.1
	4	0 0.0 0.0 0.0	1 100.0 6.3 3.1	1 3.1
COLUMN TOTAL		16 50.0	16 50.0	32 100.0

Raw Chi Square = 2.00000. DF = 2. Significance = 0.3679

Therefore: Accept H_o

Visit = 11

	COUNT / ROW % / COL % / TOT %	Group 2	Group 3	Row Total
	1	14 50.0 87.5 43.8	14 50.0 87.5 43.8	28 87.5
	2	1 50.0 6.3 3.1	1 50.0 6.3 3.1	2 6.3
	4	1 50.0 6.3 3.1	1 50.0 6.3 3.1	2 6.3
COLUMN TOTAL		16 50.0	16 50.0	32 100.0

Raw Chi Square = 0.00000. DF = 2. Significance = 1.0000

Therefore: Accept H_o.

By calculating Chi Square from crosstabulations of contact lens condition by visit it was determined that the contact lens condition is independent of visit.

Table 4.15 (b)

Summary Table of Crosstabulations of Contact Lens Condition by Visit for:

	Raw Chi Square	DF	Significance
a) Group 2	2.98933	6	0.8102
b) Group 3	5.01149	6	0.5423

Therefore, for both groups Accept H_o.

No significant change in contact lens condition was found with time or between groups, which may well be due to the prompt replacement of lenses once defects had been detected.

Section 4.16 Contact Lens Deposits

4.16 i) Contact Lens Deposit Colour

For the observations of contact lens deposit colour the following hypotheses were tested:

H_o: Contact Lens Deposit Colour was independent of Group Type.

H_1: Contact Lens Deposit Colour was not independent of Group Type.

This was achieved by calculating Chi Square from crosstabulations of contact lens deposit colour by group.

Table 4.16 (i) (a) i

Crosstabulations of Contact Lens Deposit Colour by Group

Visit = 8

Right Contact Lens Deposit Colour	COUNT / ROW % / COL % / TOT %	GROUP 2	GROUP 3	Row Total
1		16 50.0 100.0 50.0	16 50.0 100.0 50.0	32 100.0
COLUMN TOTAL		16 50.0	16 50.0	32 100.0

Therefore: Accept H_o

Visit = 9

Right Contact Lens Deposit Colour	COUNT / ROW % / COL % / TOT %	GROUP 2	GROUP 3	Row Total
1		14 48.3 87.5 43.8	15 51.7 93.8 46.9	29 90.6
4		2 66.7 12.5 6.3	1 33.3 6.3 3.1	3 9.4
COLUMN TOTAL		16 50.0	16 50.0	32 100.0

Raw Chi Square = 0.36782. DF = 1. Significance = 0.5442

Therefore: Accept H_o

Table 4.16 (i) (a) ii.

Crosstabulations of Contact Lens Deposit Colour by Group

Visit = 10

Right Contact Lens Deposit Colour	COUNT / ROW % / COL % / TOT %	GROUP 2	GROUP 3	Row Total
1		16	15	31
		51.6	48.4	96.9
		100.0	93.8	
		50.0	46.9	
4		0	1	1
		0.0	100.0	3.1
		0.0	6.3	
		0.0	3.1	
COLUMN TOTAL		16	16	32
		50.0	50.0	100.0

Raw Chi Square = 1.03226. DF = 1. Significance = 0.3096

Therefore: Accept H_o

Visit = 11

Right Contact Lens Deposit Colour	COUNT / ROW % / COL % / TOT %	GROUP 2	GROUP 3	Row Total
1		15	16	31
		48.4	51.6	96.9
		93.8	100.0	
		46.9	50.0	
4		1	0	1
		100.0	0.0	3.1
		6.3	0.0	
		3.1	0.0	
COLUMN TOTAL		16	16	32
		50.0	50.0	100.0

Raw Chi Square = 1.03226. DF = 1. Significance = 0.3096

Therefore: Accept H_o.

From crosstabulations of contact lens deposit colour by visit it was determined that there was no statistical difference in contact lens deposit colour between visits.

Table 4.16 (i) (b)

Summary Table of Crosstabulations of Contact Lens Deposit Colour by Visit for:

	Raw Chi Square	DF	Significance
a) Group 2	3.84699	3	0.2785
b) Group 3	2.06452	3	0.5591

Therefore for both groups Accept H_o.

The only other deposit colour that was detected, apart from white, was brown. Observations of brown deposits included two at visit 9 and one at visit 11 for Group 2 and one at both visits 9 and 10 for Group 3.

4.16 ii) Contact Lens Deposit Appearance

A similar analysis was calculated for contact lens deposit appearance as deposit colour.

Firstly, the following hypotheses were tested:

H_o: Contact lens deposit appearance was independent of group type.

H_1: Contact lens deposit appearance was not independent of group type.

Table 4.16 (ii) (a) i.

Crosstabulation of Contact Lens Deposit Appearance by Group

Visit = 8

RIGHT LENS DEPOSIT APPEARANCE	COUNT / ROW % / COL % / TOT %	GROUP 2	GROUP 3	ROW TOTAL
	1	0 0.0 0.0 0.0	1 100.0 6.3 3.1	1 3.1
	2	1 25.0 6.3 3.1	3 75.0 18.8 9.4	4 12.5
	3	0 0.0 0.0 0.0	5 100.0 31.3 15.6	5 15.6
	4	13 65.0 81.3 40.6	7 35.0 43.8 21.9	20 62.5
	5	2 100.0 12.5 6.3	0 0.0 0.0 0.0	2 6.3
	COLUMN TOTAL	16 50.0	16 50.0	32 100.0

Raw Chi-Square = 10.80000. DF = 4. Significance = 0.0289.

Therefore: Accept H_o.

Table 4.16 (ii) (a) ii.

Crosstabulation of Contact Lens Deposit Appearance by Group

Visit = 9

RIGHT LENS DEPOSIT APPEARANCE	COUNT / ROW % / COL % / TOT %	GROUP 2	GROUP 3	Row Total
	1	2 33.3 12.5 6.5	4 66.7 26.7 12.9	6 19.4
	2	0 0.0 0.0 0.0	1 100.0 6.7 3.2	1 3.2
	3	0 0.0 0.0 0.0	1 100.0 6.7 3.2	1 3.2
	4	11 61.1 68.8 35.5	7 38.9 46.7 22.6	18 58.1
	5	3 60.0 18.8 9.7	2 40.0 13.3 6.5	5 16.1
COLUMN TOTAL		16 51.6	15 48.4	31 100.0

Raw Chi Square = 3.72718. DF = 4. Significance = 0.4442

Therefore: Accept H_o

Table 4.16 (ii) (a) iii.

Crosstabulation of Contact Lens Deposit Appearance by Group

Visit = 10

RIGHT LENS DEPOST APPEARANCE	COUNT / ROW % / COL % / TOT %	Group 2	Group 3	Row Total
	1	0 0.0 0.0 0.0	4 100.0 25.0 12.5	4 12.5
	2	4 57.1 25.0 12.5	3 42.9 18.8 9.4	7 21.9
	3	1 25.0 6.3 3.1	3 75.0 18.8 9.4	4 12.5
	4	10 71.4 62.5 31.3	4 28.6 25.0 12.5	14 43.8
	5	1 33.3 6.3 3.1	2 66.7 12.5 6.3	3 9.4
COLUMN TOTAL		16 50.0	16 50.0	32 100.0

Raw Chi Square = 8.04762. DF = 4. Significance = 0.0898

Therefore: Accept H_o.

Table 4.16 (ii) (a) iv.

Crosstabulation of Contact Lens Deposit Appearance by Group

Visit = 11

COUNT / ROW % / COL % / TOT %	GROUP 2	GROUP 3	Row Total
1	0 0.0 0.0 0.0	2 100.0 12.5 6.3	2 6.3
2	1 20.0 6.3 3.1	4 80.0 25.0 12.5	5 15.6
3	3 37.5 18.8 9.4	5 62.5 31.3 15.6	8 25.0
4	8 80.0 50.0 25.0	2 20.0 12.5 6.3	10 31.3
5	4 57.1 25.0 12.5	3 42.9 18.8 9.4	7 21.9
COLUMN TOTAL	16 50.0	16 50.0	32 100.0

Raw Chi Square = 8.04286. DF = 4. Significance = 0.0900

Therefore: Accept H_o.

From observation of cell counts it would appear that at each visit Group 2 had a relatively higher count of specular deposits than any other deposit appearance and also that this count of specular deposits was higher in Group 2 than Group 3.

To determine if there was any change in contact lens deposit appearance with time crosstabulations of contact lens deposit appearance by visit were calculated

Table 4.16 (ii) (b)

Summary Table of Crosstabulations of Contact Lens Deposit Appearance by Visit for:

	Raw Chi-Square	DF	Significance
a) Group 2	21.23810	12	0.0470
b) Group 3	13.65903	12	0.3230

Therefore: a) Accept H_o

b) Accept H_o

From these results there is no indication of a change in the contact lens deposit appearance, with time, for either of the two groups.

Section 4.17 Red Eyes

Ten patients in all presented with acute, bilateral red eye responses. These patients comprised equal numbers from each of the contact lens wearing groups and the occurance of the red eye responses would appear to be random up to the three month data point. After 14 weeks no more red eyes were encountered. The following table illustrates the distribution of red eyes throughout the duration of the study.

Table 4.17. Red Eye Responses encountered during the study

Group	Patient name and computer number	Nearest visit number to red eye	Period of contact lens wear
A(Non-solution users)	CLAYPHAN (54)	9	9 weeks
	GREGORY (58)	4	6 days
	GROOM (59)	10	13 weeks
	HINTON (61)	5	10 days
	LYNAM (65)	8	5 weeks
B (solution users)	BETHEL (28)	7	23 days
	DALTON (31)	6	15 days
	HERBERT (34)	6	16 days
	McADAM (44)	10	14 weeks
	YATES (51)	8	4½ weeks

The patients usually presented with painful, congested lacrimating eyes often with one eye worse than the other, corneal oedema was noted in most cases. The majority of patients were first aware of pain and discomfort in the middle of the night. Contact lens removal was more difficult than usual because of increased lacrimation and minimal

movement of the lens. By the time the patient attended the clinic, the pain and lacrimation was greatly reduced. The patient was examined thoroughly at four hourly intervals during the course of the first day and twice during the second day. The lenses were autoclaved and contact lens wear was, in most cases, resumed after a recovery period of 48 hours. When necessary brolene 0.15% ointment was instilled into the affected eyes, but this was seldom necessary.

Section 4.18 Patient Withdrawal

4.18 i) Clinical Reasons

During the third week of extended contact lens wear a patient in Group A (patient file number 74) reported with foreign body sensations in both eyes. On removal of his lenses epithelial filaments were observed. These filaments stained vividly with fluorescein. Brolene 0.15% ointment was instilled into both eyes and the patient was requested to return. After four hours the foreign body sensation had virtually gone and the epithelial filaments were less numerous. After 48 hours both eyes were back to normal and contact lens wear was resumed with caution. However, after one further week of extended contact lens wear the filamentary keratopathy recurred and the patient was consequently taken off the study.

After two weeks of extended wear a patient (file number 76), again in Group A, developed a red eye condition. The patient was away at the time, did not seek prompt medical advice and persisted in wearing her lenses despite previous councilling to the contrary. As a result it was felt that the patient was unsuitable for extended wear and was rejected from the study.

4.18 ii) Non-Clinical Reasons

Two patients, both in Group A, left the study for personal reasons. The first patient (file number 77) left after only five days and the second patient (file number 75) left after three and a half weeks extended wear. Finally one patient in Group B (file number 36) failed to attend the clinic at the ninth visit, did not respond to new

appointments or reminders, and was never seen again. To remove any possible grounds for professional negligence an official letter was sent to the student's home. This stated that due to lack of co-operation it was felt impossible to give the patient the necessary clinical care required and that he should seek ophthalmic services elsewhere.

Section 4.19 Special Cases

4.19 i) Non-recurrent Filamentary Keratopathy

On the first day of contact lens wear after only 3 hours of contact lens wear, a patient (file number 35) returned to the clinic presenting with foreign body sensations in both eyes. The contact lenses were removed and slit lamp examination revealed the presence of corneal epithelial filaments in both eyes. These filaments stained heavily with 2% Fluorescein Sodium and were more numerous in the left eye. Brolene 0.15% ointment was instilled in both eyes and the patient was requested to return three hours later. Further examination revealed that the epithelial tags were less numerous and the patient reported that the foreign body sensation had virtually gone. Brolene 0.15% ointment was again instilled and the patient requested to return the next day. Meanwhile the lenses were rinsed and autoclaved. At the next visit and 24 hours later both corneae were normal. Contact lens wear was resumed with caution and the patient was monitored daily. The patient did not develop filamentary keratopathy again during the course of the study.

4.19 ii) Sub-epithelial Infiltrates

During the first month of extended wear a patient in Group A (patient file number 64) attended the clinic with ocular discomfort in the left eye. This appeared to be due to an area of epithelial staining at the nasal limbus, which extended 1mm into the cornea. Beneath this area of stain grey/white sub-epithelial infiltrates were observed. Contact lens fit and riding position bore no apparent relation to the disturbed area. Two days after contact lens wear had been stopped the infiltrates had dispersed. Contact lens wear was resumed with a new lens in the left eye. The sub-epithelial infiltrates did not recure throughout the duration of the study.

CHAPTER 5

Discussion

During the first month of extened wear transient reductions in the standard and stability of vision were noted. Both of these may have been associated with increased lacrimation, which invariably accompanies the initial periods of contact lens wear (MANDELL and HARRIS, 1968; UNIACKE and HILL, 1970; STONE and PHILLIPS, 1972; MANDELL, 1974). The subsequent improvement in recorded standard and stability could be due either to a return to more normal lacrimation or to patients' adaptation to the lens' optical performance. Although this improvement was smaller than the initial reduction, the patients reported satisfactory visual performance throughout the study.

The significantly higher number of spherical over-refractions at baseline than at successive data points was probably a result of incomplete lens conformity during the first hour of wear. Normally close conformity is expected (HOLDEN and ZANTOS, 1981).

No significant change in corneal curvature was detected during the study (a finding in agreement with Hirji (1978)) nor , as may be expected, was any significant change in spectacle refraction detected.

The non-solution using group reported with more pronounced ocular symptoms than the solution using group. These included greater instability of vision, greater ocular discomfort and more ocular discharge. The greater corneal astigmatism in the non-solution using group may have contributed to their instability of vision. However,

the greater amounts of contact lens deposition in this group may have exacerbated their subjective ocular response. It may therefore be concluded that regular cleaning is important to the success of extended wear. This conclusion was also reached by Hirji (1978) and Iwasaka and Kosaka (1979).

The contact lens wearers reported a reduction of ocular discharge as the study progressed. This may have reflected ocular adaption to the lens, or a subjective patient adaptation to a constant level of ocular discharge.

During the first week of wear, statistically significant transient corneal swelling of 3.7% was observed in the lens wearing patients. This swelling has been reported by other workers (ZANTOS and HOLDEN, 1978; SCHOESSLER and BARR, 1980). Furthermore, a significant decrease in apparent oxygen basal uptake rate was reported at the end of the first week (PARRISH, 1981). This might be the "reactive depression" described by Hill (1979), who attributed the reduced cellular oxygen consumption to oedema.

Corneal oedema can be provoked by oxygen insufficiency (De ROETTH, 1950; LANGHAM and TAYLOR, 1956; POLSE and MANDELL, 1970 (b)), changes in tear tonicity (MISHIMA and MAURICE, 1961 (b); KLYCE and RUSSELL, 1979) changes in tear pH (CARNEY and HILL, 1975), mechanical trauma (MAURICE and GIARDINI, 1951 (a)), exogenous toxins (DOHLMAN, 1971; HOGAN and ZIMMERMAN, 1962) and changes in temperature (KLYCE ET AL., 1977). Hirji (1978) demonstrated that the anterior corneal surface has an adequate supply of oxygen in the presence of a Sauflon T.M. 85 lens. However, it is accepted that initial periods of contact lens

wear are invariably accompanied by increased lacrimation (MANDELL and HARRIS, 1968; UNIACKE and HILL, 1970; STONE and PHILLIPS, 1972; MANDELL, 1974). The tonicity of unstimulated tears is approximately 0.95% of equivalent saline (MASTMAN ET AL., 1961), whilst the tonicity of stimulated tears is similar to that of plasma which is 0.89% of equivalent saline (MISHIMA and MAURICE, 1961 (a),(b); MISHIMA, 1965; TERRY and HILL, 1977). Since the epithelium acts as a near-perfect semi-permeable membrane (COGAN and KINSEY, 1942 (a),(b); MAURICE, 1951, 1961), the tonicity change resulting from increased lacrimation would be expected to produce corneal swelling of 3-4% (von BAHR, 1949; MANDELL and HARRIS, 1968). This agrees with the values obtained in the study. The subsequent reduction of swelling may reflect the return to normal lacrimation and osmolarity (HARRIS and MANDELL, 1969; UNIACKE and HILL, 1970).

Reduced oxygen tension at the anterior corneal surface may account for a small component of the swelling recorded during the adoptive period (ROSCOE and HILL, 1980), despite the findings of Hirji (1978). According to Wilson and Fatt (1980) and O'Leary et al. (1981), such swelling would be confined almost entirely to the stroma.

No further significant change in corneal thickness was observed during the study. A small degree of central corneal thinning (1.8%) was observed in the control and non-solution using groups at the two month data point, but this was considered to be a random occurrence, since it did not indicate any trend. Similarly, thinning at 30° inferiorally and nasally noted at the 6 month data point was considered to be a random occurrence and not indicative of seasonal change, in which case simultaneous central thinning would have been

observed (HIRJI, 1978).

The contact lens wearing groups presented with a significant increase in the corneal touch threshold at the 3 and 6 month data points (15.4%). Hirji (1978) reported an increase in the corneal touch threshold of 100%. The difference between these two findings probably reflects the difference between the experimental techniques used, inter-individual variations (MILLODOT, 1976 (a)), variations of humidity (MILLODOT and LARSON, 1967), the effect of apparent basal oxygen uptake rate measurements, and recovery during a period of about 10 minutes between lens removal and aesthesiometry (MILLODOT, 1974). The nature of the study dictated that apparent basal oxygen uptake measurements had to be obtained immediately the contact lens was removed (PARRISH, 1981). This was done by applying an oxygen sensor to the anterior surface of the cornea, and caused the aforementioned ten minute delay as well as affecting the accuracy of the subjective response to perceive the corneal sensitivity threshold. A few controls (numbers 6,8,13,19,25) presented with significant random reductions in corneal sensitivity. This further illustrates the adverse effect the oxygen uptake readings had on the sensitivity. However, despite the limitations of the joint study, the reduced corneal sensitivity recorded shows a trend similar to that found by Hirji (1978), suggesting similar ocular responses.

Large quantities of acetylcholine (ACh) and Choline acetyltransferase (an enzyme involved in the synthesis of ACh) have been observed in the corneal epithelium (von BRUCKE ET AL., 1949; HELLAUER, 1950; FITZGERALD and COOPER, 1971; GNADINGER ET AL., 1973; MINDEL and MITTAG, 1976, 1977). Hellauer (1950) suggested that this cholinergic

system is involved in corneal sensitivity. Prolonged reduction in oxygen tension at the corneal anterior surface, as caused by lid closure (e.g. at night), leads to reduced corneal sensitivity in man (MILLODOT and O'LEARY, 1979), and in rabbits suppresses choline acetyltransferase (ChAc) activity (MINDEL and MITTAG, 1978) and reduces ACh (MINDEL ET AL., 1979). The subsequent recovery of sensitivity (MILLODOT and O'LEARY, 1979) has been found to be analogous to ACh recovery when the eyelids were reopened (MINDEL ET AL., 1979). Furthermore, both the corneal sensitivity (BOBERG-ANS, 1955; COCHET and BONNET, 1960; MILLODOT and LARSEN, 1969) and the level of ACh (HELLAUER, 1950; MINDEL and MITTAG, 1977) are greater in the centre of the cornea than at the periphery, by a ratio of approximately 2:1. If corneal sensitivity is related to ACh levels, as suggested above, then reduced levels of corneal ACh would be expected to have occurred during the study (the relevance of reduced ACh levels to the formation of micro-epithelial cysts will be discussed in Chapter 6).

However, the hypothesis of Hellauer (1950) has not not been conclusively demonstrated, and it is possible that the increased corneal sensitivity thresholds result from a reduction of the efficiency of corneal nerves in reduced oxygen environments (WRIGHT, 1946; SCHEINER, 1946).

Greater frequency and severity of vital staining was observed in this study than reported by Hirji (1978). Of the two contact lens wearing groups, the non-solution users stained more often and more severely with fluorescein. This could be due to the greater amounts of contact lens deposition observed in the non-solution using group. Recently Hamano et al. (1979) attributed the high frequency of staining in

extended wear patients to variations in the geometrical shape of the lens due to evaporation. In the normal rabbit eye, Kikkawa (1972) related the fluorescein staining to the normal process of corneal epithelial desquamation, while in the normal human eye vital staining was considered to be due to inadequate blinking, lid pressure, and unknown changes in the tear components (KORB and KORB, 1970). Possibly, these factors combine, where desquamating cells are prematurely sloughed off the surface, leaving small areas containing disrupted cells which would take up vital stain. Conversely, when changes in environmental conditions cause an increase in airborne particles, the contact lens might be expected to act as a shield. This may be illustrated by the greater incidence of staining observed in controls than lens wearers at the same visits, for which the causative factor was considered to be an increase in airborne particles (LARKE, 1981).

The rapidity with which deposits were formed on all the lenses (one month) posed certain problems. Firstly a high incidence of lens breakage was associated with the monthly cleaning. Secondly, lens deposits have been proposed as the antigen reponsible for giant papillary conjunctivitis (GPC) (ALLANSMITH ET AL., 1977). Recently this has been substantiated by observations of GPC sufferers, for great numbers of degranulated mast cells have been found in the superficial layers of the tarsal conjunctiva, indicating that the antigen enters from the environment (ALLANSMITH and BAIRD, 1981). Emphasising the problem in soft lens wear, Allansmith and Baird (1981) observed that in a sample of GPC sufferers the soft lens wearers' response was more severe than the hard lens wearers'. Whatever controls the occurrence

of GPC or an individual's susceptibility to it remains unknown. However, it does appear that GPC is not related to an atopic history (ALLANSMITH ET AL., 1977), nor to specific lens deposits (FOWLER ET AL., 1979). In the present study no patients presented with GPC, suggesting either that the factors necessary to provoke GPC were absent, or that the study was not long enough for formation or detection of papillae.

An unexpectedly high percentage of red eye responses occurred during the study. The symptoms were first noted, by all patients, in the middle of the night, as reported also by Holden and Zantos (1979). This meant that an average of seven hours elapsed before examination. Therefore, as various degrees of oedema were observed in all patients with this response, it may be postulated that their greatest levels of oedema were much higher. Corneal swelling of 6 to 12% has been reported in the closed eye contact lens wear situation, and was attributed to reduced oxygen tension at the anterior corneal surface, and the production of isotonic tears (SARVER ET AL., 1981; FATT and CHASTON, 1981). However, the factor or factors which provoke the red eye response are unknown. Fichman et al., (1978) found a high incidence of red eyes amongst users of enzymatic cleaners. However, the results from this study do not support the thesis of Fichman et al. (1978) as no enzymatic cleaners were used. Furthermore, equal numbers of solution users and non-solution users had the response, suggesting that the lens cleaners used in this study were not connected with the responses. Factors such as the incidence of red eyes and the associated levels of pain and distress which were reported are serious contraindications for the cosmetic wear of extended wear lenses.

There is no wholly satisfactory system for recording vascularization in contact lens wearers. Photography does not reveal the overall response whilst ranked observations do not give detailed information of early vascular changes. However, the results from both biomicroscopical and photographic observations have given similar indications of vascular changes. The greatest degree of injection, recorded at 3 months by ranking, was not reflected by photographic recording of apparent lumen width, which was equal or even greater at 6 months. The two observations may not be contradictory, however, because injection at 3 months was possibly indicative of a mild inflammatory response due to mechanical irritation caused by the contact lens, whereas the sustained on increased lumen width may have been a more profound response to a vaso-stimulating factor. Signficant increases in both photographic and biomicroscopic indications of limbal depth are also likely indicators of vaso-stimulating activity.

Fluorescein angiography, a valuable technique for observing blood vessels and active inflammatory responses (BRON and DIXON, 1972; VANNAS, 1980), has been used to observe the limbus in patients with extended wear lenses (VANNAS, 1980; MACKMAN ET AL., 1981). Vannas (1980) noted that the majority of patients showed early limbal blood vessel growth of less than 1mm, which did not progress even after 3 years of wear. The minority, however, with early growth of greater than 1mm, were found to be more likely to develop further vascularization with the resulting cessation of lens wear (VANNAS, 1980). Similarly, it was noted in this study that some patients presented with a much greater vascular response than the majority. However, assessing whether these patients would neovascularize with prolonged contact lens

can only be conjecture.

Vascularization is a pronounced complication of soft lens wear (SLATT and STEIN, 1979; KAUFMAN, 1979; MOMOSE, 1978; KOHRI, 1979). However, the factor or factors which stimulate vessel proliferation in soft lens wear, as in vaso-proliferation disorders, have yet to be determined. The author is in agreement with a report (BRON and DIXON, 1972) which concluded that

"We cannot yet report if the gel lens itself represents a stimulus to corneal neovascularization. Compared to the microcorneal lens, however, the gel lens has many characteristics which could stimulate neovascularization.

The entire cornea is covered, and the tear flow beneath the lens is minimal because of the relatively tight fit which is needed to keep the lens in position. This encourages hypo-oxygenation of the superficial cornea which is not completely relieved by the somewhat greater permeability of the gel lens to oxygen compared to the methylmethacrylate lens."

Peripheral corneal oedema, suggested to be a pre-requisite for neovascularization (ASHTON and COOK, 1953; MAURICE ET AL., 1966; IMRE and PAL, 1968) was not detected in this study. Conventional pachometry has limitations and would not detect oedema of less than 2%, or oedema situated in the extreme periphery of the cornea surrounding the limbal blood vessels. Therefore, such oedema may have been present but undetected. In the extreme periphery, where the contact lens is thickest, oxygen supply to the cornea would be expected to be lowest (DECKER ET AL., 1978) and, therefore, oedema would be greatest (NATSUMEDA and FATT, 1981). Certainly when oedema is

detected in the soft lens wearer centrally, peripheral oedema is also present (MANDELL, 1976; SANDERS ET AL., 1975; HIRJI, 1978). However, detection of the low levels of oedema, which may have been present in this study, requires the development of new techniques.

The straddling of the limbus by the lens may cause mechanical trauma with the action of blinking (BRON and DIXON, 1972). Should such trauma cause damage to the endothelium of limbal blood vessels then this in itself could cause vascular changes (FISHMAN ET AL., 1975; SHOLLEY ET AL, 1977 (b)).

Lactic acid, a product of anaerobic glycolysis, has been implicated as the vaso-stimulating factor in the cornea (IMRE, 1966, 1969). Raised lactic acid levels have been noted adjacent to the limbus prior to vascularization (LEVENE ET AL., 1963; CSERNOVA, 1968), and in the cornea and tears of rabbits wearing contact lenses (DREIFUS ET AL., 1970; RUBEN and CARRUTHERS, 1972). In anoxic conditions a build up of lactic acid in the cornea has been demonstrated by several workers (SMELSER, 1952; MAURICE and RILEY, 1970; KLYCE ET AL., 1977), although the levels reported by Wigham (1978) were somewhat varied. Since extended wear lenses are known to reduce the oxygen level in the environment at the corneal interface (HIRJI, 1978; ROSCOE and HILL, 1980), an increase in lactic acid concentrations in the cornea of low order may have occurred in this study. However, the increased concentration of lactic acid was presumably less than that observed in complete anoxia, and whether this concentration was sufficient for vasostimulating activity is not known.

Prostaglandins (PG's), in particular PG E_1, have recently been proposed

as the inducers and regulators of corneal vascularization (BENEZRA, 1978 (b), 1979 (a), (b)). It is possible that PG's could be released by the conjunctiva surrounding the limbus in the event of a mild allergic-type response (BHATTACHERJEE and EAKINS, 1974; NISHIOKA and KATAYAMA, 1978; BENEZRA, 1978 (a); PLISKIN ET AL., 1980), where the antigen responsible for the reaction could emanate from the lens deposits (ALLANSMITH ET AL., 1977). As a result increased vascular permeability (BEITCH and EAKINS, 1969; KALEY and WEINER, 1971 (a); PEDERSON, 1980), vasodilation (STARR, 1971; WHITELOCKE and EAKINS, 1973), oedema (VANE, 1976) and possible leucocyte imigration (HIGGS and YOULTEN, 1972) may ensue. However, the role of PG's in corneal vascularization still has to be clarified.

Leucocytes have been frequently observed in the vascularizing cornea and were therefore, proposed as important factors in the vascular response (COLLIN, 1973; FROMER and KLINTWORTH, 1975 (a), (b)). While observing the corneal vascular response to lymphocytes it was noted that a sustained stimulus was required to promote neovascular growth (BENEZRA, 1978 (b); EPSTEIN and HUGHES, 1981), a factor which could be provided in extended wear. Leucocytes may enter the cornea if their chemo-attractants, such as plasmin (WEIMAR, 1957; KENYON ET AL., 1979; O'FLAHERTY and WARD, 1979) on lysosomal fraction of the cornea (HATVANI, 1980) were released as a result of tissue injury (BERMAN ET AL. 1980; HATVANI, 1980). However, the concentrations of chemo-tactic factors in the cornea during lens wear would be small. Alternatively, if frequent minor injuries occurred with lens wear, a build up of cellular debris and such chemo-tactic factors would form beneath the contact lens. These factors would be in close contact with the anterior corneal surface, and if present in sufficient concentrations

could initiate the chemotactic migration of leucytes. However, the role of the leucocyte in corneal vascularization is not clear. Release of vasostimulating factor or factors by the invading leucocyte is one possible mechanism but the factor or factors have yet to be identified, although PG's are one possibility (HIGGS and YOULTEN, 1972).

In conclusion, the objective findings of significant vascular changes, micro-epithelial cysts and cases of acute red eye response cast considerable doubt on the recommendation of extended wear contact lenses for purely cosmetic applications.

CHAPTER 6

Micro-epithelial Cysts

Section 6:1 Introduction

At the eighteenth week of the study a male subject in group "B" presented with symptoms of discomfort in the right eye. The conjunctiva was mildly congested and showed evidence of superficial erosion in the lower nasal quadrant. This area stained with 2% fluorescein sodium and the visual acuity was reduced to 6/7.5 from a previously corrected 6/5. The contact lens previously worn on the eye was observed to be damaged, and it was considered that the ocular signs and symptoms were secondary to the damaged lens. However, further examination revealed the presence of a number of small, discrete, unstained micro-epithelial cysts, present in the lower portion of the cornea in both eyes. After this observation six further subjects were examined and all showed presence of similar bodies. As a consequence, all the remaining contact lens wearing subjects were carefully examined at the six month data point, and a number of slit lamp photomicrographs were taken with the apparatus previously described (HOLDEN ET AL., 1978) (Plate 6.1). Of all the subjects examined only one patient did not present with micro-epithelial cysts at the six month data point, but two weeks after termination of contact lens wear, micro-epithelial cysts had developed in both the patient's eyes. All the patients were asymptomatic. The severity of the cysts observed in the patients varied considerably, and was ranked into five levels (Section 6:2) (Appendix 6.1), to aid monitoring. Although the presence of cysts was not considered to be particularly serious, their presence in all subjects caused the study to be abandoned and lens

wear was stopped (HUMPHREYS ET AL., 1980; HUMPHREYS and LARKE, 1980). Previous workers also reported the presence of micro-epithelial cysts in hard contact lens wearing patients (HODD, 1964; SAMPSON ET AL., 1969; SABELL, 1979) and in both day and extended wear soft contact lens patients (BROWN and LOBASCHER, 1975; RUBEN ET AL., 1976; JOSEPHSON, 1979; de CARLE, 1978), but from these reports no suggestions as to their pathogenises emerged.

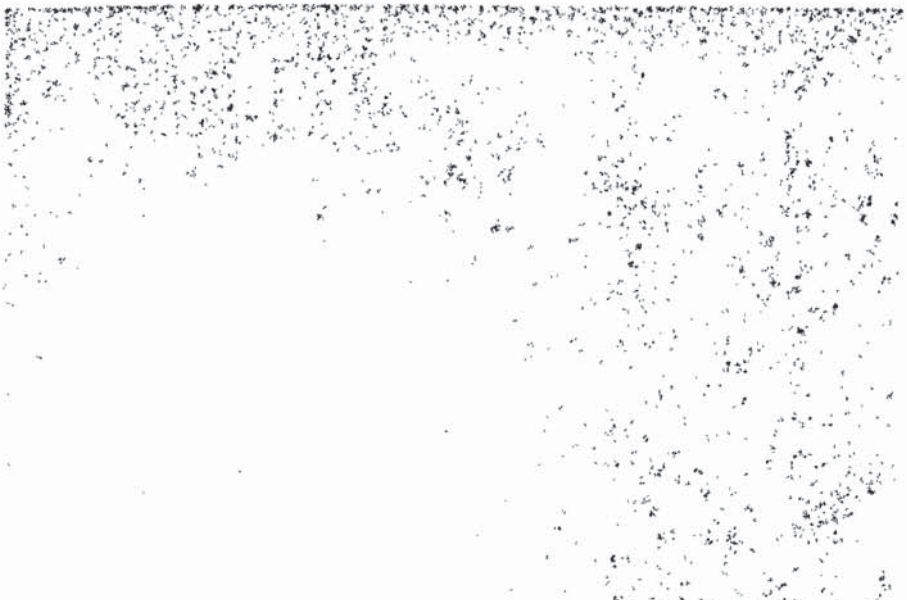


PLATE 6.1

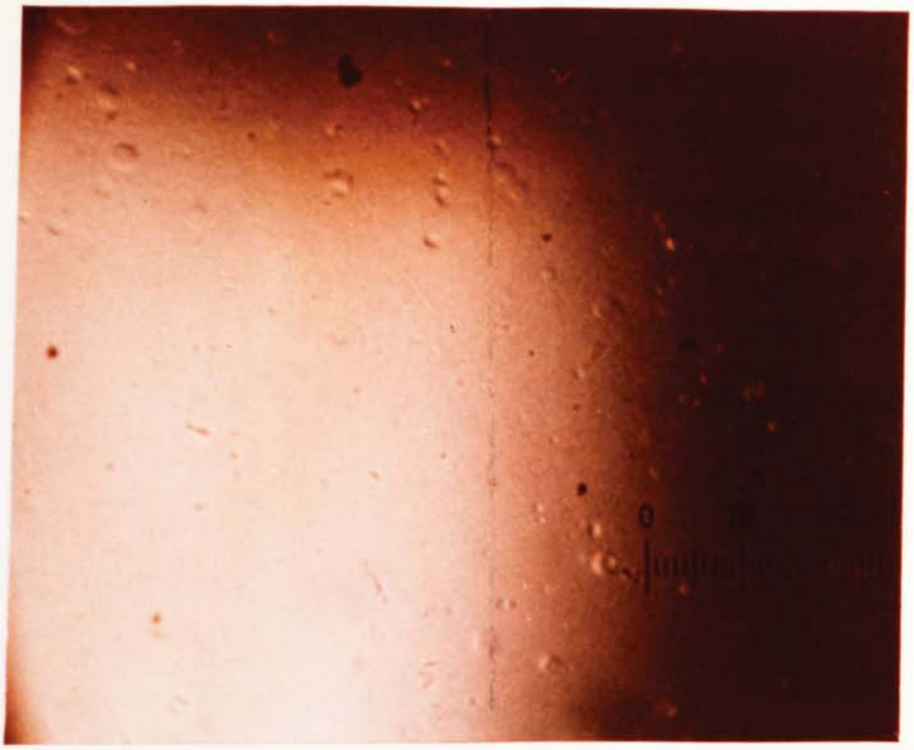
MICRO-EPITHELIAL CYSTS : CHARACTERISTIC TYPES

(a) Micrograph of a non-solution using patient. The three characteristic types of micro-epithelial cysts are seen here : "bubble-like", "crater-like" and "dimpled". The cysts vary in size from approximately 5 to 35 microns in diameter.

(b) One of the largest cysts observed among the study patients, measuring approximately 90 microns in diameter.

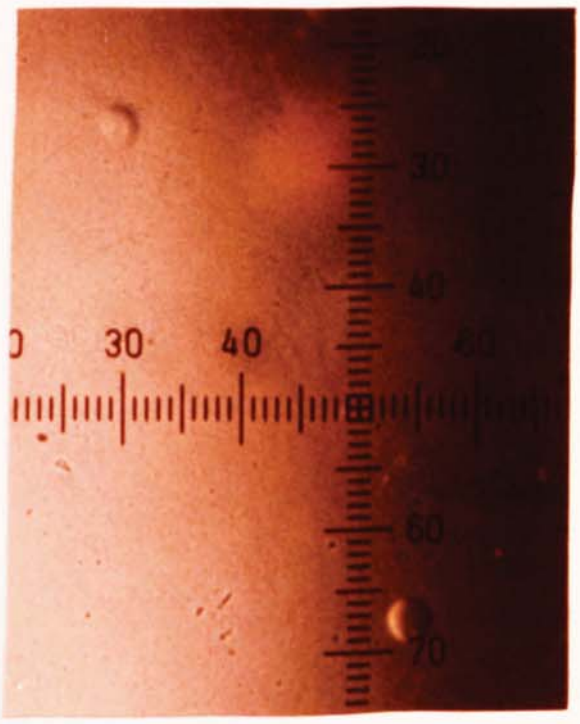
(c) Two examples of the commonest appearance of cysts encountered during the study. The larger of the two has a diameter of approximately 60 microns.

For each micrograph 10 scale divisions = 140 microns.



(a)

(b)



(c)

PLATE 6.1

Section 6.2 Classification of Micro-epithelial Cysts

When the classification of micro-epithelial cysts was considered, the fact that they were an unknown entity caused certain problems. As the distribution and density of micro-epithelial cysts appeared to be the most variable features it was decided to rank them into five grades. The following classification was adopted for recording micro-epithelial cysts:

Distribution: defined as the area of the cornea containing micro-epithelial cysts, which was expressed as a percentage of the total corneal surface area. "1" denoted an affected area estimated to be of less than 20% of the total corneal surface, "2" denoted an affected area estimated to be greater than 20% but less than 40% of the total corneal surface, "3" denoted an affected area estimated to be greater than 40% but less than 60% of the total corneal surface, "4" denoted an affected area estimated to be greater than 60% but less than 80% of the total corneal surface and "5" denoted an affected area greater than 80% of the total corneal surface (Table 6.2) (Appendix 6.1).

Density: defined as the surface area of the micro-epithelial cysts, themselves, within the boundary of the affected region to the surface area of the cornea, also within the boundary of the affected part of the cornea, in which micro-epithelial cysts are absent. The severity of the density of cysts within the boundary of the region affected was expressed as a percentage and ranked at five levels identical to those for distribution (Table 6.2) (Appendix 6.1).

TABLE 6.2

Classification of Severity of Corneal Micro-Epithelial Cysts

ITEM	DISTRIBUTION	DENSITY
A. Distribution: The area containing micro-epithelial cysts is expressed as a percentage of the total corneal surface area.	1 Distribution < 20% 2 20% < Distribution < 40% 3 40% < Distribution < 60% 4 60% < Distribution < 80% 5 80% < Distribution	
B. Density: The ratio of the surface area of micro-epithelial cysts to the surface area of the affected cornea, expressed as a percentage.		1 Density < 20% 2 20% < Density < 40% 3 40% < Density < 60% 4 60% < Density < 80% 5 80% < Density

Section 6.3 Clinical observation and monitored recovery of micro-epithelial cysts in humans

After the initial examination of micro-epithelial cysts the patients were observed at weekly intervals, where possible, to examine, photograph and to classify their rate of recovery. Because this period coincided with the summer vacation, patient attendance was poor and the results that were obtained were incomplete (Appendix6.3(a)).However, observations of their recovery revealed various characteristics:

1. Micro-epithelial cysts were translucent and best viewed with marginal retro-illumination (Plate 6.3(a)), which revealed their characteristic "dimpled", "crater-like" and "bubble-like" appearances (BROWN, 1971) (Plates 6.1 and 6.3 (b)).

2. The region occupied by the cysts was in the majority a crescent or half-moon area aligned with the lower pupillary margin (Fig 6.3 (i)(a)). It was noted that cysts may or may not be present in the periphery.

3. One week after contact lens wear was terminated (Fig 6.3 (i)(b)), the affected area appeared to be larger and more densely packed with cysts, some of which appeared grey and opaque. Also grey infiltrates were noted in the affected region, amongst the cysts. Again cysts were sometimes observed in the periphery of the cornea.

4. Three weeks, after contact lens wear was terminated (Fig 6.3 (i)(c)), the infiltrates were no longer present. The density of cysts was reduced to its original degree or less, and again cysts were noted in the periphery of some patients.

5. Five weeks after contact lens wear was terminated (Fig 6.3 (i)(d)) the central area of the cornea was almost devoid of cysts. If present, they were approximately a tenth the size of the cysts seen originally.

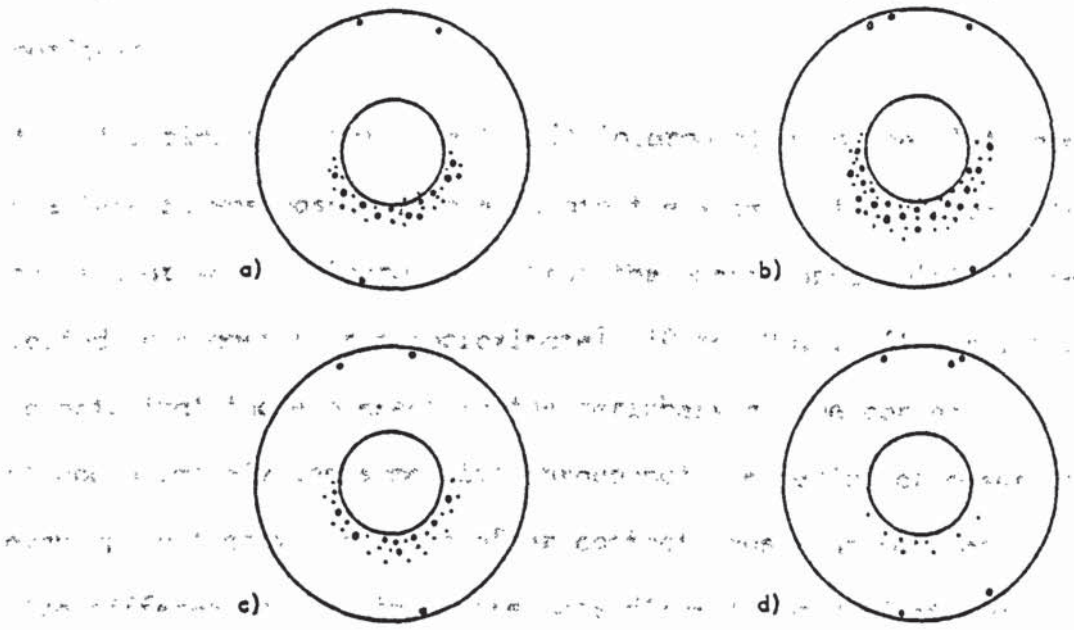
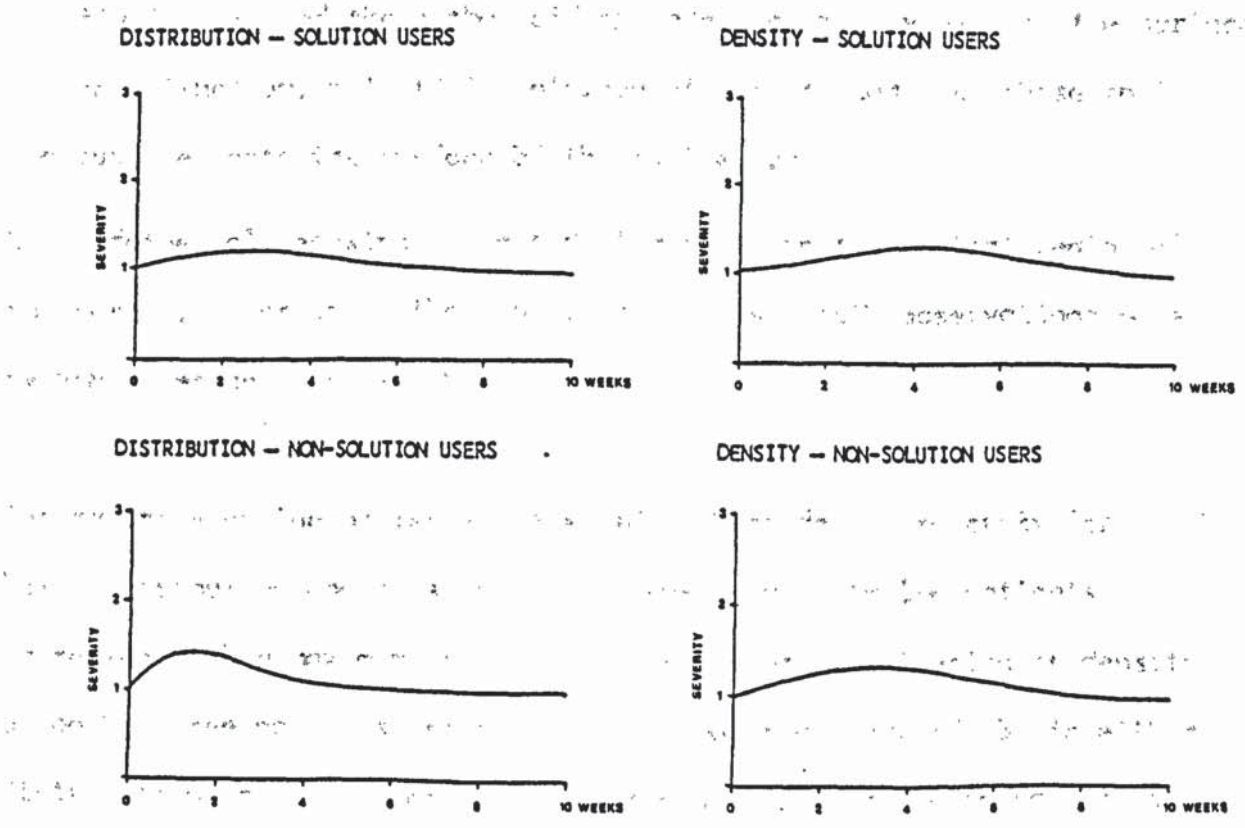


Figure 6.3 (i)

Schematic Representation of the Distribution of Micro-epithelial Cysts

a) Initial observation and termination of contact lens wear. b) One week later. c) Three weeks later. d) Five weeks later.



RATE OF RECOVERY OF MICRO-EPITHELIAL CYSTS FOR PATIENTS WITH AN INITIAL SEVERITY OF GRADE I

FIGURE 6.3(ii)

Again, cysts were observed in the periphery of the cornea in some patients.

6. Utilizing the graticule (E 18) incorporated in the slit lamp eyepiece it was possible to estimate the size of the micro-epithelial cysts that were photographed. From the photographs obtained the cysts varied in diameter from approximately 10 to 90 μ . It was interesting to note that those present in the periphery of the cornea remained at approximately the same size throughout the period of observation, even up to twenty two weeks after contact lens wear had ceased. They also differed in that they were more disc-like and flattened in appearance; central cysts were more spherical in appearance.

7. The cysts appeared to originate in the basal layers of the epithelium and migrate forwards, in agreement with Holden and Zantos (1979). The number of cysts that stained with fluorescein was relatively few, and those that did appeared to be very near to the surface of the epithelium, but still contained within it, and also those that had ruptured onto the surface of the epithelium.

8. Endothelial bedewing was noted, typically in the central region of the cornea, inferior to the pupil, in agreement with observations made by McMonnies and Zantos (1979).

The majority of the patients presented with grade "1" severity for both distribution and density, thirty one in all, twelve patients presented with a maximum grade of "2" in either distribution or density or both, three patients presented with a maximum grade of "3" in either distribution or density or both and only one patient presented with a maximum grade of "4" in either distribution or density or both (Appendix 6.3 (a)). The average period of recovery for each initial

grade of severity (taken as the maximum grade observed in either eye) was obtained (Table 6.3), where the recovery point was defined as the third consecutive visit at which the cornea appeared normal, with the minimal observed appearance of micro-epithelial cysts ("minimal", because even up to twenty two weeks after termination of contact lens wear micro-epithelial cysts were still observed by the author (Appendix 6.3 (a)), who also observed them in non-contact lens wearing subjects (Section 6.6 (ii)). Therefore, from these averages obtained (Table 6.3), the mean recovery time for all the patients was nine weeks.

The rate of recovery for an initial severity of grade "1" in both groups (Fig 6.3 (ii)) illustrated the observation that after contact lens wear was terminated the severity of the cysts appeared to increase. As previously mentioned, the same appearance of micro-epithelial cysts, as seen at the five week interval after contact lens wear was terminated, was also noted in some patients in the control group, and in untrained patients (Section 6.6 (ii)). This was seem to indicate that at this level micro-epithelial cysts may be physiological, and would also account for the rate of recovery graphs remaining at grade "1" instead of reaching zero, where no cysts would have been present.

Patients with an initial severity of grade "2" appeared to follow a similar trend to those with grade "1" severity, but because of the limited data no further observations were possible. Patients with initial severities of grades "3" and "4" showed a slightly different recovery pattern. One week after contact lens removal there appeared to be a marked reduction in both density and distribution of cysts.

The recovery thereafter followed a similar trend to that described for grades "1" and "2". Again, because of the small sample size and the limited amount of data that was collected, a more detailed assessment of the recovery was impossible.

After termination of the project, one interesting case emerged. The patient in group "A" presented with a reduction in corneal sensitivity, which was noted to be slightly less at the six month data appointment than the baseline value, but thereafter markedly decreased even though contact lens wear had been terminated. Other signs that the patient presented with were endothelial bedewing, pigment deposits on the endothelial surface, endothelial bullae and micro-epithelial cysts, which were large (of the order of 70μ) (Plate 6.3 (b)), and confined to the superior and inferior mid-periphery and periphery of the cornea in both eyes. All these signs were reported to be characteristic of the combined corneal dystrophy of Fuchs' (McTIGUE, 1967; SCHROEDER and HANNA, 1971). Coincidentally, a girl of eighteen years of age was reported to have developed Fuchs' corneal dystrophy as a direct result of twelve months of extended contact lens wear (TRAEGER, 1979), where her vision was reduced to light perception in both eyes. In view of this report (TRAEGER, 1979) and the signs observed in the patient on this study, the patient was referred to a consultant Ophthalmologist, who felt that the patient did not have Fuch's dystrophy, but advised careful monitoring of the cornea and corneal sensitivity until each factor had reached its original baseline level (CREWS, 1979). Indeed, the patient recovered fully, after a period of six months (Appendix 6.3 (b)).

TABLE 6.3

Mean recovery periods of micro-epithelial cysts

for each grade of severity

Ranked Severity	Number of Eyes	Average Recovery Time (weeks)
1	67	8.9
2	19	8.9
3	3	12.0
4	1	11.0
5	0	0.0

The severity was ranked using the classification described previously (see Table 6.2).

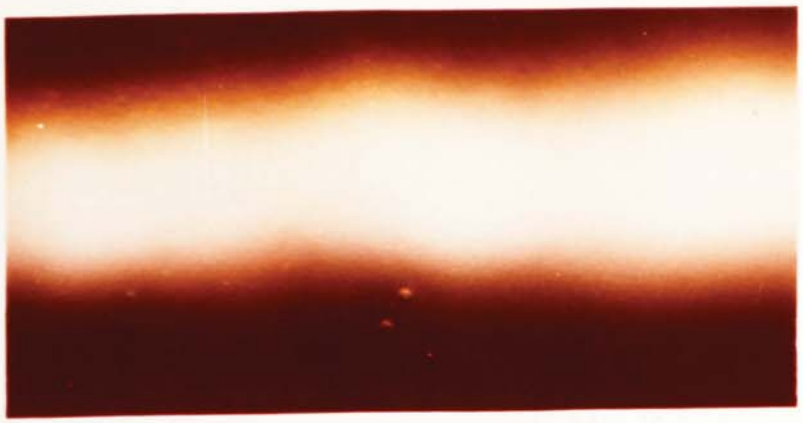
If the grades of severity of distribution and density differed in an eye, then the more severe grade of the two was noted for this table.

PLATE 6.3 (a)

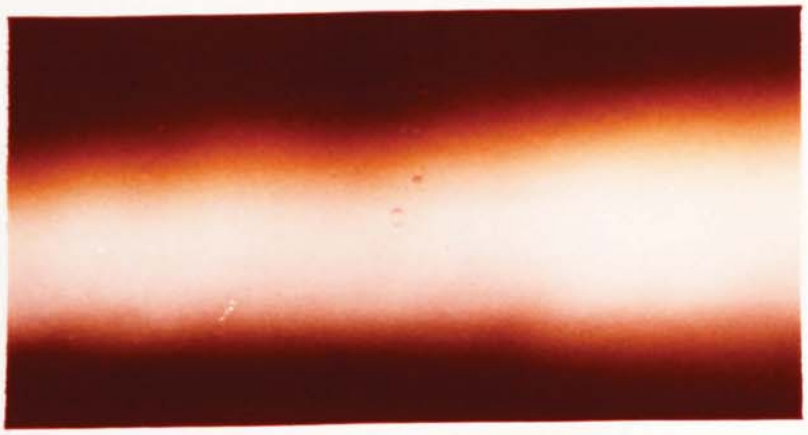
MICRO-EPITHELIAL CYSTS : ILLUMINATION TECHNIQUES USED

Marginal retroillumination (a) enabled the cysts to be viewed in greater detail than did direct retroillumination (b), or indirect retroillumination (c). (Approximate magnification 30x).

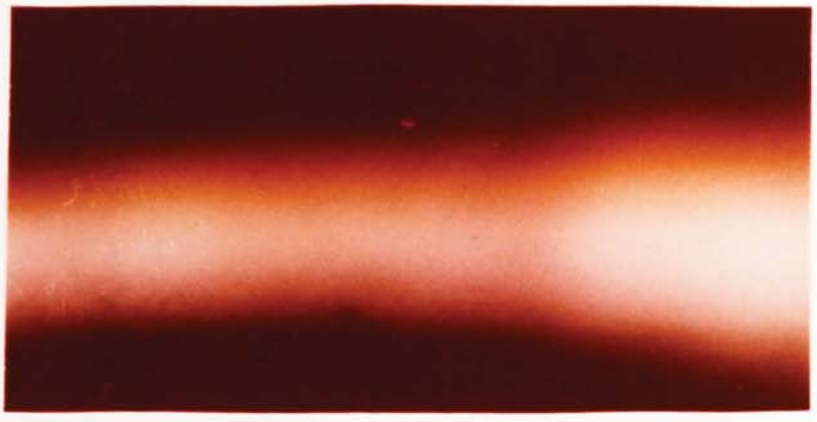
Note: The photographic process used to produce the plates have caused a reduction from the original quality.



(a)



(b)



(c)

PLATE 6.3 (a)

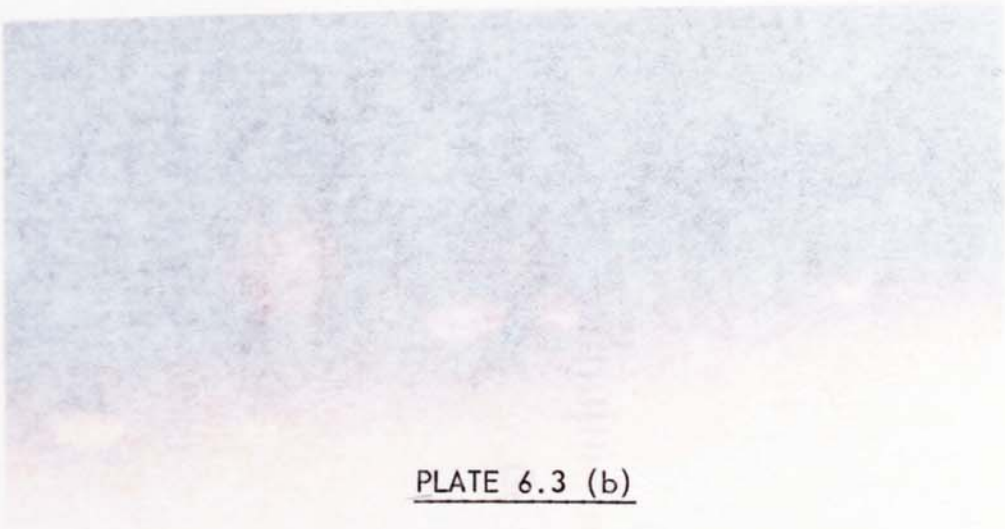
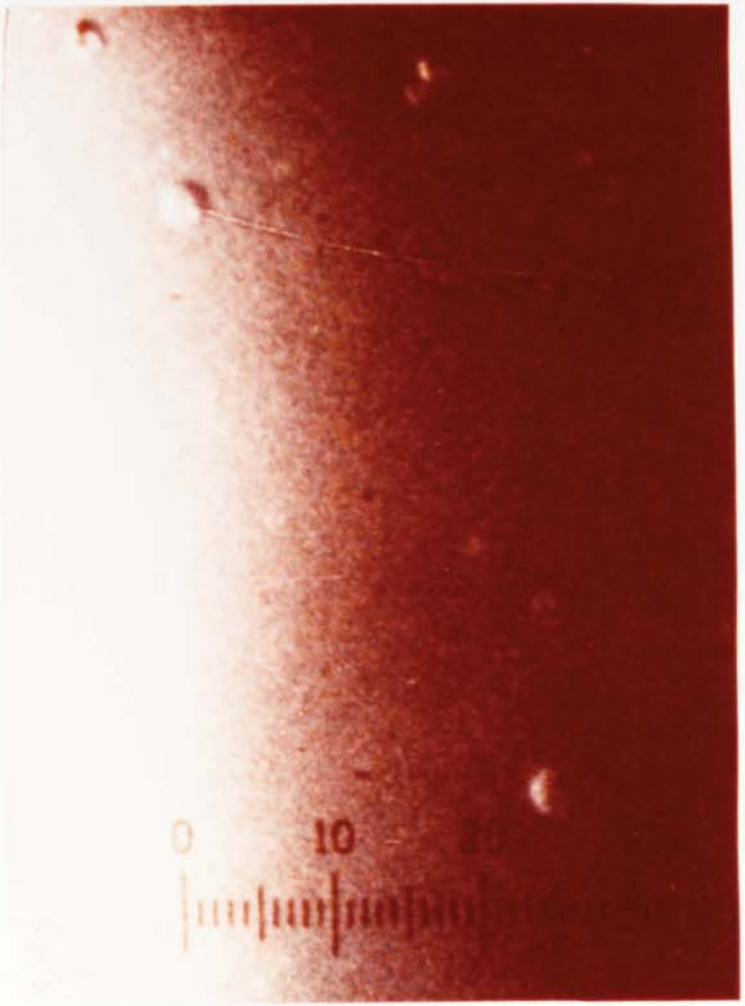


PLATE 6.3 (b)

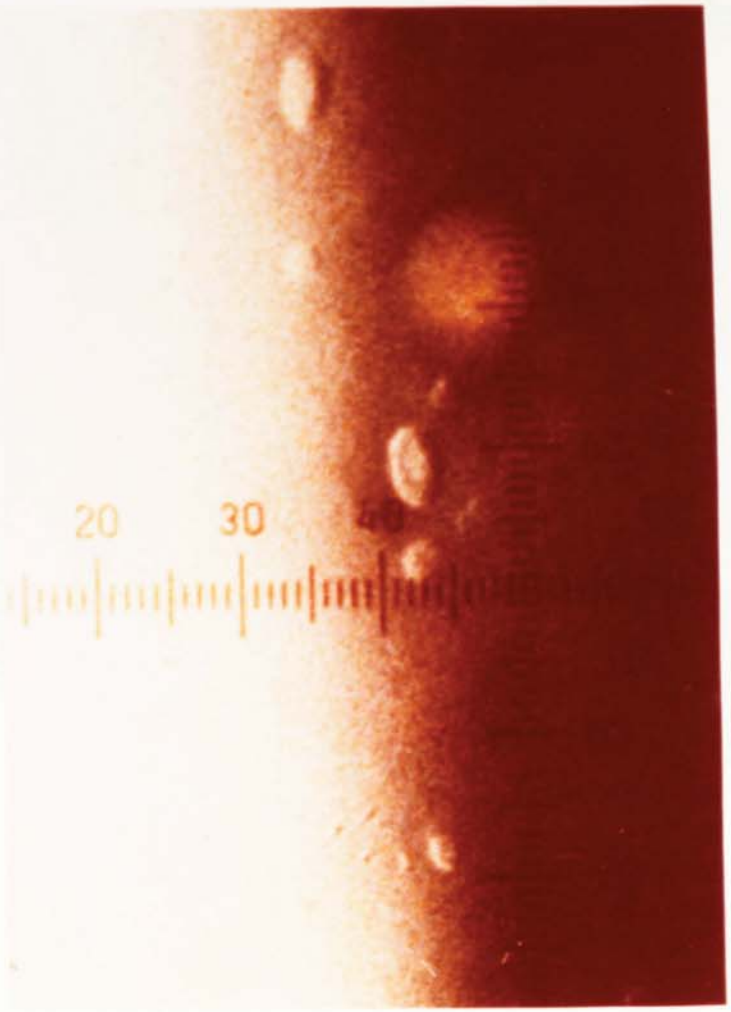
MICRO-EPITHELIAL CYSTS

(a) Two characteristic "dimple-like" cysts positioned in the top left hand corner of the picture. Processes of reproduction and magnification have resulted in a loss of clarity in the lower of these two cysts, which measures approximately 50 microns in diameter (Ten scale divisions = 140 microns).

(b) Micro-cysts observed in the patient presenting with signs of Fuch's corneal dystrophy. The largest cyst in the photograph measures approximately 75 microns vertically (Ten scale divisions = 140 microns).



(a)



(b)

PLATE 6.3 (b)

Section 6.4 The Microcystic Dystrophies : possible indicators of the pathogenises of Micro-epithelial Cysts in Extended Wear

Even though micro-epithelial cysts have been observed in most forms of contact lens wear for some time (HODD, 1964; SABELL, 1979; RUBEN ET AL., 1976; BROWN and LOBASCHER, 1975; JOSEPHSON, 1979; DE CARLE, 1978; HOLDEN and ZANTOS, 1979; ATHANASSIADIS and RUBEN, 1979), their aetiology is still unknown. While considering their pathogenises it was decided to examine the histological results from the cystic disorders of the corneal epithelium.

Epithelial microcysts were an observed feature of many corneal disorders, including the recurrent erosion syndrome (VOGT, 1921, 1930; CHANDLER, 1945; GOLDMAN ET AL., 1969; KHODADOUST ET AL., 1968; TRIPATHI and BRON, 1972), Meesman's epithelial dystrophy (PAMEIJER, 1935; MEESMAN and WILKE, 1939; BÖCK, 1941; BÜRKI, 1946; SNYDER, 1963; STOCKER and HOLT, 1955; KUWABARA and CICCARELLI, 1964; BURNS, 1968), Cogan's microcystic dystrophy (COGAN ET Al., 1964, 1974; GUERRY, 1965, 1966; KING and GEERAETS, 1972; RODRIGUES ET AL., 1974; LAIBSON and KRACHMER, 1975), bullous keratopathy (COGAN, 1940, 1941; DUKE-ELDER and LEIGH, 1965) and the combined dystrophy of Fuch's (McTIGUE, 1967; SCHROEDER, 1971). Their presence was also noted in a complex of superficial corneal lines and associated superficial corneal disorders (BRON and BROWN, 1971). The aforementioned corneal disorders were clinically observed and described by Bron and Tripathi (1973) (Table 6.4), and the cysts present in Meesman's dystrophy appeared to have the closest resemblance to those seen in extended wear. However, histologically these various conditions (VOGT, 1921; MEESMAN and WILKE, 1939; COGAN ET AL., 1964) were reported to appear

TABLE 6.4

Characteristics of Corneal Cysts

CLINICAL FEATURES	EPITHELIAL CYSTS OF THE CORNEA			
	BULLOUS KERATOPATHY	MEESMANN'S DYSTROPHY	RECURRENT EROSION	COGAN'S DYSTROPHY
Size (microns)	20-75	10-50	15-100	20-900
Shape	Globular; ovoid fused 	Globular 	Globular; ovoid conglomerate 	Globular; elongated 
Contour	Smooth or irregular	Smooth	Smooth or irregular	Smooth
Content	Empty	Debris+	Debris+	Debris++
Intervening epithelium	Cloudy	Faint haze	Clear or cloudy	Geographical opacity
Slit lamp: Focal	Clear in cloudy ground	Opaque flecks	Opaque flecks or masses	Large opaque masses
Retro	Clear cysts	Clear cysts: some debris	Some clear cysts many with debris	Diffuse debris
Staining: Rose Bengal	++	+	+	-
Fluorescein	++	+	+	-

Note: Accompanying the above, thinning of the tear-film and symptoms are present

After Bron and Tripathi (1973)

identical (TROBE and LAIBSON, 1972; RODRIGUES ET AL., 1974; BRODRICK ET AL., 1974, 1976).

Meesman's corneal dystrophy, a rare form of familial dystrophy of the corneal epithelium, was first described clinically by Pameijer (1935), and later was pathologically studied by Meesman and Wilke (1939) who found an abundance of glycogen in the corneal epithelium. However, later authors (BÖCK, 1941; BÜRKI, 1946; SNYDER, 1963; STOCKER and HOLT, 1955; KUWABARA and CICCARELLI, 1964) were unable to identify the glycogen deposits originally described by Meesman and Wilke (1939). Kuwabara and Ciccarelli (1964) noted that glycogen was present in cells above the basal layer, but attributed this to the rapid turnover of the epithelial cells, and contrary to Meesman and Wilke (1939), they found that the cysts consisted of cellular debris. The observation of a "peculiar substance" that had accumulated in some of the basal cells was also made by Kuwabara and Ciccarelli (1964), which was later supported by Burns (1968), who found a similar substance in the epithelial basement cells. Burns (1968) went on to suggest that this "peculiar substance", which he could not positively identify, was probably deposited in the corneal epithelial cells while under the influence of an "inducing factor" in the superficial corneal stroma. This "inducing factor" was suggested to be in part responsible for the thickened multilaminar B.M. (BURNS, 1968), noted in some patients with Meesman's dystrophy (KUWABARA and CICCARELLI, 1964; BURNS, 1968). Burns (1968) further postulated that this "peculiar substance" led to cell death and cyst formation in the epithelium, with rapid regrowth of the epithelium.

Cogan's microcystic dystrophy (COGAN ET AL., 1964), an apparently

dominant hereditory dystrophy (LAIBSON and KRACHMER, 1975), was characterised by microcysts consisting of lacunae in the epithelium containing pyknotic nuclei and cellular debris. The cysts were observed to move forward in the epithelium, where spontaneously, they would evacuate themselves and give rise to punctate erosions (COGAN ET AL., 1964). Cogan's microcystic was also characterized by an anomalous mid-epithelial B.M. (COGAN ET AL., 1964, 1974; GUERRY, 1966; KING and GEERAETS, 1972; RODRIGUES ET AL., 1974) which displayed a few excrescences into the basal epithelium (WOLTER+FRALICK, 1966), while some patients were reported to have areas with a thickened multilaminar B.M. and other areas with an incomplete B.M. (KING and GEERAETS, 1972; FOGLE ET AL., 1975). Guerry (1966) described a map-like appearance in Cogan's microcystic dystrophy and attributed this to the presence of the anomalous B.M., a thesis later supported by Levitt (1971) and Dark et al. (1973). The precise mechanism of the microcyst formation (or more correctly "pseudo microcyst" as the cyst walls were apparently formed by surviving cells around it (COGAN ET AL., 1974)) is still in dispute. Among the theories that were put forward were those of Cogan et al (1974) and Rodrigues et al (1974). Cogan et al. (1974) postulated that the mid-epithelial B.M. interfered with the normal exteriorization of maturing cells by preventing desquamation, thus causing the cells to become clustered together, after which they would undergo disintegration forming mycrocysts. From histological observations on fingerprint dystrophy, Rodrigues et al. (1974) noted that the anomalous B.M. comprised two layers of basal cells that had come together base to base. Rodrigues et al. (1974) suggested that this could be due to a preceding minute epithelial looseness (produced either by a slight oedema of the basal cells or by migration of cells from the stroma into the subepithelial plane) which

would become attenuated into the more superficial epithelial layers so that two layers of basal cells may come together base to base, or due to an unnoticed abrasion, where the usual epithelial slide toward healing may override, with one edge continuing to grow over the everted, opposite edge of the epithelium. With this arrangement of the mid-epithelial B.M. it was suggested (RODRIGUES ET AL., 1974) that the desquamation of the cells into the enclosed space, beneath the B.M., formed a small cyst-like arrangement analogous to an "intra-epithelial" epithelialization. It was reported that the periphery of the cornea can produce a greater or lesser extent of multilaminar B.M. (FINE, 1972), but why excessive production in abnormal regions occurred is still not clear.

The knowledge of the aetiopathogenisis of recurrent erosion syndrome is also limited. From observations of cases which were precipitated by trauma, it was suggested that the B.M. over the traumatized area of the cornea was defective (GOLDMAN ET AL., 1969; KHODADOUST ET AL., 1968, FOGLE ET AL., 1975). An ultrastructural study of recurrent erosion syndrome (TRIPATHI and BRON, 1972) described the absence of hemidesmosomes, separation of the B.M. and a predominance of "pale" cells in the basal layer, which were suggested to represent intra-cellular oedema, but the authors were unable to substantiate the previous observations that reported a defective B.M. (GOLDMAN ET AL., 1969; KHODADOUST ET AL., 1968).

Hydrokeratopathy, at an intermediate stage, was described to be characterized by the appearance of many tiny vesicles or cysts, which were distributed throughout the oedematous epithelium (BRON and TRIPATHI, 1973; DUKE-ELDER and LEIGH, 1965) and which were observed

in cases of Fuch's combined dystrophy (SCHROEDER and HANNA, 1971; IWAMOTO and DE VOE, 1971; DUKE-ELDER and LEIGH, 1965). In Fuch's combined dystrophy the epithelium was noted to be oedematous, mostly in the basal layer, and it was suggested that subepithelial bullae were formed by the bursting and then coalescing of the oedematous cells (IWAMOTO and DE VOE, 1971).

A light and E.M. (electron microscopic) study which followed the clinical study previously mentioned (BRON and TRIPATHI, 1973), revealed the following features which were common to most specimens studied; cysts, "pale" cells and spongiosis (TRIPATHI and BRON, 1973). The "pale" cells were swollen in appearance, had a low cellular density and reacted poorly with stains, and it was suggested that they represented a state of intra-cellular oedema (TRIPATHI and BRON, 1973). It was further postulated that they were the precursors of the cysts, the intra-cellular oedema progressing and resulting in hydropic degeneration of the cell, with the eventual release of intra-cellular fluid, where the end-result would be cellular lysis with the formation of a cyst containing some cellular debris (TRIPATHI and BRON, 1973). Larger cysts, it was suggested (TRIPATHI and BRON, 1973), may be formed by the coalescing of microcysts or by the disintegration of a group of "pale" cells. In conclusion, Tripathi and Bron (1973) suggested that oedematous processes play a dominant role in the morphogenisis of cysts, whether it was caused by endothelial or epithelial dysfunction.

Later clinical work by Brown and Bron (1976 (a), (b)) supported an earlier report, which described a relationship between recurrent epithelial erosion and Cogan's microcystic dystrophy (BRON and BROWN,1971)

and they further added that map-like changes were also associated (BROWN and BRON, 1976 (b)). The common ultrastructural basis of those disorders (COGAN ET AL., 1974; RODRIGUES ET AL., 1974; BRODRICK ET AL., 1974; DARK, 1977) was the deposition of an abnormal or excessive fibrillo-granular protein, which accumulated deep to the basal cells and in the respective cases of fingerprint and microcystic dystrophies, was also found at the mid-epithelial level enveloped in B.M. (COGAN ET AL.,1974; RODRIGUES ET AL., 1974; BRODRICK ET AL., 1974). Dark (1977) suggested that recurrent epithelial erosions observed in cases of bleb dystrophy of the cornea, resulted from shearing of this fibrillo-granular protein which was deposited between the B.M. and Bowman's layer, as he found the B.M. and hemidesmosome system to be normal.

From further work it was suggested that cyst formation represented a process whereby the corneal epithelium may extrude degenerating cells, a type of phagocytosis, although a true phagosome was probably not formed (BRODRICK ET AL., 1974). A more recent report from Brodrick (1979) described the rapid evolution, probably precipitated by aphakic surgery, from a clinically normal cornea to the typical appearance of Cogan's microcystic dystrophy with fingerprint lines. It was suggested from this observation (BRODRICK, 1979) that the fundamental disorder was probably that of a disturbance in the metabolism of the basal cells, which resulted in the formation of subepithelial material responsible for epithelial adhesion problems and fingerprint lines and so stimulating the formation of cysts (BRODRICK, 1979).

The origins and mechanisms of cyst formation in extended wear are still unknown, however, certain factors are predominant:

1. Extended wear contact lenses may cause subtle changes in the corneal epithelium and/or P.O.T.F.

2. "Minor" abrasions during contact lens wear are relatively common among soft contact lens wearers. Whether daily or extended wear.

Micro-epithelial cysts may not in themselves be serious, but Ruben (1979) suggested that a proportion may progress to sub-epithelial fibrillar changes with eventual involvement of Bowman's layer and corresponding reduction in vision, which, in view of the previously mentioned report of an induced Fuch's combined dystrophy (TRAEGER, 1979) was considered a possibility too serious to ignore.

Section 6.5 Rationale for Further Investigation

The unexpected occurrence of micro-epithelial cysts presented the author with a phenomena, associated with contact lens wear, which had been already reported in the literature (HODD, 1964; RUBEN ET AL., 1976; BROWN and LOBASCHER, 1975; JOSEPHSON, 1979; DE CARLE, 1978; HOLDEN and ZANTOS, 1979), but which, to date, had not been studied in any depth. Following on from the study, one of the most logical steps to take, in an attempt to determine the aetiopathogenisis of contact lens induced micro-epithelial cysts, would be the selection of a suitable experimental model in which the cysts could be induced and then studied histologically and ultrastructurally. From the work already discussed on the pathogenisis of the microcystic dystrophies (KUWABARA and CICCARELLI, 1964; BURNS, 1968; COGAN ET AL., 1964, 1974; GUERRY, 1966; KING and GEERAETS, 1972; RODRIGUES ET AL., 1974) it would appear that the formation of cysts was mainly due to abnormalities of the B.M. and possibly the metabolism of the basal cells of the corneal epithelium. The rabbit corneal epithelium and B.M. was shown to be structurally very similar to that in humans (ISHIDA, 1958 (a),(b): TENG, 1961, 1962; KAYE and PAPPAS, 1962; JAKUS, 1961; PRINCE, 1964) and was therefore considered as an experimental model. However, there were also many reported differences between rabbit and human cornea, including the greater apparent importance of the rabbit corneal epithelium in the maintenance of corneal hydration than in the human cornea (DOANE and DOHLMAN,1970), and also that after partial epithelial removal the human epithelium recovered faster than the rabbit epithelium (MISSOTEN and MAUDGAL, 1977; PRINCE, 1964; KAYES and HOLMBERG, 1960). In view of the fact that the rabbit has been used extensively in research of the cornea (UNIACKE and HILL, 1972; VAN DER

HEYDEN ET AL., 1975; KLYCE ET AL., 1973; LOWTHER and HILL, 1973; DE ROETTH, 1950; SRINIVASAN and EAKINS, 1979; KAYE and PAPPAS, 1962; NORN, 1980; DOANE and DOHLMAN, 1970), from which a great deal is known about the metabolism and structure of the rabbit cornea, plus the fact that a more suitable experimental model was not obtainable, the rabbit was chosen as the model for additional studies on micro-epithelial cysts.

Further research into micro-epithelial cysts in human corneae was more problematical. Initially, histological observation of graft tissue from contact lens wearing patients (courtesy of Birmingham Eye Hospital) was considered. However, few patients prior to keratoplasty wore contact lenses becasue they were observed to cause an increase in vascularization (BARRY, 1979), and the graft material if obtained would have been in all cases that of diseased eyes and the likelihood of obtaining discernible sections of cystic material was considered to be virtually impossible (BARRY, 1979). Therefore, this approach was abandoned. Continued observation in humans was, as a consequence, restricted to clinical observation only. It was considered that examination of a sample of contact lens patients could provide additional knowledge to that already gained about cysts in extended wear, as well as giving the incidence of micro-epithelial cysts and their severity in different forms of contact lens wear. It was also considered that a sample size of non-contact lens wearing people, similar to that obtained for each form of contact lens wear in the proposed survey, should also be observed to establish if micro-epithelial cysts in any form were physiological.

Section 6.6 Experimental Design and Procedure

6.6 i) Induction of micro-epithelial cysts in the rabbit cornea

Because of the limited resources and the time that was available, only a small number of rabbits (sandylops) could be used. In view of these restrictions and the additional factor of reported variations in corneal parameters between individual animals of the species, due to age (SORSBY and SHERIDAN, 1953; STONE and LEARY, 1957; KAYE, 1969) and weight (PRINCE, 1964; EDELHAUSER, 1974), it was felt that a paired organ study was most appropriate. The author was aware of the disadvantages of this type of study, as it was reported in the literature that mitotic activity differed between the two corneae of one animal (PRINCE, 1964) and that a sympathetic oedematous response was noted in the cornea of a unilateral contact lens wearer (TOMLINSON ET AL., 1981), which also may occur in the rabbit, both of which would cause variations in the control eye. All rabbits used were one year old Sandylops, weighing 5 to 6 Kg.

Initially a pilot study was set up to observe the effect of Sauflon T.M. 85 extended wear lenses on the rabbit cornea. Because of the larger dimensions of the rabbit cornea (DAVIS, 1929; PRINCE, 1964), with a radius of curvature reported to measure from approximately 7.3mm (DAVIS, 1929; PRINCE, 1964) to 8.25mm (SORSBY and SHERIDAN, 1953), it was estimated that a lens 16.0mm in diameter with a back central optic radius of 8.50mm would be required to provide an adequate fit. Indeed, the lenses fitted satisfactorily, with the usual optimum requirements of centralization, 2mm of movement on blinking and no apparent limbal blanching. The first rabbit was fitted with such a Sauflon T.M. 85

lens to its right eye only, the left was used as the control. Prior to lens wear the rabbit's corneae were carefully examined with the slit lamp for any apparent abnormalities, while the rabbit was held in position by an assistant. Once it was determined that both corneae were normal lens wear was commenced and the rabbit was examined weekly. At each weekly check the contact lens was scrutinized carefully for any defects, and then was removed. Both corneae were examined intensively for any signs of cystic changes, though the fact that the rabbit had a large oval pupil affected to a certain extent the success of micro-epithelial cyst detection which requires retro-illumination. At six weeks the cornea had developed a para-central opacification with associated vascularization (Plate 6.6 (i)(a)). No micro-epithelial cysts at the six week check were observed, or indeed had been observed during the course of this pilot study. After the six week check the animal was sacrificed by a firm blow to the neck, as described in the Universities Federation for Animal Welfare (1976) handbook. The eyes were enucleated immediately to avoid post-mortem changes (SHIMIZU, 1969) and fixed in buffered 10% Formalin. The active area of the right eye (Fig 6.6 (i)(a)) and a corresponding area in the left eye, were removed and embedded in paraffin wax (DRURY ET AL., 1967). Serial sections 5μ thick were cut, and stained with the Periodic Acid-Schiff (PAS) reaction (McMANNUS, 1946; PEARSE, 1959) as described in Carleton's Histological Technique (DRURY ET AL., 1967), with the exception that the nuclear stain used was Solochrome Cyanine R 0.2%. The sections were then dehydrated, cleared with xylene and mounted in DPX, composed of Distrene, a plasticiser and Xylene. Paraffin wax embedding was used because, if required, large numbers of serial sections could be obtained. Also PAS stain was used because it readily stains B.M.'s and glycogen (DRURY ET AL., 1967) which is present in the corneal

epithelium, and therefore would stain the areas which would most likely be abnormal. The sections were then viewed by light microscopy with the Olympus F.H.A. microscope, and photomicrographs were taken with the Zeiss photomicroscope. (Plate 6.6 (i)(a)).

The severe reaction of the first rabbit to the Sauflon T.M. 85 extended wear contact lens at six weeks indicated that the formation of micro-epithelial cysts, a relatively subtle change in the corneal epithelium, would take place within the first few weeks of extended wear. The second experimental rabbit was examined at 4 - daily intervals after commencement of contact lens wear because of the expected early appearance of micro-epithelial cysts. The procedure of fitting and examination for the second experimental rabbit was identical to the first. The first apparent observation of micro-epithelial cysts was only 16 days after the commencement of contact lens wear. Photomicrographs of the suspected area were taken with the Zeiss photo-slit lamp (Plate 6.6 (i)(b)), the Nikon T.M. photo-slit lamp being inoperative due to a flash unit fault. It was decided to prolong contact lens wear after this observation because of the uncertainty of their presence and apparent sparcity. Four days later no cysts were detected. After a further four days, however, many fine cysts were observed in two main regions ("B" and "C" in fig 6.6 (i)(b)) with an area of opacification ("A" in fig 6.6 (i)(b)) which corresponded to the initial observation of cysts at the 16 day examination. Photomicrographs of areas "B" and "C" were taken with the Zeiss photo-slitlamp (Plate 6.6 (i)(b)). The animal was sacrificed, by the same method as described before, and both eyes were enucleated. With the right eye stabilized and orientated correctly, each of the three areas required for sectioning were marked with a scalpal blade prior to fixation

in buffered 10% formalin. Areas "A", "B" and "C" were disected from the right cornea and a central full width area of the left eye was also removed, all were embedded in paraffin wax and serial sections 5μ thick were cut. All the sections were stained by the method previously described and observed with the Olympus F.H.A. microscope (Plate 6.6(i)(c)).

From the observations made on the second experimental rabbit it was apparent that the microcystic area rapidly developed to produce an area of corneal opacification. Therefore it was decided that in subsequent studies the rabbits would be examined more frequently, at 2 - day intervals, and that when the microcystic features were first sighted the rabbit should be sacrificed and the tissue fixed before any further changes could develop.

The third experimental rabbit was fitted, observed and monitored using the same procedures as before, and the subsequent slit lamp observations were carried out at 2 - day intervals. The first appearance of cysts was at the 14 day check (fig 6.6 (i)(c)), but because of circumstances beyond the authors control the animal could not be sacrificed. The following day, the same area was examined but no microcysts were present. Two days later microcysts were again observed in two different and adjacent areas (fig 6.6 (i)(d)). Photomicrographs were taken of the microcystic areas (unfortunately these were of poor quality due to animal movement, but the appearance of the microcysts strongly resembled those of rabbit 2 after 24 days of extended contact lens wear (Plate 6.6 (i)(b)), the animal was sacrificed, and the eyes enucleated. The area required for sectioning (fig 6.6 (i)(d) was excised, with a corresponding area from the left eye, and both were

fixed in buffered 10% formalin. The two corneal specimens were embedded in paraffin wax, serial sections 5μ thick were cut, stained and mounted using the same techniques employed previously. The sections were examined with the Olympus F.H.A. microscope and photomicrographs were taken with the Zeiss photo-microscope. (Plates 6.6 (i)(d))and 6.6 (i)(e)).

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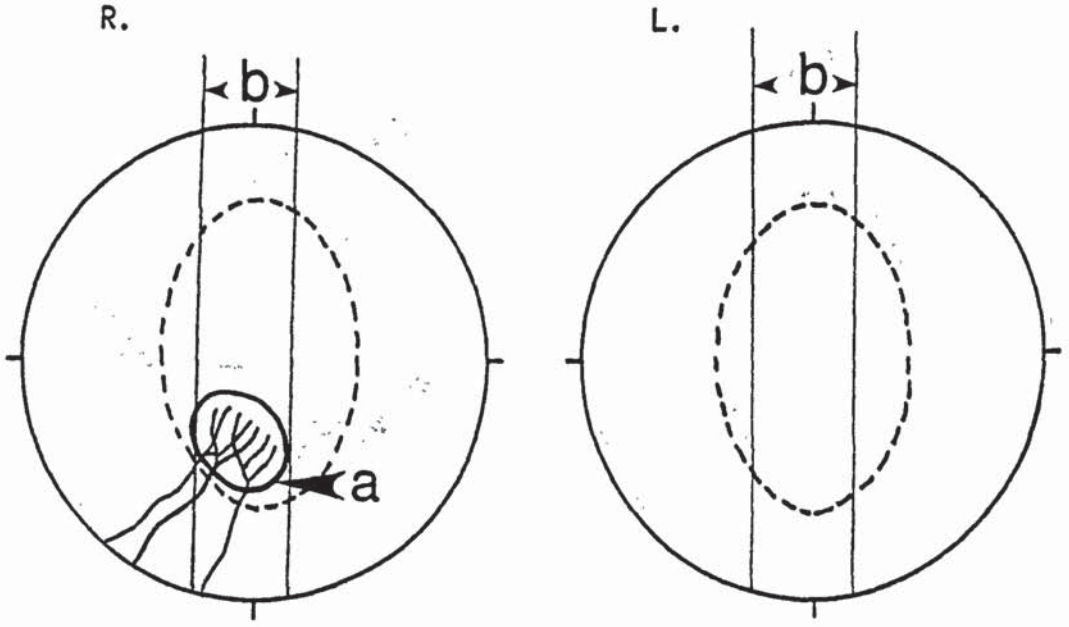
Soft Lens Research

MICRO-EPITHELIAL CYST RECORDING SHEET

Rabbit 1.

Date: 10/ 1 /80

	R	L
a) No micro-epithelial cysts present ✗ / b) Presence of micro-epithelial cysts ✓	✗	✗
c) Grade of severity of distribution	—	—
d) Grade of severity of density	—	—
e) Degree of involvement 1 = epithelial, 2 = stromal, 3 = endothelial	—	—
f) Area of corneal involvement		



a. Area of corneal opacification and associated vascularization.

b. Areas from which serial sections were taken.

Fig. 6.6(i)(a)

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MICRO-EPITHELIAL CYST RECORDING SHEET

Rabbit 2

Date: 18 / 2 / 80

a) No micro-epithelial cysts present ×
b) Presence of micro-epithelial cysts ✓

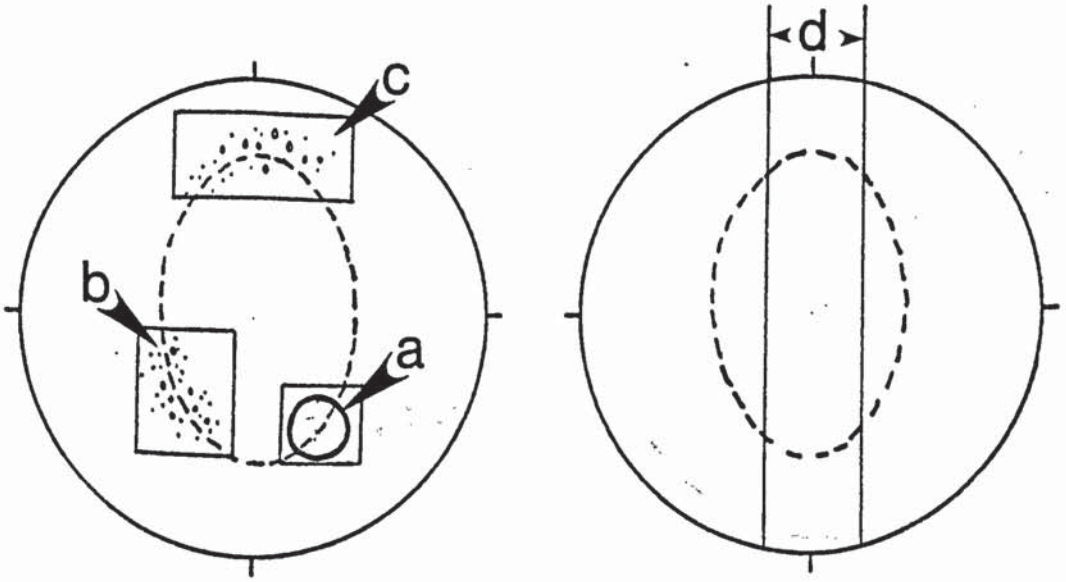
c) Grade of severity of distribution
d) Grade of severity of density

e) Degree of involvement
1 = epithelial, 2 = stromal, 3 = endothelial

f) Area of corneal involvement

R	L
✓	×
2	—
2	—
1	—

R. L.



a. Area of opacification.

b and c Micro-cystic areas.

The boxes indicate the areas "A", "B" and "C" which were sectioned.

d. Area sectioned in the control eye.

Fig. 6.6(i)(b)

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The Department of Ophthalmic Optics
Soft Lens Research

MICRO-EPITHELIAL CYST RECORDING SHEET

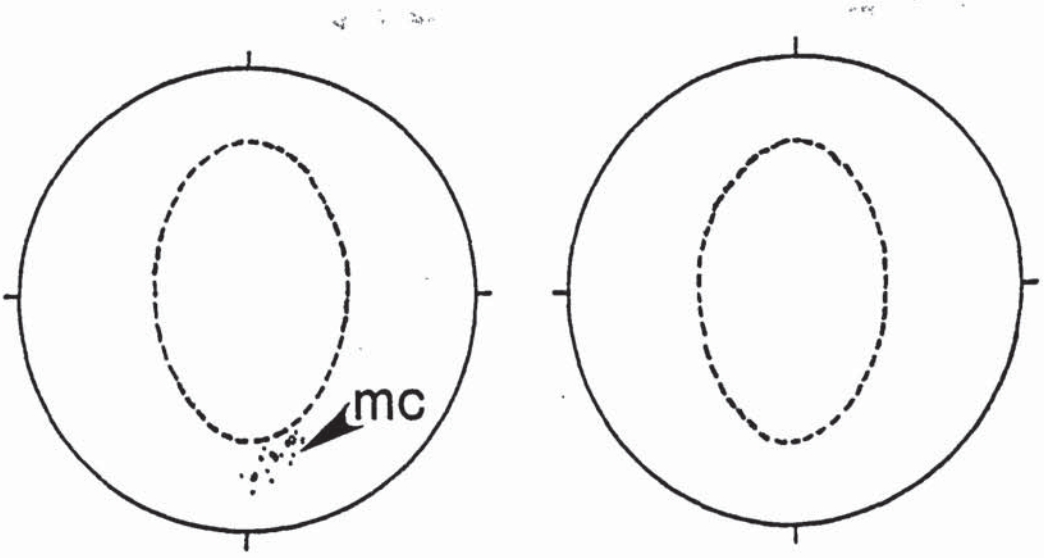
Rabbit 3

Date: 18 / 4 / 80

	R	L
a) No micro-epithelial cysts present ✕ b) Presence of micro-epithelial cysts ✓	✓	✕
c) Grade of severity of distribution	1	—
d) Grade of severity of density	1	—
e) Degree of involvement 1 = epithelial, 2 = stromal, 3 = endothelial	1	—

f) Area of corneal involvement

R. L.



mc. Micro-epithelial cysts.

Fig. 6.6(i)(c)

The University of Aston in Birmingham
The Department of Ophthalmic Optics
Soft Lens Research

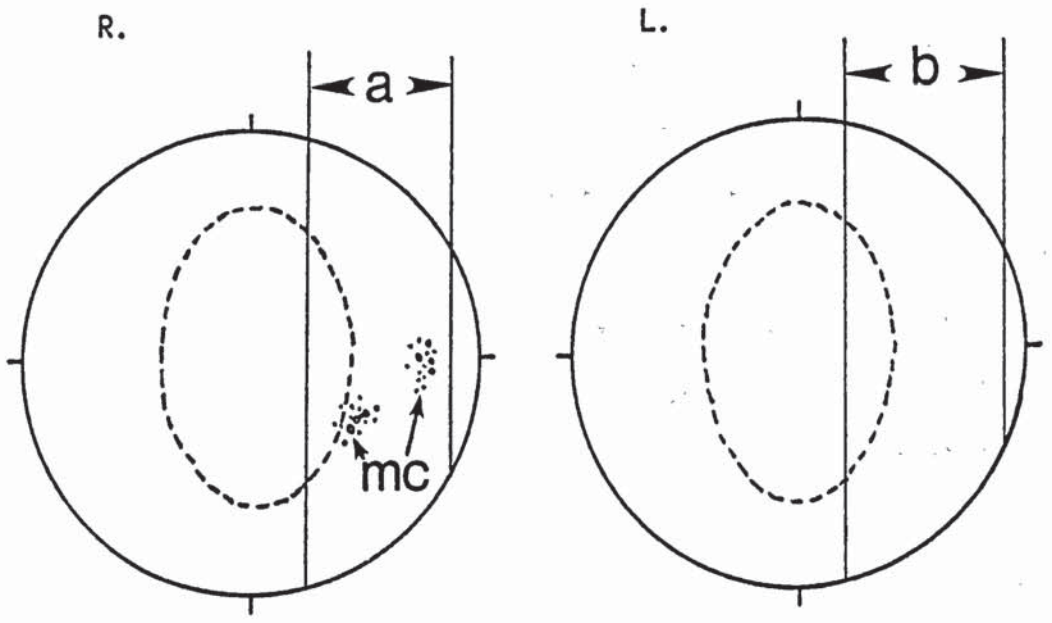
MICRO-EPITHELIAL CYST RECORDING SHEET

Rabbit 3

Date: 21/ 4 / 81

	R	L
a) No micro-epithelial cysts present ✗ b) Presence of micro-epithelial cysts ✓	✓	X
c) Grade of severity of distribution	1	—
d) Grade of severity of density	1	—
e) Degree of involvement 1 = epithelial, 2 = stromal, 3 = endothelial	1	—

f) Area of corneal involvement



mc. Two adjacent micro-cystic areas.

a. Area of cornea sectioned.

b. Corresponding area in the control eye sectioned.

Fig. 6.6(i)(d)

6.6 ii) Survey of the incidence of Micro-epithelial Cysts in various types of contact lens wear and in non-contact lens wearing patients

The contact lens wearing patients were observed by courtesy of Mr R Holmes and the Ophthalmic Optics Department at the University of Aston in Birmingham, both of which allowed the author to monitor and examine patients within their own clinics. Because of the wide variety of contact lenses that were fitted at the two clinics it was decided to categorise the patients viewed into three basic groups: hard, corneal contact lens wearers, daily wear soft contact lens wearers and extended wear soft contact lens wearers. From this type of categorization a qualitative assessment of differing cystic appearances between the three main forms of contact lens wear could be obtained. In addition to the classification adopted previously (Appendix 6.1) several other features were also monitored, which included a geographic description of the distribution of cysts, an estimate of the percentage of cysts that stained with 2% Fluorescein sodium, presence of oedema, presence of sub-epithelial infiltrates within the cystic region and the presence of any limbal blood vessel congestion or encroachment which could have been associated with the cystic areas (Appendix 6.6 (ii)(a)). These additional observations were made because it was reported (SABELL, 1979) that micro-epithelial cysts in hard lens wearers often correspond to 3 and 9 o'clock staining with some limbal engorgement, and also because of the author's own observations that extended wear soft lens wearers appeared to have fine cysts centrally, and/or occasional large clusters of cysts in the mid-periphery of the cornea, and often, few, but larger cysts in the periphery of the cornea. The author also noted that of the patients

monitored in the extended wear study, cysts, when observed seldom stained and were not accompanied by any detectable limbal changes.

For the contact lens wearing patients additional information on the type of lens worn, duration of contact lens wear and the cleaning procedure used by the patient were also monitored (Appendix 6.6 (ii)(b)).

In total 134 patients were observed, comprising 29 hard lens wearers, 72 daily soft lens wearers, 3 extended wear soft lens wearers and 30 non-contact lens wearers. The three extended wear patients were all aphakic and, therefore, in view of the fact that their corneae were abnormal, the observations made were treated with caution.

The non-contact lens wearing group comprised 19 controls and 11 untrained patients.

All the patients examined were between 18 and 40 years of age with the exception of the three extended wear patients who were between 60 and 65 years of age. To be included in this survey, each patient must have worn his/her lenses for at least six hours each day on a regular basis. Prior to the appointment each patient wearing soft lenses was requested to bring their spectacles because of the use of vital stain (2% Fluorescein sodium).

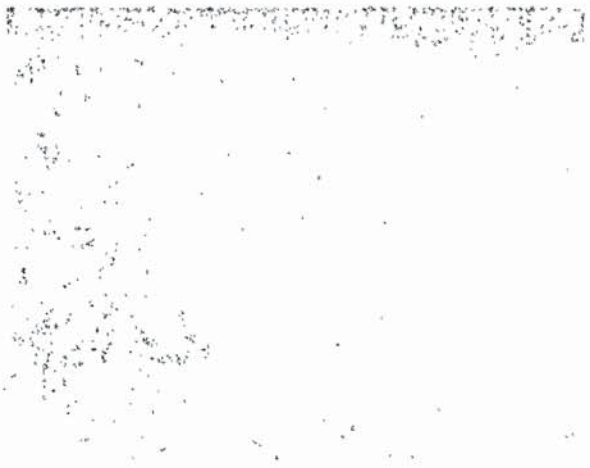
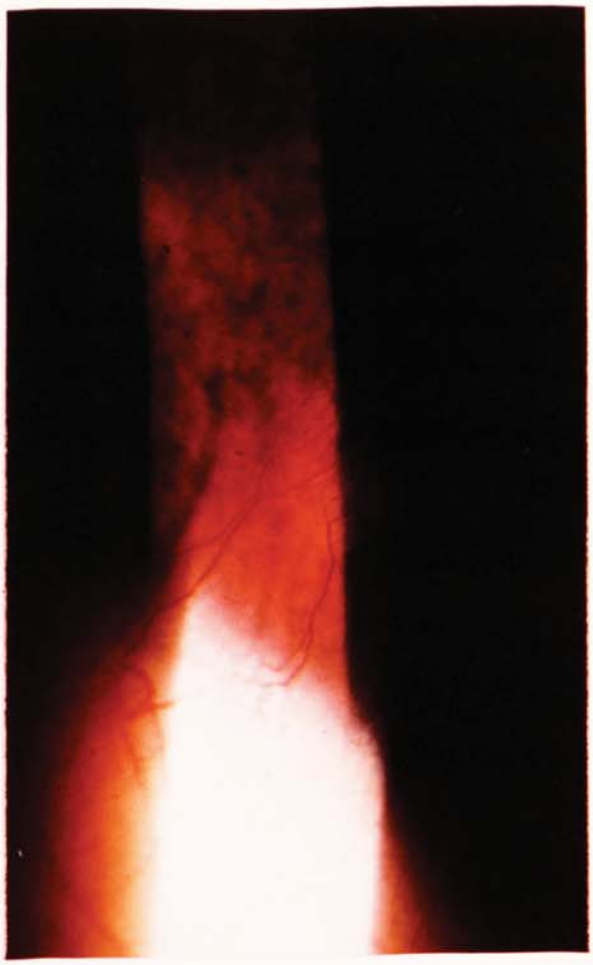


PLATE 6.6 (i)(a)

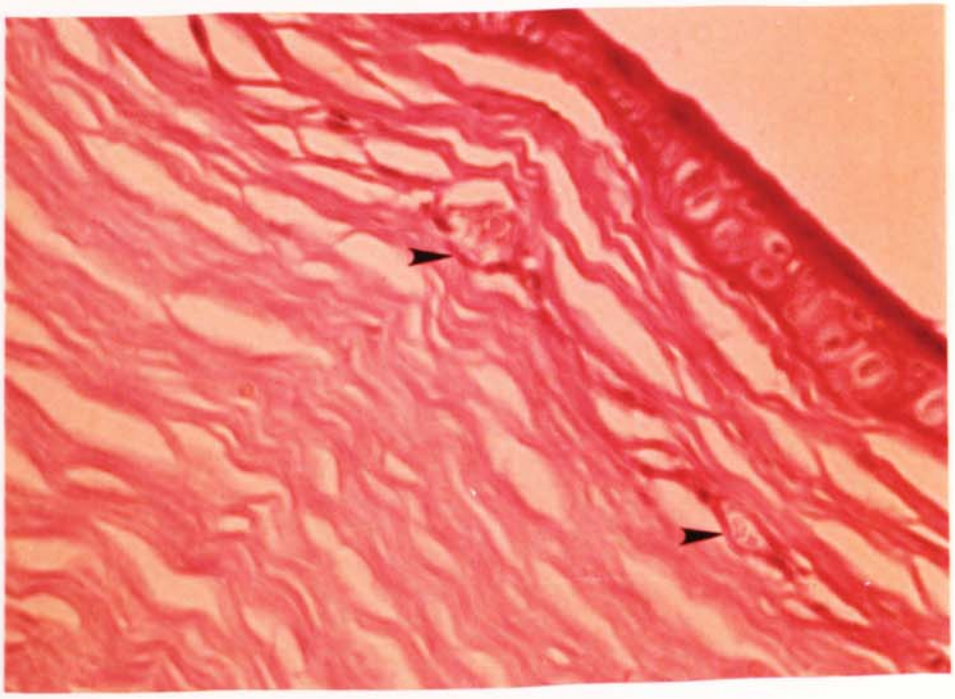
RABBIT 1 : AFTER 6 WEEKS OF EXTENDED CONTACT LENS WEAR

(a) Clinical appearance of the experimental eye, showing the opacified vascularized area.
(Approximate magnification 30x).

(b) Histological appearance of the same eye. The arrows indicate blood vessels situated in the superifical stroma.
(Approximate magnification 1350x, 5 micron section, Periodic Acid-Schiff stained.)



(a)



(b)

PLATE 6.6 i) (a)

PLATE 6.6 (i)(b)

RABBIT 2 : CLINICAL APPEARANCE OF MICRO-EPITHELIAL CYSTS AFTER EXTENDED CONTACT LENS WEAR

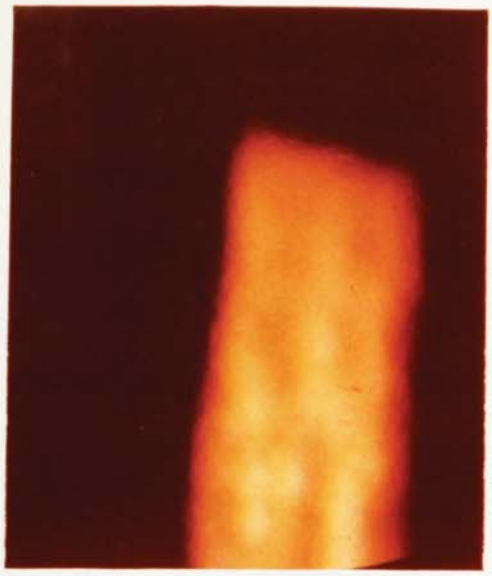
Cysts of various sizes can be seen at the borders between the illuminated areas and the dark backgrounds.

(a) micro-epithelial cysts observed after 16 days of extended wear in clinically designated area "A" which later became opacified.

(b) Cysts observed after 24 days of extended wear, corresponding to the clinically designated area "C".

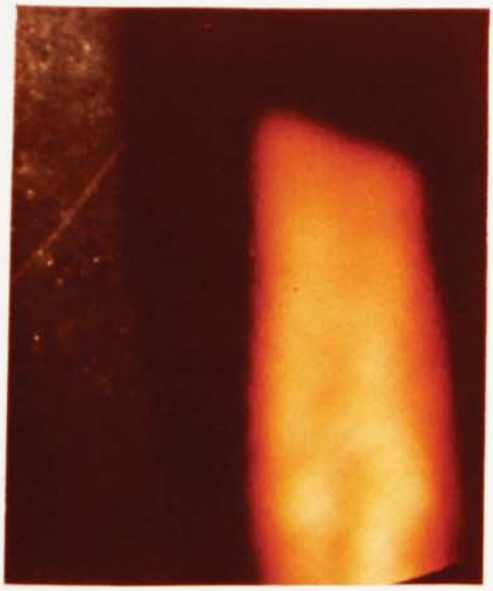
(c) and (d) Micrographs of cysts observed after 24 days of extended wear in the area clinically designated as "B".

(In each micrograph the approximate magnification is 30x).

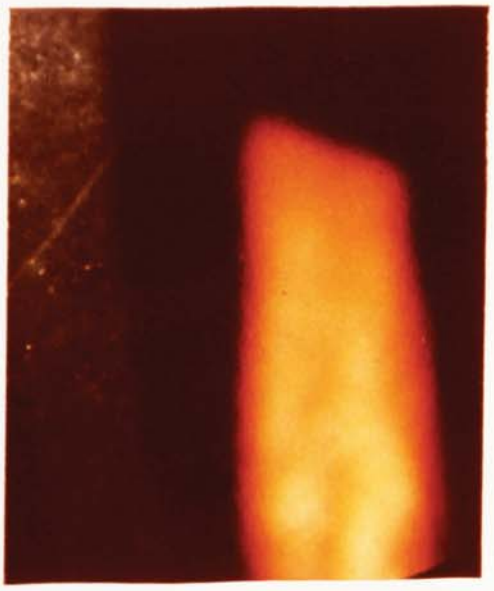


(a)

(b)



(c)



(d)

PLATE 6.6 i) (b)

PLATE 6.6 (i)(c)

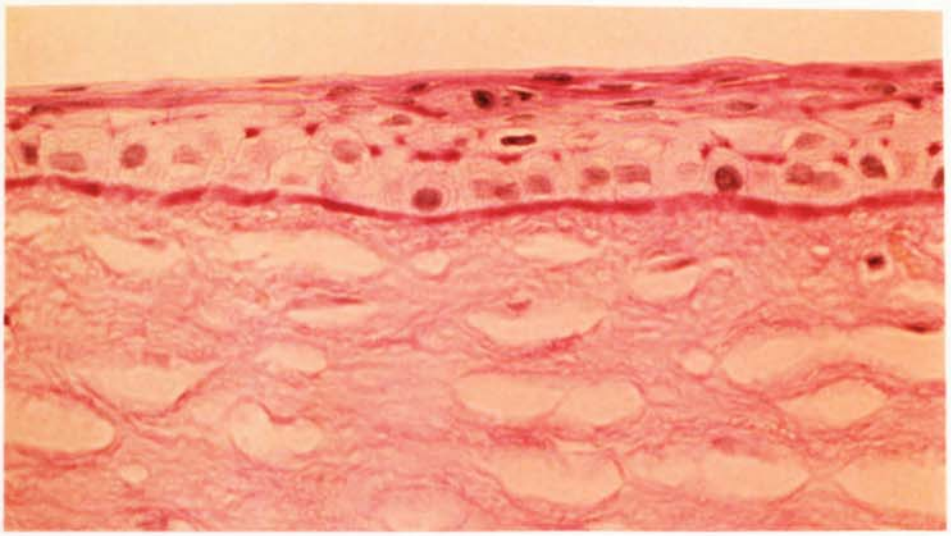
RABBIT 2 : HISTOLOGICAL SECTIONS

(a) Epithelium and superficial stroma of area "A".
Note the "spongy" appearance in the cytoplasm of several epithelial cells. (Approximate magnification 1350x).

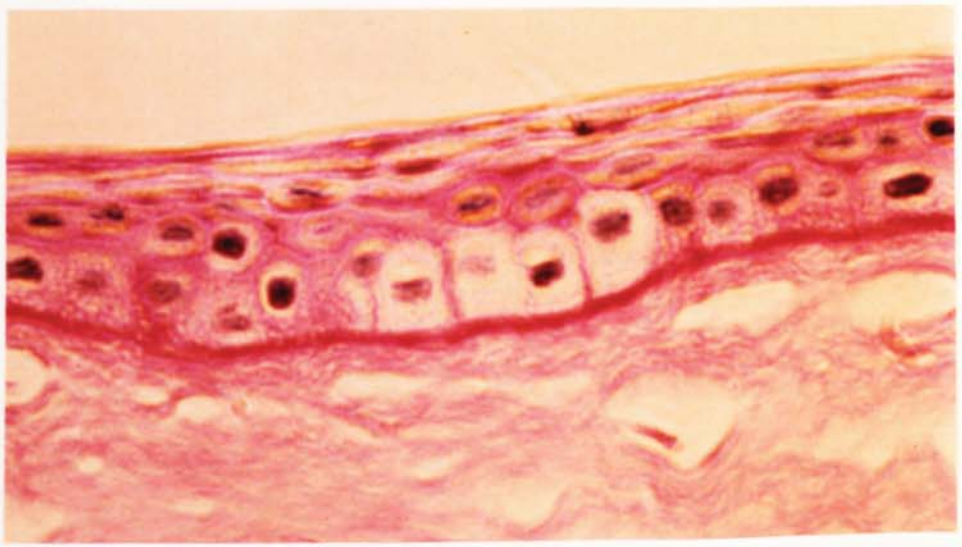
(b) Epithelium and superficial stroma of area "B". A group of pale, swollen basal cells, again with a "spongy" appearance in the cytoplasm, are located at the centre of the micrograph. The superficial stroma also has a "spongy" appearance.
(Approximate magnification 2100x).

(c) A typical representation of the epithelium and stroma in area "C", which on the whole appeared normal.
(Approximate magnification 2100x).
(All sections were fixed in buffered 10% formalin, embedded in paraffin wax, 5 microns thick and Periodic Acid-Schiff stained).

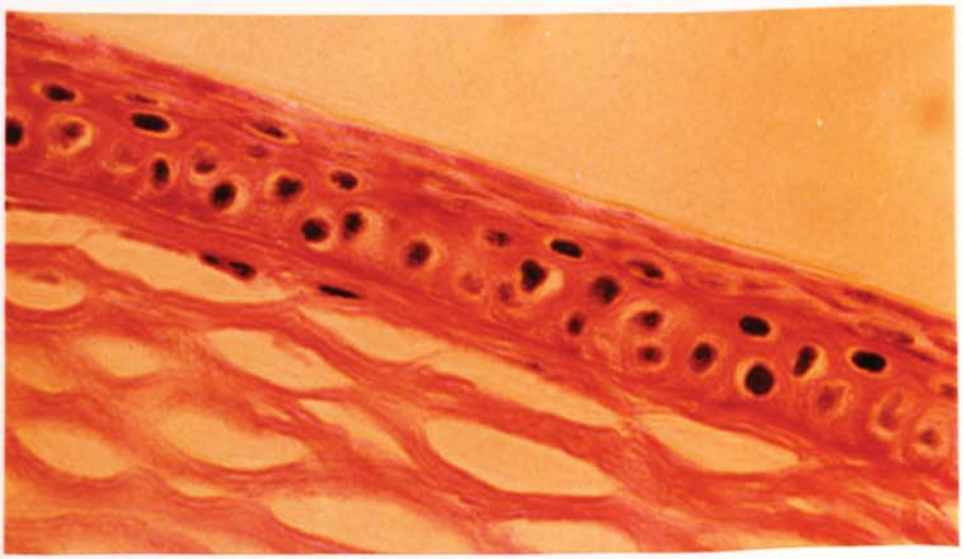
Note: The appearance of the epithelial cells in (c) closely resembles the appearance of the epithelial cells observed in the rabbit's control eye .



(a)



(b)



(c)

PLATE 6.6 i) (c)

PLATE 6.6 (i)(d)

RABBIT 3 : HISTOLOGICAL SECTIONS OBTAINED AFTER 17 DAYS OF EXTENDED WEAR

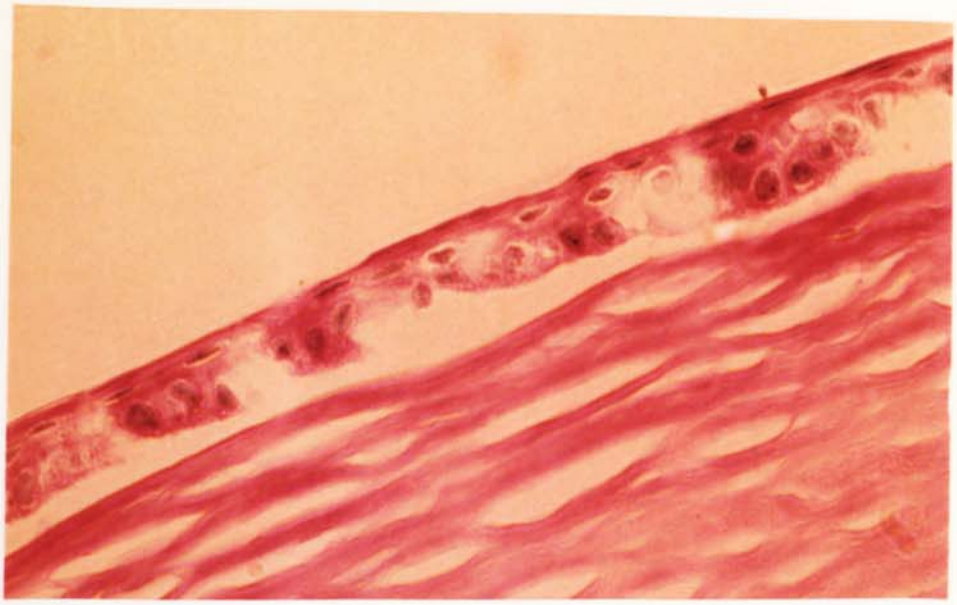
Three sections taken from the same oedematous area.

(a) Separation of the epithelium and B.M. from the superficial stroma forming bullous-like appearances. (Approximate magnification 1350x).

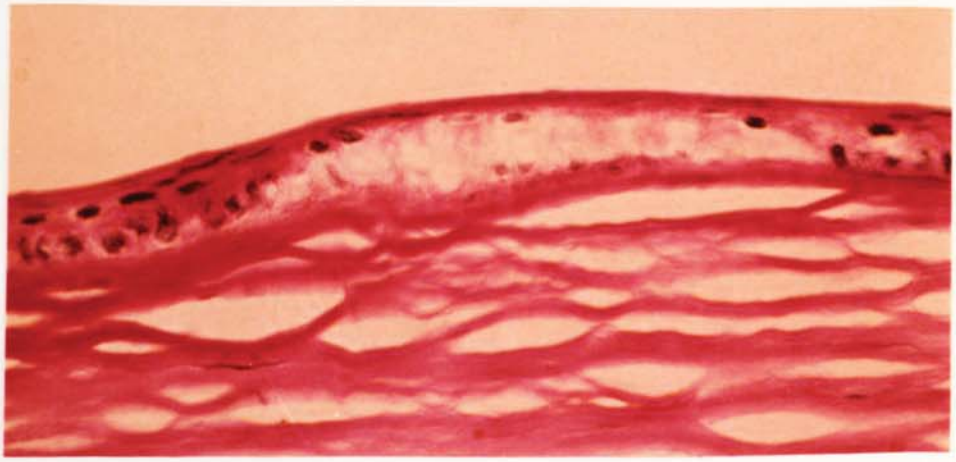
(b) Area of cellular oedema, approximately 20 cells long, in which the cytoplasm has a spongy appearance. (Approximate magnification 1350x).

(c) Similar area of oedema, again the cytoplasm of the cells has a spongy appearance. (Approximate magnification 2100x).

(All sections were fixed with buffered 10% formalin, embedded in paraffin wax, 5 microns thick and stained with Periodic Acid-Schiff).



(a)



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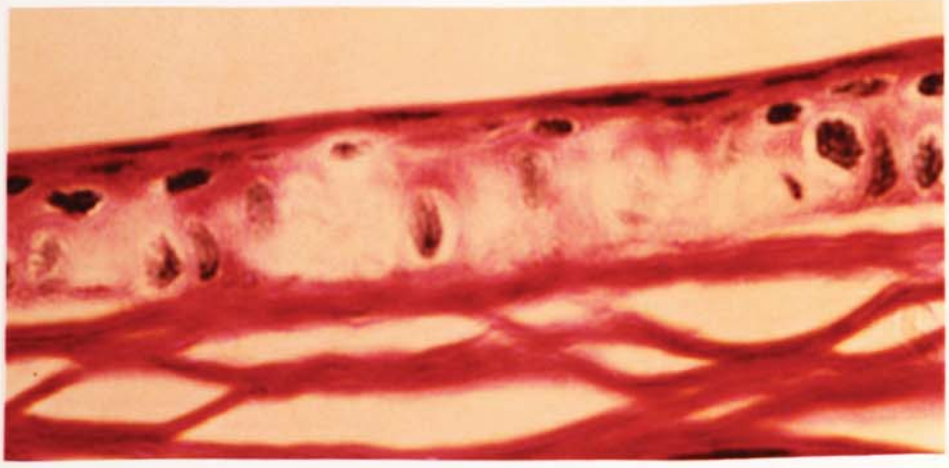


(c)

PLATE 6.6 i) (d)

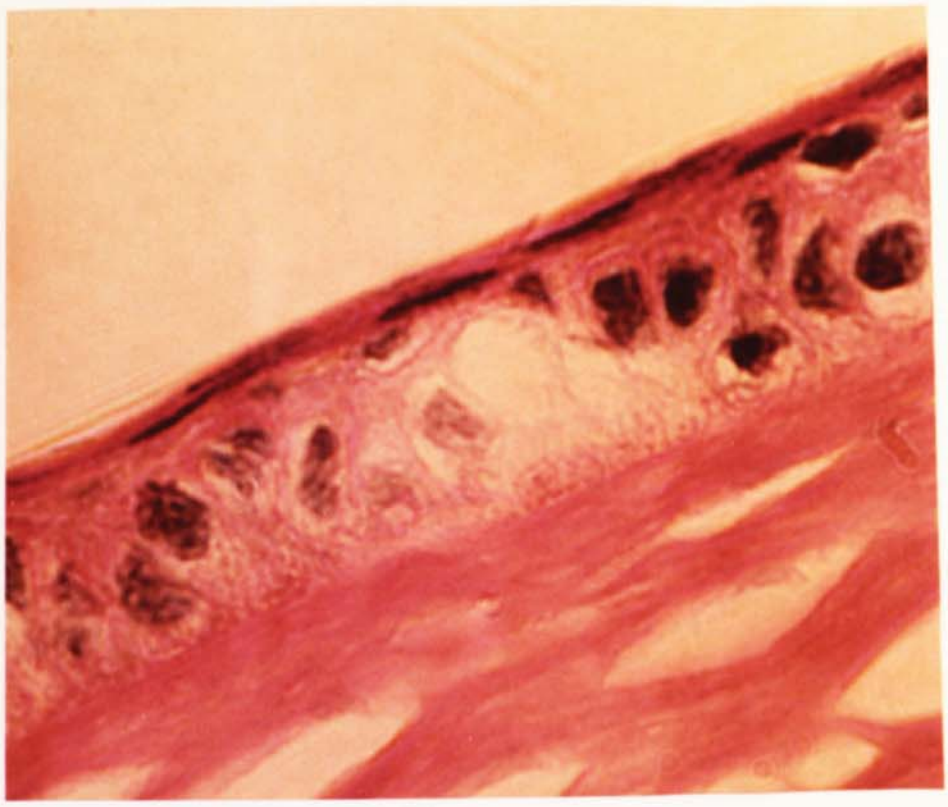
PLATE 6.6 (i)(e)

RABBIT 3 : FURTHER HISTOLOGICAL SECTIONS

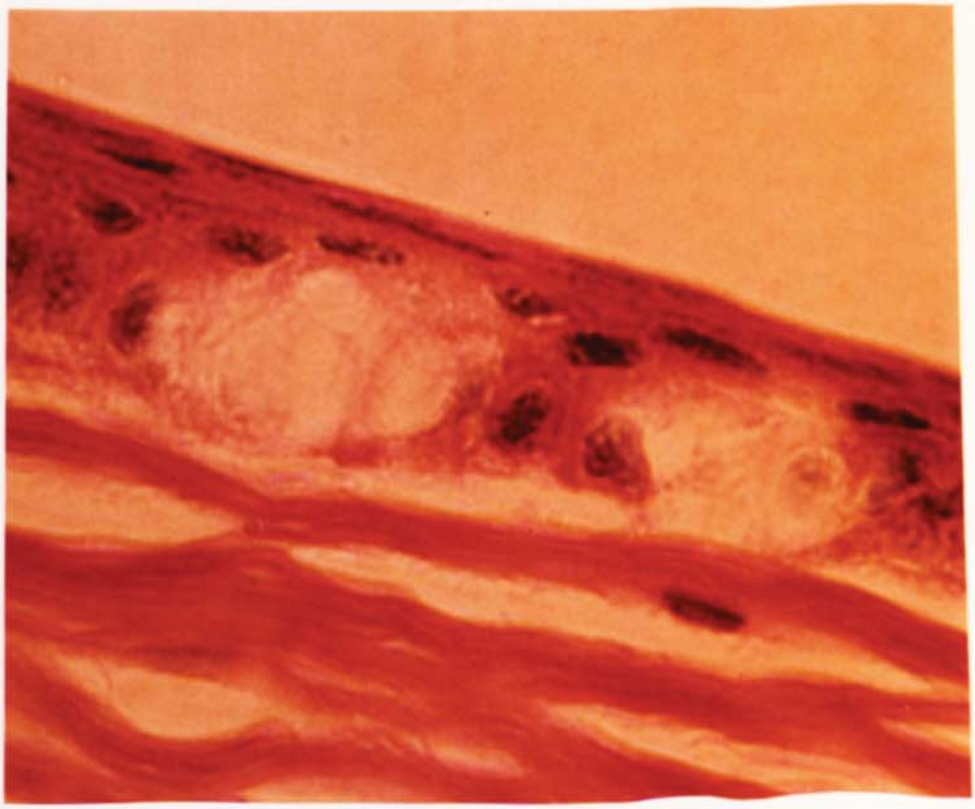
AFTER 17 DAYS OF EXTENDED WEAR

Small areas of basal and mid-epithelial cell oedema, commonly encountered in the sections of rabbit 3 are visible in (a) and (b).

(Approximate magnification for (a) is 3350x, and for (b) 3350x. The sections were fixed in buffered 10% formalin, embedded in paraffin wax, 5 microns thick and Periodic Acid-Schiff stained).



(a)



(b)

PLATE 6.6 i) (e)

Section 6.7 Results

6.7 i) Histological Observations

The histological results from the first pilot study reflected the clinical observations (Plate 6.6(i) (a)). Blood vessels were detected in the superficial stroma along with polymorphonuclear leucocytes and a certain degree of superficial stromal oedema, indicated by the fact that the separation between the lamellae in the superficial region tended to be consistantly greater than in the deeper layers and therefore, not artefacts. There were areas where the corneal epithelium was absent and also areas of abnormal epithelial thickening, up to eleven cells thick in places. Areas of pale cells were also noted indicating a degree of intra-cellular oedema, but no signs of micro-cystic changes were detected. The cornea, it was felt, presented with a markedly inflamed appearance. The control eye histologically had a normal appearance.

Area "A" in the second rabbit, which at the 16 day examination had developed micro-epithelial cysts (Plate 6.6 (i)(b)) and which clinically appeared opaque on the day of sacrifice, showed a slight but definite inflammatory cellular response. At the centre of the section the epithelium was grossly thinned while surrounding this area the epithelium was markedly thickened. Polymorphonuclear leucocytes were present in the stroma, and a degree of stromal oedema was again observed in the more superficial layers. Many areas of localized marked intra-cellular oedema were observed, usually in the basal layers of the epithelium, the cytoplasm of the cells having a "spongy" appearance (Plate 6.6(i)(c)) No micro-epithelial cystic changes were detected.

Area "B" in the second rabbit, which clinically appeared to have fine micro-epithelial cysts, again had many clusters of swollen basal cells along the section. Many had a "spongy","bubble-like" appearance in their cytoplasm (Plate 6.6 (i)(c)). The superficial stroma also had a "spongy" appearance, which it was felt was not wholly due to artefacts, as the separation of the stromal lamellae in the deeper layers of the cornea was consistantly of a lesser extent.

Area "C" in the second rabbit had a similar appearance clinically to area "B", but the cysts observed were smaller. This was reflected histologically with fewer "pale" basal cells, which were isolated in small clusters. The stroma did not have the same degree of swelling and on the whole the section had a normal appearance (Plate 6.6 (i)(c)).

The control eye in the second rabbit appeared, histologically, to be normal, with absence of "pale" cells and thickened epithelium, suggesting that those observed in the experimental eye were not artefacts (PERERA, 1969; MARSHALL and GRINDLE, 1978).

Rabbit 3 histologically showed many areas of basal cell oedema. Some areas were small and isolated (Plate 6.6 (i)(e)). While others encompassed many cells (Plate 6.6 (i)(d)). The cytoplasm of these "pale" cells often had a "spongy","bubbled" appearance, and in some areas (often adjacent to areas of "pale" cells) the epithelium, with the basal lamina, was noted to be separated from the superficial stroma forming a bullous-like appearance (Plate 6.6 (i)(d)). This would seem to indicate that not only intra-epithelial oedema had developed but also that sub-epithelial oedema was also present. It was suggested that the appearance of these bullae was similar to those observed in bullous keratopathy (BARRY, 1981). As

successive sections had the same, or similar, appearance it may be assumed that these formations were not artefacts, but real changes. In some areas, even though the thickness of the cornea was normal, the cells had a distinctly irregular appearance, while other areas staining slightly paler than the rest, had a dystrophic appearance (BARRY, 1981). In addition, other unusual features were also observed. Areas where the epithelium and basement membrane had lifted from the superficial stroma, and areas where sections of cells were lost from the mid-part of the epithelium were thought to be due to histological artefacts. However, as these observations were very similar on successive sections it was felt that oedema, if present in these regions sub - or mid - epithelially, may enhance the formation of these artefacts (BARRY, 1981). This would indicate that the oedema present in the rabbit cornea may have been far more extensive than the oedema it was possible to observe from the histological sections. Areas of irregularities in the epithelial surface, which varied in depth but never reached the basement membrane were also observed in successive sections. They did not have the appearance of a corneal abrasion which may have been caused during processing but had a similar appearance to those noted by Tripathi and Bron (1973) (Figure 6.7 (i)(a)), who suggested that they probably resulted from the eruption of an intra-epithelial cyst. However, whether this was the case in rabbit 3 or not was not ascertained. As no micro-epithelial cysts were observed histologically in all the rabbit 3 sections examined (approximately 700), some doubt is cast on this suggestion (TRIPATHI and BRON, 1973) with regard to rabbit 3.

The control eye, in common with the first two rabbits, did not have the appearance of such oedematous areas with "pale" cells, further

indicating that these apparent cellular changes in the experimental eye were not artefacts (PERERA, 1969; MARSHALL and GRINDLE, 1978), but were the result of changes similar to those observed in corneal epithelial disorders (Figure 6.7 (i)(b)).

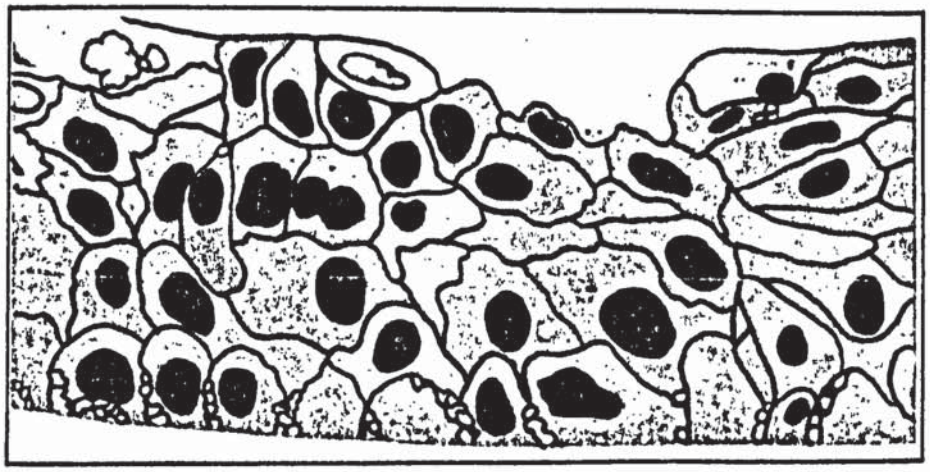


FIGURE 6.7 i) (a) Irregularity of epithelial surface probably resulting from eruption of an intra epithelial cyst. A few "pale" cells are present in the superficial region with some degree of spongiosis in the basal region. Unspecified epithelial dystrophy. Araldite embedded, toluidine blue stained. X1,050. Drawn from Tripathi and Bron (1973).

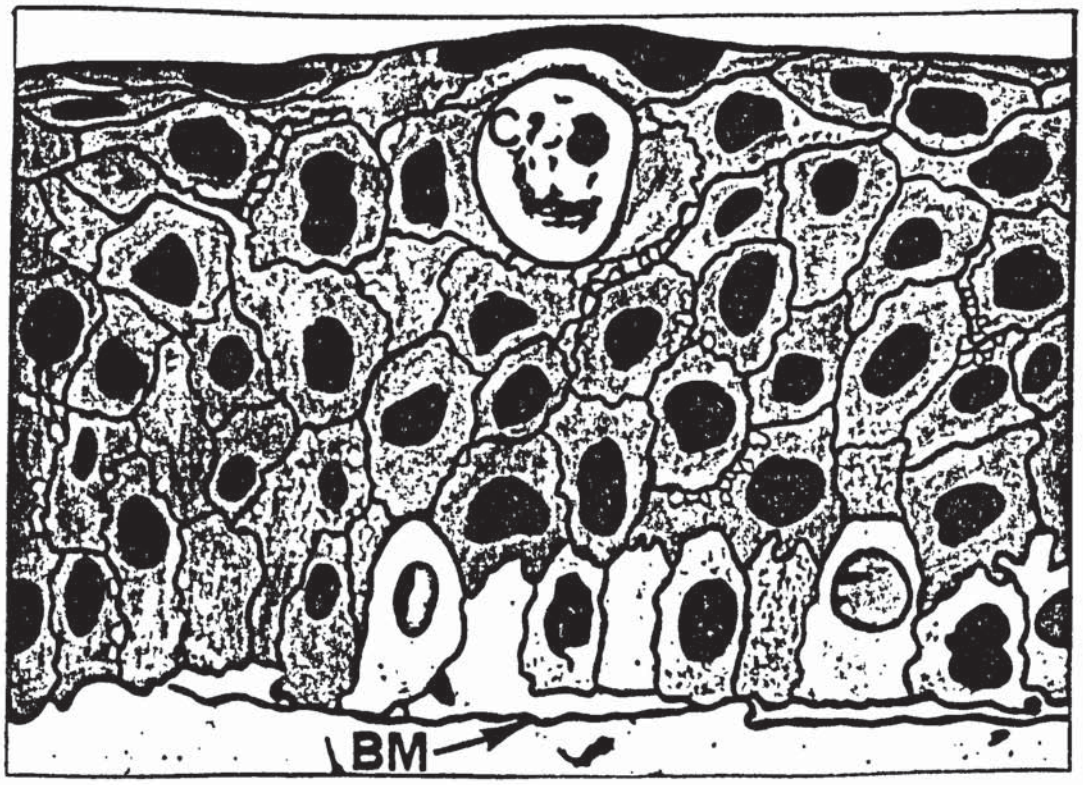


FIGURE 6.7 i) (b) Light photomicrograph of corneal epithelium showing "pale" cells in basal zone with loosely attached basement membrane (B.M.) widespread intercellular oedema, and an intraepithelial location of a cyst (c) containing cellular debris. Araldite embedded. toluidine blue stained. X1,150. Drawn from Tripathi and Bron (1972).

6.7 ii) Clinical Survey

The results obtained from the survey were input into the ICL1904S computer (Appendix 6.7 (ii)(a)). Before the analysis of the results the three extended wear cases were removed because it was felt that the sample size was too small to give significant results and also because the patients, by virtue of the fact that they were aphakic and hence abnormal would be expected to have markedly different features from the other groups. One way analysis of variance was undertaken, using the SPSS (Statistical Package for the Social Sciences) subprogram "Oneway". The fact that the three groups were of unequal sizes (29 hard lens wearers = CLENS 1, 72 daily wear soft lens wearers = CLENS 2 and 30 non-contact lens wearers = CLENS 3) was taken into account by the SPSS package. For each patient observed the results from one eye only were analysed; analysing both sets of data would not have increased the sample size, nor could it have been considered as a form of replication.

For each variable monitored during the survey the following hypotheses were tested:

H_o The variable observed was independent of the class of group.

H_1 : The variable observed was not independent of the class of group.

TABLE 6.7 (ii)(a)

Micro-epithelial Cyst Survey : Summary of Oneway Analysis of Variance of Variables recorded by, Group

Variable	D.F.	F Ratio	F Prob	Conclusion
Micro-cyst presence	2	1		Accept Ho
Density of micro-cysts	2	1.6997	0.1868	Accept Ho
Distribution of micro-cysts	2	1.8208	0.1661	Accept Ho
Degree of corneal involvement	2	1	0.5000	Accept Ho
Presence of fine cysts in the central cornea	2	7.4992	0.0008	Accept H1
Presence of cysts of varying size in the periphery	2	7.5145	0.0008	Accept H1
Presence of cysts in the mid-periphery of the cornea, nasally and/or temporally	2	18.4774	<0.0001	Accept H1
Presence of cysts in the mid-periphery of the cornea, superiorally and/or inferiorly	2	5.4320	0.0054	Accept H1
Degree of micro-cyst staining with 2% fluor-escein sodium	2	54.7042	<0.0001	Accept H1
Presence of oedema	2	1	0.5000	Accept Ho
Presence of corneal infiltrates	2	2.1511	0.1205	Accept Ho
Presence of limbal vascular congestion which may be associate with cystic areas.	2	12.7842	<0.0001	Accept H1
Presence of limbal vas-cular infiltration which may be associated with cystic areas	2	7.5854	0.0008	Accept H1

TABLE 6.7(ii) (a) continued

The following variables were similarly tested for the contact lens groups.

Variable	D.F	F Ratio	F Prob	Conclusion
Contact lens prescription		3.7175	0.0569	Accept Ho
Average length of wear/day		2.5735	0.1119	Accept Ho
Total period of wear, years	1	1.2438	0.2675	Accept Ho
Type of cleaning procedure	1	0.4004	0.5284	Accept Ho

TABLE 6.7 ii)(b) Incidence of Micro-epithelial cysts in Non-contact Lens Wearing Patients

Condition	Number of eyes examined meeting specified condition
Observation of micro-epithelial cysts	58
Microcysts present having a Distribution of Grade I	58
Microcysts present having a Density of Grade I	58
Fine cysts observed centrally	56
Cysts varying in size, viewed peripherally	27
Degree of involvement - epithelial	58
25% or less of cysts observed to stain with 2% fluorescein sodium	58

Note: A total of 60 eyes were examined (19 Controls, 11 untrained patients).

From the results of the analysis it would appear that there is no statistically significant difference between the groups for micro-cyst presence, severity of micro-epithelial cysts and degree of corneal involvement. Also the two contact lens wearing groups were shown to be drawn from the same population for all variables associated with contact lens wear. However, highly significant differences between the groups for the type of micro-cyst appearance and the degree of staining of micro-cysts were obtained. Hard contact lens wearers had cysts in the periphery of the cornea and in the mid-periphery on the nasal and temporal aspects of the cornea, over 50% of the mid-peripheral cysts in the majority of cases stained with 2% fluorescein sodium. Few hard lens wearers had fine cysts centrally and only rarely were cysts observed in the mid-periphery of the cornea, superiorally and inferiorally. The daily wear soft lens wearers presented with cysts which bore a close resemblance to those observed in the Sauflon T.M. 85 extended wear study. The cysts were often observed centrally and peripherally but more often in the superior and inferior of the mid-periphery of the cornea, most of which frequently corresponded to the crescent or half-moon area inferior to the pupil margin often occupied by cysts in extended wear patients. Few of these cysts stained with 2% fluorescein sodium. The non-contact lens wearing group had on the whole very fine central cysts, which seldom stained with 2% fluorescein sodium, occasionally cysts were viewed in the periphery, but seldom in the mid-periphery of the cornea (Table 6.7 (ii)(b)). In all the cases observed no oedema was detected and only one case, a soft contact lens wearer, presented with infiltrates.

Finally, the results from possible associations of limbal vascular

changes with microcystic areas was also highly significant. The hard lens wearers showed a strong apparent correlation between the cystic areas and limbal vascular congestion by comparison with the other groups, whereas the soft lens wearers presented with a significant apparent connection between limbal vascular invasion and micro-cystic areas, again in comparison to the other groups. There was also some vascular congestion in the daily wear soft lens wearers which may have been connected with the micro-cystic areas, but the apparent association was not as marked as that in the hard lens wearing group.

Section 6.8 Discussion

The clinical appearance of micro-epithelial cysts in the rabbit cornea closely resembled the micro-cysts observed in extended wear of Sauflon T.M. 85 lenses. The cysts were clear, indicating that they contained little cellular debris (BRON and BROWN, 1971). Histological preparations of the rabbit cornea revealed the presence of "pale" cells, spongiosis, occasional sub-epithelial bullae and no cysts containing cellular debris. It is unlikely that cysts would have regressed during the period between lens removal and the rabbits' death. Tripathi and Bron (1973) suggested that epithelia exhibit a limited reaction to a wide variety of pathological stimulae. The pale cells observed in the sections are probably indications of intracellular oedema (HOGAN and ZIMMERMAN, 1962; GOLDMAN and KUWABARA, 1968; IWAMOTO and DeVOE, 1971, TRIPATHI and BRON, 1972). Such cellular oedema has been suggested to be an essential part of the process of microcystic formation in many corneal epithelial dystrophies (TRIPATHI and BRON, 1973) and may in this case be indicative of eventual cystic formation. The appearance of sub-epithelial bullae, similar to those observed in the rabbit sections, has also been observed in bullous keratopathy (COGAN, 1941; BARRY, 1981) and in Fuchs' endothelial dystrophy (TRIPATHI and BRON, 1973). Cogan (1941) suggested that the sub-epithelial bullae were formed by the bursting of extremely swollen epithelial cells with the contents being disgorged beneath the epithelium. Certainly the bullae were often associated with "pale" basal cells, but the lack of cellular debris within the sub-epithelial bullae does not substantiate Cogan's suggestion. However, it could well be that oedematous fluid leaked through a defective part of the basement membrane and formed sub-epithelial bullae. From the histological

preparations it may be concluded that cysts induced in the rabbit corneal epithelium were manifestations of oedema in the basal layer of the epithelium.

Cysts in hard contact lens wearers closely corresponded to 3 and 9 o'clock staining patterns. (WILSON, 1970; STONE and PHILLIPS, 1972; SABELL, 1979). Inadequate blinking has been suggested as the cause of the staining (MANDELL, 1974), causing a reduction in the wettability of the corneal epithelium by reducing its mucous glycoprotein layer (LEMP ET AL., 1970; HOLLY ET AL., 1970). Dead and partially dehydrated cells on the surface could provide a barrier to the passage of oxygen to the underlying cells. Such oxygen deprivation may enhance or even cause formation of some cysts. The staining of a high percentage of cysts in hard lens wearers may be due to the presence of superficial erosions. Bron and Tripathi (1973) suggested that such erosions as well as degenerated cells would allow entry of fluorescein into areas of oedematous and cystic epithelium. It may also be postulated that superficial erosions could exacerbate formation of cysts by allowing entry of the aqueous phase of the tears, especially in areas deficient in the mucous glycoprotein layer. A report of one hard lens patient (MACKIE, 1967) who developed an infiltrated lesion, presumed to be a progression of previous 3 and 9 o'clock staining, may be connected with presence of cysts.

Of the cysts observed in both daily and extended soft lens wearers only a small proportion stained with fluorescein. Those which did may have represented erupting cysts, or cysts near to degenerated cells on the surface (BRON and TRIPATHI, 1973). The cysts observed were not

surrounded by clinically detectable oedema. It is possible that cells in the surrounding area received more oxygen because the oedematous (or dead) cells forming the cysts would be expected to consume less oxygen (PARRISH, 1981). It has been shown that soft contact lenses inhibit the supply of oxygen to the cornea (HILL and CUCKLANZ, 1967; HILL and AUGSBURGER, 1971; PETERSON and FATT, 1973). As basal cells are the primary site for cell mitosis in the corneal epithelium (CALMETTES ET AL., 1956) it may be expected that their oxygen requirement is higher (ZEUTHEN, 1949). Therefore, in a reduced oxygen environment it is reasonable to deduce that basal cells would be the first to suffer. This is consistent with the hypotheses of several workers who felt that microcysts were situated in the basal layer (WILSON, 1970; HOLDEN and ZANTOS, 1979). Furthermore, oedema and cellular lysis in the basal cells could result in basal lamina defects because of interference with the synthesising activity of the basal cells (BLUMCKE ET AL., 1969). Certainly epithelial basement membrane dystrophy is common and has even been described as the most common anterior corneal dystrophy (WARING ET AL., 1978). Also corneal micro-cysts have frequently been associated with defects of the basement membrane (CHANDLER, 1945; BRON and BROWN, 1977). The observations mentioned above would seem to support a recent hypothesis which suggests that in lens wearers, the cysts are pure blebforms of a subtle type of epithelial basement membrane dystrophy (McMONNIES, 1981). Furthermore, McMonnies (1981) reported varying degrees of recurrent epithelial erosion in some patients with micro-cysts, also indicating a defective B.M. (KHODADOUST ET AL., 1968), which was attributed to trauma induced by contact lens wear.

The suggestion that a high concentration of ACh in the corneal epithelium is essential for its integrity (van ALPHEN, 1957; GNADINGER ET AL., 1973) is supported by the work of von Brucke et al. (1949), who demonstrated an increase in epithelial regeneration with local administration of ACh. More recently it has been suggested that the greatest inhibition of corneal epithelial healing occurs if increased inflammatory factors (such as prostaglandins and catecholamines) and decreased cholinergic levels are concurrent (CAVANAGH, 1975; CAVANAGH ET AL., 1976; CAVANAGH and COLLEY, 1979). Cavanagh (1975) found that both factors, in varying degrees, were present in patients who developed persistent epithelial defects. In the present case it may also be that both factors were present (see Chapter 5), and by reducing the regenerative capacity of the corneal epithelium, contributed to the formation of cysts. Furthermore, both the cysts in this study, and ChAc activity monitored after 8 days of lid closure in rabbits (MINDEL and MITTAG, 1978; MINDEL ET AL., 1979), took an average of 28 days to recover, the similar recovery periods may support Cavanagh's hypothesis (CAVANAGH, 1975) or may indicate that successive generations of cells are affected to a similar extent.

It is difficult to explain why fine central cysts and occasional larger peripheral cysts are present in the corneae of non-contact lens wearing patients. They might be small defects as found in epithelia in other parts of the body (ROOK ET AL., 1972), merely indicating that the cells are not perfectly regular, and not implying that a progressive condition is present. It would appear from all the observations made that cysts do not have serious implications

for the majority of contact lens patients. However, for some patients the presence of cysts may be an early sign of corneal epithelial degenerative changes (McMONNIES, 1981).

CHAPTER 7.

Conclusions, and Suggestions for Further Work

Section 7.1 Conclusions

1. Subjectively Sauflon T.M. 85 extended wear contact lenses are an acceptable, convenient form of optical correction.

2. Significant changes in the limbal vasculature were observed during six months of extended contact lens wear.

3. A significant decrease in corneal sensitivity was observed after extended wear of Sauflon T.M. 85 lenses, although its magnitude was substantially smaller than had been expected.

4. Joint clinical studies have a major limitation in that the requirements for measurement of different parameters may clash (this is illustrated by the aesthesiometry results).

5. A signficant degree of transient swelling was observed after one week of extended contact lens wear.

6. The initial corneal swelling decreased in the first month of wear and no further significant swelling was detected.

7. Four to six months of extended wear resulted in the formation of micro-epithelial cysts in every patient.

8. Micro-epithelial cysts were of themselves not particularly serious, but in some cases they might have further progressed resulting in severe, possibly irreversible, degenerative changes.

9. Micro-epithelial cysts, with a similar clinical appearance to those observed in extended wear patients can be induced in rabbit corneae.

10. Histological results suggest that cysts observed in rabbits are manifestations of epithelial and sub-epithelial oedema.

11. In one rabbit the micro-epithelial cysts appeared to progress, forming an opacified, vascularized lesion.

12. Micro-epithelial cysts are generally present in hard lens wearers, in day and extended soft lens wearers and in non contact lens wearers, though for each category their characteristic location, size and degree of staining varies.

13. A significant number (17.7%) of acute red eye responses were encountered with extended wear of Sauflon T.M. 85 lenses.

Section 7.2 Recommendations and Suggestions for further work

1. Study histologically (including scanning electron microscopy) micro-epithelial cysts induced by extended soft lens wear in a suitable experimental model.

2. Observe the anterior corneal mosaic (a clear omission in the present study) during clinical examinations of micro-epithelial cysts, as the mosaic may indicate defects in Bowman's layer (BRON and TRIPATHI, 1970).

3. Use radio immuno assay techniques with specific antiserum (DHIR ET AL, 1979) in a suitable experimental model. Monitor tear levels of prostaglandins in vascularized eyes, the vascularization preferably being induced by extended contact lens wear.

4. Set up an on-going study at an established contact lens clinic to monitor pre- and regular post-lens fitting tear prostaglandin levels using the technique described by Dhir et al (1979). In conjunction with the above, monitor changs in the limbal vasculature, formation of papillae (such as GPC), acute red eye responses and any other adverse response encountered, in order to determine if any correlations with prostaglandins exist.

5. Use fluorescein angiography to monitor changes in limbal blood vessels and in the palisades of Vogt (BRON and GOLDBERG, 1980), with long term extended contact lens wear using a suitable experimental model.

6. Firstly monitor areas of stain with both Sodium Fluorescein 2% and Rose Bengal 1% in a suitable experimental model. Secondly study histological appearance of these areas to determine the causative factors.

Note:

It is the author's opinion that in all cases in which an experimental model is required, primates are the only satisfactory models.

APPENDICES

APPENDIX 3.3 ii) (a)

DEPARTMENT OF OPHTHALMIC OPTICS

Soft Lens Research

VOLUNTEERS REQUIRED

Experimental Subjects

Experimental subjects are required to wear, 'Extended Wear ' soft contact lenses for a period of not less than two years. Lenses and ancillary solutions will be supplied, without cost, to participating patients.

Control Subjects

Control subjects are also required for the above experiment. Suitable subjects, who should be spectacle wearers, will be subject to the same examinations as the experimental subjects, and will be paid 50p. (expenses) for each examination.

Interested subjects should contact,

Miss Judith Humphreys
Soft Lens Research
Room 188
Main Building

APPENDIX 3.3 ii) (b)

PATIENT ACCEPTANCE PROFILE

1. Patient's age must be within the limits of 18 and 36 years of age.
2. Patients may be male or female.
3. Patient must not have received a previous eye injury or operation.
4. Patient must not have had any recent (6/12) ocular medication nor worn contact lenses.
5. Patient not at present receiving any form of drug for systemic use (excluding oral contraceptive).
6. Patient not at present receiving any form of drug for ocular use.
7. Patient must not have had any form of orthoptic treatment (principally strabismus leading to abnormal eye positions).
8. Patient does not suffer from "hay fever".
9. Patient does not suffer from asthma, allergic dermatitis, or any other allergic conditions.
10. Patient is not subject to recurrent or persistent red eyes, repeated styes, intolerance to light, watery eyes, scaly eyelids, repeated colds.
11. Patient is not at present receiving any psychiatric care.
12. Patient is of Caucasian extract.
13. Palpebral aperture not greater than 12mm or less than 8mm vertically.
14. Palpebral aperture not greater than 32mm or less than 28mm horizontally in either eye.
15. No abnormal lid/cornea relationship.
16. Myopia of -1.00D to -8.00D in either eye.
17. Myopia of 0.00D to -0.75D in either eye.
18. Hypermetropia of 0.00D to +4.00D in either eye.

19. Not more than 1.50D astigmatism in either eye.
20. Visual acuity of not less than 6/6 in either eye (with prescription if needed).
21. Apparent central corneal thickness between 0.47mm to 0.62mm in either eye (p.m.)
22. Central keratometry value not less than 6.95 or greater than 8.54mm.
23. No congenital or pathological anomaly of the cornea as indicated by slit lamp examination.
24. No Fluorescein staining of the cornea.
25. No unusual Rose Bengal (1%) staining of the cornea/ bulbar conjunctiva.
26. Central corneal touch threshold not greater than 0.96 gm mm^{-2}.
27. No obvious congenital or pathological anomaly as indicated by ophthalmoscopy.

Non compliance with factors 1, 3 to 6, 8 to 15, 19 to 27, excluded the patient from the study. The contact lens wearing volunteer's prescription must comply with 16, the control volunteer's prescription must comply with 16, 17 and 18, failure of either type of patient to do so excluded that patient from the study. Non compliance with factor 7 did not exclude the patient from the study, providing orthoptic treatment had been completely successful. Presence of more than one of the conditions referred to in factors 8 and 9, excluded the patient from participating in the study.

APPENDIX 3.4 ii)

THE UNIVERSITY OF ASTON IN BIRMINGHAM

THE DEPARTMENT OF OPHTHALMIC OPTICS

SOFT LENS RESEARCH

CONTROL	
EXPERIMENTAL	
SOLUTION USER	

Gauflon 85

Continual Wear Project

Patient Aftercare Sheet

PLEASE COMPLETE THE FOLLOWING:

NAME : _____ ADDRESS : _____ Visit No.

Tel/Contact : _____ Date:

Last visit: _____ Total Wearing Time: _____

Data File :

Please tick the statement which reflects your symptoms most accurately:

A. COMFORT How comfortable are your lenses?

	Right Eye	Left Eye
1. Completely comfortable presence of lens not felt	☐	☐
2. Presence of lens felt but not uncomfortable	☐	☐
3. Lenses uncomfortable but no irritation	☐	☐
4. Irritation but not painful	☐	☐
5. Lenses painful	☐	☐

B. SUBJECTIVE 'HALOES' Do you see rainbow coloured rings (haloes) round lights?

	Right Eye	Left Eye
1. No haloes	☐	☐
2. Slight haloes on waking	☐	☐
3. Mild halo persists throughout waking hours	☐	☐
4. Marked haloes persisting throughout day	☐	☐
5. Marked haloes and blue 'mistiness' of vision throughout day	☐	☐

C. BURNING SENSATION Do you suffer fron a 'burning sensation in your eyes?

	Right Eye	Left Eye
1. No burning sensation	☐	☐
2. Slight intermittent burning sensation	☐	☐
3. Slight but constant burning sensation	☐	☐
4. Moderate burning sensation	☐	☐
5. Marked burning sensation	☐	☐

E. QUALITY OF VISION

Can you see satisfactorily with your contact lenses for:

	Right Eye Yes	Right Eye No	Left Eye Yes	Left Eye No
Distance vision	☐	☐	☐	☐
Near vision	☐	☐	☐	☐

Does your vision vary or fluctuate?
Please tick appropriate box

1. Vision completely stable	☐	☐
2. Vision slightly unstable on some occasions	☐	☐
3. Vision slightly unstable on most occasions	☐	☐
4. Vision moderately unstable	☐	☐
5. Vision very unstable	☐	☐

D. PHOTOPHOBIA Do you suffer from unusual discomfort or pain (photophobia) in the presence of bright light.

	Right Eye	Left Eye
1. No photobia	☐	☐
2. Slight occasional photophobia	☐	☐
3. Slight but persistent photophobia	☐	☐
4. Moderate photophobia	☐	☐
5. Marked photophobia	☐	☐

F. OCULAR DISCHARGE Do you notice any discharge from your eyes?

1. No discharge	☐	☐
2. Occasional discharge on waking	☐	☐
3. Discharge on waking and sometimes at other times of the day	☐	☐
4. Moderate discharge during waking hours	☐	☐
5. Marked discharge	☐	☐

GENERAL

During the time that you have worn soft contact lenses continually have you suffered from an eye disease, or suffered any form of adverse response to your lenses? Please give details:

APPENDIX 3.4 vi)

THE UNIVERSITY OF ASTON IN BIRMINGHAM
THE DEPARTMENT OF OPHTHALMIC OPTICS
SOFT LENS RESEARCH

"SLIT LAMP EXAMINATION"

Name: _____ Control

Date: _____ Sol

Visit No: _____ Non-sol

"A" OEDEMA

		R	L
1.	None (Physiological	☐	☐
	Micro oedema -intercellular accumulation of fluid which is limited to the epithelium and is seen only by the use of the slit lamp.		
	Slight amounts in the epithelium, seen only by retro-illumination:		
2.	(a) Localised - over less than 50% of the cornea.	☐	☐
3.	(b) Generalised - over more than 50% of the cornea	☐	☐
	Moderate amounts of the epithelium, seen by direct illumination.		
4.	(a) Localised - over less than 50% of the cornea.	☐	☐
5.	(b) Generalised - over more than 50% of the cornea.	☐	☐
	Gross oedema -intracellular cystic accumulation of fluid, viewed by the naked eye using oblique flash light illumination.		
	Slight case without any stromal involvement.		
6.	(a) Circumscribed - over less than 50% of the cornea.	☐	☐
7.	(b) Generalised - over more than 50% of the cornea.	☐	☐
	Severe case with stromal involvement.		
8.	(a) Circumscribed - over less than 50% of the cornea.	☐	☐
9.	(b) Generalised - over more than 50% of the cornea	☐	☐

APPENDIX 3.4 (viii)

"B" FLUORESCEIN STAINING

(a) EVIDENCE OF STAINING

		R	L
1.	No staining	☐	☐
2.	Diffuse	☐	☐
3.	Punctate	☐	☐
4.	Linear	☐	☐
5.	Arcuate	☐	☐
6.	Other ....specify	☐	☐

(b) DEPTH OF STAINING IF PRESENT

1.	Epithelial.	☐	☐
2.	Involves stroma (partial)	☐	☐
3.	Involves full cornea thickness	☐	☐

(c) AREA OF STAINING IF PRESENT - CORNEA AREA

1.	Involving < 1% of the total cornea area	☐	☐
2.	Involving > 1% but < 3% of the total cornea area.	☐	☐
3.	Involving > 5% but < 10% of the total cornea area.	☐	☐
4.	Involving > 10% but < 25% of the total cornea area.	☐	☐
5.	Involving > 25% but < 50% of the total cornea area.	☐	☐
6.	Involving > 50% but < 75% of the total cornea area.	☐	☐
7.	Involving the total area of the cornea.	☐	☐

"C" ROSE BENGAL STAINING

(a) EVIDENCE OF STAINING

	R	L
1. No staining	☐	☐
2. Diffuse	☐	☐
3. Punctate	☐	☐
4. Linear	☐	☐
5. Arcuate	☐	☐
6. Other ... Specify	☐	☐

(b) AREA OF STAINING IF PRESENT - (CORNEA ONLY)

1. Involving 1% of the total cornea area	☐	☐
2. Involving 1% but 5% of the total cornea area.	☐	☐
3. Involving 5% but 10% of the total cornea area.	☐	☐
4. Involving 10% but 25% of the total cornea area.	☐	☐
5. Involving 25% but 50% of the total cornea area.	☐	☐
6. Involving 50% but 75% of the total cornea area.	☐	☐
7. Involving the total area of the cornea.	☐	☐

"D" ANTERIOR CHAMBER DISTURBANCE

1. No flare or cells	☐	☐
2. Minimal (1+)	☐	☐
3. Mild (2+)	☐	☐
4. Moderate (3+)	☐	☐
5. Marked (4+)	☐	☐

APPENDIX 3.4 ix) (a)

THE UNIVERSITY OF ASTON IN BIRMINGHAM
THE DEPARTMENT OF OPHTHALMIC OPTICS

Soft Lens Research

Limbal Blood Vessel Examination

CONTROL	
NON-SOL	
SOL	

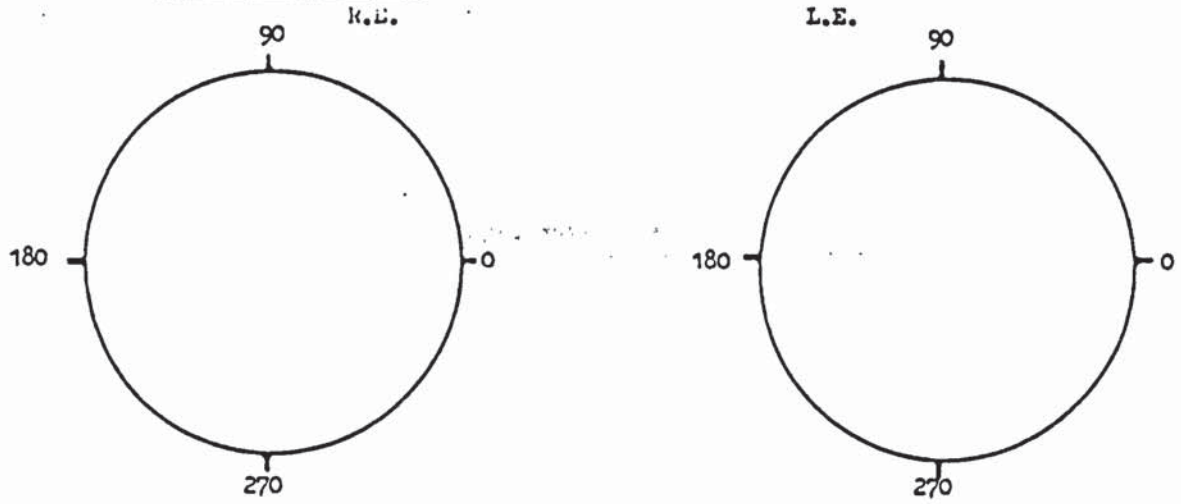
Patient.....

Visit No..... DATE...../..../.....

Total wearing time.....

Data File.....

LIMBAL BLOOD PLEXUS (Note: R=Reference vessel, U=Unlooped vessel)



Number of unlooped vessels

R.....	L.....

Apparent limbal width

R.E.		L.E.	
	0.....		0.....
	90.....		90.....
	180.....		180.....
	270.....		270.....

HYPERAEMIA (dilation of existing blood vessels)	R	L
1.None		
2.Mild congestion and dilation of limbal conjunctival vessels.		
3.Moderate congestion and dilation of limbal conjunctival vessels.		
4.Marked congestion and dilation of limbal conjunctival vessels.		
5.Severe hyperaemia with excessive lacrimation.		
6.Other comments		

VASCULARISATION (growth of new blood vessels into the cornea)	R	L
1.None		
2. Extension of limbal vessels more than 1.5mm. corneal/scleral junction		
.a. Superiorily		
.b. Inferiorily		
.c. Nasal/Temporal		
3.Extension of limbal vessels more than 1.5mm. over the entire periphery		
4.Severe vascularisation (to within 2mm. of the corneal apex)		

APPENDIX 3.4 ix) (b) (i)

Results of photographic blood vessel measurement obtained using white and green light.

In order to determine the best colour of illumination for limbal blood vessel photography, a series of photographs was taken of the same section of limbus in each of two patients. Half of each patient's photographs were taken using white light, the other half using green. Four transparencies of similar high quality were chosen from amongst these, one of each colour from each patient. Using the procedure described in Chapter 3, section (ix), blood vessel diameters, apparent limbal depths and the number of filled, partially filled and empty blood vessels were all measured.

The results were analysed using the t - test with paired values and no statistically significant differences between the values obtained, using white and green light, were found.

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: X - Green Light

Group: -

Data Point: -

SCALE: 20 Div. 3.725 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A 9.300	0.735	0.710	0.775	0.740	0.720	
B 9.250	0.660	0.675	0.680	0.625	0.660	
C 9.500	0.945	0.930	0.935	0.945	0.935	
D 11.500	0.755	0.760	0.735	0.740	0.780	
E 5.000	0.252	0.510	0.535	0.540	0.555	

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	17.3	17.2	17.1	17.1	17.2	
B	14.3	14.2	14.1	14.3	14.2	
C	10.9	11.1	11.0	11.0	11.1	
D	20.6	20.5	20.6	20.5	20.7	
E	21.6	21.3	21.3	21.4	21.3	

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	3	2	2	2	3	
Partially filled	8	9	9	9	8	
Empty	0	0	0	0	0	

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: X - White Light

Group: -

Data Point: -

SCALE: 20 Div. 13.720 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A 9.300	0.720	0.735	0.715	0.730	0.775	
B 9.250	0.630	0.675	0.645	0.660	0.645	
C 9.500	0.965	0.925	0.930	0.925	0.950	
D 11.500	0.735	0.755	0.780	0.760	0.745	
E 5.000	0.550	0.545	0.525	0.530	0.530	

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	17.1	17.3	17.2	17.1	17.2	
B	14.2	14.0	14.1	14.3	14.1	
C	10.9	11.1	10.9	11.2	11.1	
D	20.6	20.7	20.5	20.6	20.6	
E	21.3	21.4	21.5	21.3	21.4	

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	3	2	3	3	2	
Partially filled	8	9	8	8	9	
Empty	0	0	0	0	0	

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Y - Green Light

Group: - Data Point: -

SCALE: 20 Div. 13.760 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A 6.700	0.640	0.655	0.660	0.610	0.625	
B 8.900	0.780	0.785	0.750	0.755	0.780	
C 9.600	0.530	0.515	0.490	0.495	0.530	
D 11.200	0.815	0.820	0.855	0.880	0.850	
E 9.400	0.580	0.540	0.545	0.575	0.570	

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	13.3	13.3	13.0	13.0	13.1	
B	11.7	11.7	11.5	11.6	11.6	
C	15.3	15.1	15.3	15.3	15.2	
D	18.8	18.7	18.5	18.6	18.5	
E	16.2	16.1	15.9	16.0	16.0	

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	7	6	5	5	4	
Partially filled	6	7	8	8	9	
Empty	0	0	0	0	0	

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Y - White Light

Group: - Data Point: -

SCALE: 20 Div. 13.755 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A 6.700	0.670	0.635	0.625	0.640	0.650	
B 8.900	0.775	0.750	0.755	0.780	0.785	
C 9.600	0.510	0.495	0.525	0.520	0.490	
D 11.200	0.815	0.865	0.865	0.800	0.820	
E 9.400	0.585	0.570	0.545	0.550	0.565	

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	13.2	13.0	13.1	13.2	13.1	
B	11.9	11.6	11.7	11.7	11.6	
C	15.3	15.2	15.1	15.1	15.3	
D	18.6	18.5	18.7	18.7	18.5	
E	16.1	16.2	15.9	15.9	16.0	

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	6	5	5	4	6	
Partially filled	7	8	8	9	7	
Empty	0	0	0	0	0	

APPENDIX 3.4 ix) (b) (ii)

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: _____

Group: _____ Data Point: _____

SCALE: _____ Div. _____ cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A						
B						
C						
D						
E						

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A						
B						
C						
D						
E						

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled						
Partially filled						
Empty						

APPENDIX 3.4 x) (d)

Table of the vertical distances between the five reference points from a 25% sample of the patients

PATIENT NAME	VERTICAL DISTANCES			
	1	2	3	4
Medlock	33.0	11.0	-	-
Mackie	9.5	1.4	13.1	8.5
Martin	12.8	10.1	20.0	1.5
Matheson	11.3	10.1	16.9	23.0
Matthews	17.0	11.5	3.2	34.9
McAdam	5.6	22.4	1.9	9.0
McCormick	12.0	10.0	14.9	6.4
Mills	4.1	15.5	21.5	8.4
Munks	5.9	20.4	1.9	7.5
Neely	15.4	6.4	16.5	7.4
Newell	22.7	20.4	11.0	9.1
Owens	2.7	40.2	2.6	21.1
Peters	19.7	9.0	22.3	11.2
Plum	17.4	27.7	20.0	2.0
Evans	24.0	18.9	13.5	21.0
Savage	18.8	3.5	1.1	11.0
Scott	14.5	11.5	17.3	18.9
Shackleton	12.9	19.0	5.9	26.9
Silverwood	21.8	27.4	3.1	5.5

From these figures the average value for the vertical distance between two reference points was calculated to be 13.8 cm.

APPENDIX 3.4 xi)

THE UNIVERSITY OF ASTON IN BIRMINGHAM.
DEPARTMENT OF OPTICAL PHYSICS.
Soft Lens Research

Examination of the Tarsal Conjunctiva of the upper eyelids.

CONTROL	
NON-SCL	
SCL	

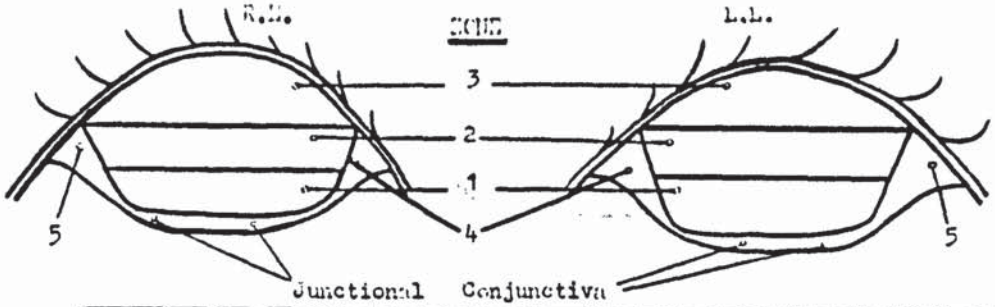
Patient.....

Tel/Contact.....

Visit No..... DATE...../...../.....

Data File.....

TARSAL CONJUNCTIVA



Classification of upper tarsal conjunctival [illegible]	R	L
.A. S.P.L. appearance(where the conjunctiva is devoid of papillae and had a smooth surface).		
.B. [illegible] appearance(in which small(4 to 8 per sq.mm.) microscopically elevated papillae were detected over zones 1,2 and 3.)		
.C. [illegible] papillary appearance(in which some of the papillae were 0.4 to 0.6mm. in diameter resulting in non-uniform appearance		
.D. [illegible] appearance(in which papillae 1mm. in diameter or greater were present in zones 1,2 or 3).		
.E. Severity of GPC papillae: .a. 0 .b. 1 .c. 2 .d. 3 .e. 4		

.F. Description of zones 4 and 5.....

.G. Other Comments

APPENDIX 3.4 xiv)

Not Applicable for BASELINE or CONTROL measurements

LENS CONDITION

A. LENS CONDITION	R	L
1. Good	☐	☐
2. Split/Cracked	☐	☐
3. Bad Edge	☐	☐
4. Other ... specify _____		
_____		

B. COLOUR OF DEPOSIT/LENS	R	L
1. White/Cloudy	☐	☐
2. Pinkish Tint	☐	☐
3. Yellowish Tint	☐	☐
4. Brown	☐	☐
5. Other ... specify _____		

C. SLIT LAMP APPEAPANCE OF DEPOSIT	R	L
1. Crystalline	☐	☐
2. Film-like/Haze	☐	☐
3. Granular	☐	☐
4. Speckles	☐	☐
5. Other ... specify _____		

Additional comments (in relation to lens condition and particularly to deposits or the changes in the lens)

FURTHER INFORMATION AND ACTION

A. LENS REPLACED/REFITTED FOR:	R	L
1. Patient lost or misplaced	☐	☐
2. Change of Rx/Fit	☐	☐
3. Bad edge/damaged	☐	☐
4. Bad surface quality	☐	☐
5. Discoloration/Deposits	☐	☐
6. Other _____		

B. PATIENT LOST TO PROGRAMME:	
1. Acuity	☐
2. Comfort	☐
3. Interest	☐
4. Pathology	☐
5. Other _____	
_____	

APPENDIX 3.4 (xvi)

An extract from a typical patient record.

APPENDIX 3.5

THE UNIVERSITY OF ASTON IN BIRMINGHAM

Gosta Green, Birmingham B4 7ET/Tel: 021.359 3611 Ex

Department of Ophthalmic Optics

Head of Department: Professor G V Ball MSc, FBOA, HD

Dear Patient,

The following appointment dates and times have been allocated for your ' after-care ' visits (including data collection) to see us in connection with your eyes / contact lenses.

A very short note is also given as to the nature of each visit. It is very important that you attend.

DATE	TIME	NATURE OF VISIT/COMMENTS.

Telex 336997

J.Humphreys, C.T.Parrish.

APPENDIX 3.8 (a)

Controls	Solution Users	Non-solution Users
1. Cargill	26. Bell	52. Arnold
2. Chalklin A.	27. Booth	53. Besley
3. Collins	28. Bethel	54. Clayphan
4. Cotton, S.	29. Carr	55. Cotton, T.
5. Craine	30. Chalklin J.	56. Duncan
6. Culverwell	31. Dalton	57. Gatward
7. Edyvean	32. Dawson	58. Gregory
8. Faulkner	33. Gribbin	59. Groom
9. Furness	34. Herbert	60. Higgerson
10. Harrison	35. Hogan	61. Hinton
11. Henderson	36. Howells	62. Hudman
12. Hodges	37. Humm	63. Joyce
13. Jones	38. Kehoe	64. Longsreth
14. Kirkham	39. Lawrence	65. Lynham
15. Konieczny	40. Lee	66. McCormick
16. Matthews	41. Mackie	67. Newell
17. Medlock	42. Martin	68. Peters
18. Mills	43. Matheson	69. Plum
19. Neely	44. McAdam	70. Shackleton
20. Owens	45. Munks	71. Silverwood
21. Rhys-Evans	46. Siniak	72. Whitehouse
22. Richards	47. Timlin	73. Young
23. Savage	48. Travers	74. Fennel
24. Scott	49. Warren	75. Keeling
25. Tate	50. Wightman	76. Skitt
	51. Yates	77. Woof

APPENDIX 3.8 (b)

Key to Primary Clinical File

Each data point occupies a set of four lines, thus for each patient these are forty four lines of data in this file. The first two values (patient and visit numbers) are repeated on the second, third and fourth lines to facilitate re-sequencing shuffled cards.

Line	Columns	Variable recorded
1	1 - 2	Patient number
	4 - 5	Visit number
	7	Card number
	9 - 13	Keratometry max radius, right
	15 - 17	Keratometry max radius axis, right
	19 - 20	Visual acuity, right
	22 - 26	Aesthesiometry, right
	28	Lens deposit colour, right
	30 - 33	Pachometry temporal 30 degrees, right
	35 - 38	Pachometry inferior 30 degrees, right
	40 - 43	Pachometry nasal 30 degrees, right
	45 - 48	Pachometry superior 30 degrees, right
	50 - 54	Over refraction sphere, right
	60 - 64	Spectacle refraction sphere, right
	70	Red eye, right

Line	Columns	Variable recorded
2	1 - 2	Patient number
	4 - 5	Visit number
	7	Card number
	9 - 13	Keratometry min radius, right
	15 - 17	Keratometry min radius axis, right
	20	Tarsal conjunctiva, right
	23 - 26	Central pachometry, right
	28	Lens deposit appearance, right
	30 - 33	Pachometry temporal 15 degrees, right
	35 - 38	Pachometry inferior 15 degrees, right
	40 - 43	Pachometry nasal 15 degrees, right
	45 - 48	Pachometry superior 15 degrees, right
	50 - 54	Over refraction cylinder, right
	56 - 58	Over refraction cylinder axis, right
	60 - 64	Spectacle refraction cylinder, right
	66 - 68	Spectacle refraction cylinder axis, right
	70	Contact lens condition
3	1 - 2	Patient number
	4 - 5	Visit number
	7	Card number
	9 - 13	Keratometry max radius, left
	15 - 17	Keratometry max radius axis, left
	19 - 20	Visual acuity, left
	22 - 26	Aesthosiometry, left
	28	Lens deposit colour, left
	30 - 3	Pachometry temporal 30 degrees, left

Line	Columns	Variable recorded
3 continued.	35 - 38	Pachometry inferior 30 degrees, left
	40 - 43	Pachometry nasal 30 degrees, left
	45 - 48	Pachometry superior 30 degrees, left
	50 - 54	Over refraction sphere, left
	60 - 64	Spectacle refraction sphere, left
	70	Red eye, left
4	1 - 2	Patient number
	4 - 5	Visit number
	7	Card number
	9 - 13	Keratometry min radius, left
	15 - 17	Keratometry min radius axis, left
	20	Tarsal conjunctiva, left
	23 - 26	Lectral pachometry, left
	28	Lens deposit appearance, left
	30 - 33	Pachometry temporal 15 degrees, left
	35 - 38	Pachometry inferior 15 degrees, left
	40 - 43	Pachometry nasal 15 degrees, left
	45 - 48	Pachometry superior 15 degrees, left
	50 - 54	Over refraction cylinder, left
	56 - 58	Over refraction cylinder axis, left
	60 - 64	Spectacle refraction cylinder, left
	66 - 68	Spectacle refraction cylinder axis, left
	70	Contact lens condition, left

01	01	1	7.600	100	4		0.61	0.63	0.66	0.69		-0.50	
01	01	2	7.525	005	3	0.57	0.55	0.58	0.51	0.56		-0.25	100
01	01	3	7.500	090	4		0.58	0.64	0.66	0.64		-0.25	
01	01	4	7.500	180	3	0.52	0.56	0.59	0.61	0.57		-0.25	175
01	02	1			4								
01	02	2				0.55							
01	02	3			4								
01	02	4				0.57							
01	03	1			4								
01	03	2				0.52							
01	03	3			4								
01	03	4				0.53							
01	04	1			4								
01	04	2				0.52							
01	04	3			4								
01	04	4				0.53							
01	05	1			4								
01	05	2				0.54							
01	05	3			4								
01	05	4				0.55							
01	06	1			4								
01	06	2			3	0.54							
01	06	3			4								
01	06	4			3	0.56							
01	07	1			4								
01	07	2			3	0.54							
01	07	3			4								
01	07	4			3	0.55							
01	08	1			4	1.08						-0.75	
01	08	2			3	0.53						-0.50	010
01	08	3			4	0.96						-0.25	
01	08	4			3	0.54						-0.25	180
01	09	1			4	1.08						-0.50	
01	09	2			3	0.51						-0.50	180
01	09	3			4	11.60						-0.25	
01	09	4			3	0.53						0.00	000
01	10	1	7.575	005	4	1.08	0.61	0.65	0.66	0.64		-0.50	
01	10	2	7.550	090	3	0.53	0.55	0.55	0.56	0.59		-0.25	015
01	10	3	7.550	175	4	0.96	0.57	0.62	0.63	0.65		-0.25	
01	10	4	7.525	075	3	0.54	0.55	0.56	0.58	0.60		-0.25	180
01	11	1											
01	11	2											
01	11	3											
01	11	4											
02	01	1	3.125	170	4	0.96	0.67	0.64	0.76	0.66		-0.50	
02	01	2	7.925	080	1	0.57	0.63	0.62	0.65	0.65		-0.50	100
02	01	3	8.250	005	4	0.96	0.64	0.65	0.79	0.79		-0.50	
02	01	4	8.075	100	1	0.59	0.61	0.64	0.67	0.65		-0.25	060
02	02	1			4								
02	02	2				0.59							
02	02	3			4								
02	02	4				0.58							
02	03	1			4								
02	03	2				0.60							
02	03	3			4								
02	03	4				0.59							
02	04	1			4								
02	04	2				0.60							
02	04	3			4								
02	04	4				0.59							
02	05	1			4								
02	05	2				0.58							
02	05	3			4								
02	05	4				0.59							
02	06	1			4								
02	06	2			1	0.58							
02	06	3			4								
02	06	4			1	0.59							
02	07	1			4								
02	07	2			1	0.59							

02	07	3			4								
02	07	4			1	0.61							
02	08	1			4	0.96						-0.50	
02	08	2			1	0.59						-0.50	100
02	08	3			4	0.96						-0.50	
02	08	4			1	0.59						-0.25	060
02	09	1			4	0.96						-0.50	
02	09	2			1	0.57						-0.25	095
02	09	3			4	0.96						-0.25	
02	09	4			1	0.58						-0.25	080
02	10	1			4	0.96	0.67	0.61	0.69	0.66		-0.50	
02	10	2			1	0.57	0.61	0.61	0.63	0.63		-0.25	095
02	10	3			4	0.96	0.65	0.61	0.78	0.66		-0.50	
02	10	4			1	0.59	0.59	0.61	0.66	0.64		0.00	000
02	11	1	8.125	175	4	0.96	0.67	0.62	0.75	0.77		-0.50	
02	11	2	7.925	080	1	0.57	0.62	0.61	0.62	0.63		-0.25	115
02	11	3	8.250	005	4	0.96	0.69	0.64	0.77	0.79		-0.50	
02	11	4	8.075	100	1	0.60	0.61	0.62	0.66	0.65		0.00	000
03	01	1	8.075	005	4	1.08	0.58	0.61	0.60	0.67		0.50	
03	01	2	7.925	095	2	0.50	0.52	0.50	0.54	0.57		0.00	000
03	01	3	8.050	180	4	0.96	0.53	0.60	0.65	0.63		0.50	
03	01	4	7.900	095	2	0.50	0.50	0.52	0.56	0.52		0.00	000
03	02	1			4								
03	02	0				0.51							
03	02	3			4								
03	02	4				0.50							
03	03	1			4								
03	03	2				0.49							
03	03	3			4								
03	03	4				0.49							
03	04	1			4								
03	04	2				0.51							
03	04	3			4								
03	04	4				0.51							
03	05	1			4								
03	05	2				0.50							
03	05	3			4								
03	05	4				0.50							
03	06	1			4								
03	06	2			2	0.49							
03	06	3			4								
03	06	4			2	0.50							
03	07	1			4								
03	07	2			2	0.49							
03	07	3			4								
03	07	4			2	0.49							
03	08	1			4	1.08						0.50	
03	08	2			2	0.50						0.00	000
03	08	3			4	0.96						0.25	
03	08	4			2	0.50						-0.50	005
03	09	1			4	0.96						0.25	
03	09	2			2	0.49						0.00	000
03	09	3			4	0.96						0.50	
03	09	4			2	0.49						0.25	180
03	10	1	8.050	180	4	0.96	0.57	0.61	0.61	0.63		0.75	
03	10	2	7.900	080	2	0.49	0.49	0.56	0.52	0.54		-0.25	095
03	10	3	8.050	180	4	1.08	0.53	0.59	0.61	0.66		0.50	
03	10	4	7.875	080	2	0.49	0.49	0.53	0.55	0.54		-0.25	020
03	11	1	8.100	015	4	0.96	0.56	0.58	0.59	0.63		0.50	
03	11	2	7.925	095	2	0.49	0.51	0.50	0.51	0.53		0.00	000
03	11	3	8.050	005	4	0.96	0.55	0.57	0.63	0.65		0.75	
03	11	4	7.900	095	2	0.50	0.50	0.51	0.53	0.55		-0.25	180
04	01	1	8.000	070	4	0.96	0.58	0.60	0.62	0.64		-0.50	
04	01	2	7.925	175	2	0.49	0.50	0.51	0.50	0.52		-0.50	075
04	01	3	7.950	095	4	0.96	0.58	0.58	0.64	0.61		-0.75	
04	01	4	7.800	005	2	0.49	0.48	0.50	0.52	0.53		-0.50	090
04	02	1			4								
04	02	2				0.50							
04	02	3			4								
04	02	4				0.51							

04	03	1			4						-0.50	
04	03	2				0.49					-0.50	085
04	03	3			4						-0.75	
04	03	4				0.50					-0.75	095
04	04	1			4						-0.50	
04	04	2				0.51					-0.50	085
04	04	3			4						-1.00	
04	04	4				0.51					-0.50	095
04	05	1			4						-0.75	
04	05	2				0.51					-0.25	085
04	05	3			4						-1.00	
04	05	4				0.49					-0.50	095
04	06	1			4						-0.75	
04	06	2			2	0.50					-0.25	085
04	06	3			4						-1.00	
04	06	4			2	0.48					-0.50	095
04	07	1			4						-0.75	
04	07	2			2	0.49					-0.25	085
04	07	3			4						-1.00	
04	07	4			2	0.48					-0.50	095
04	08	1			4	0.96					-0.75	
04	08	2			2	0.48					-0.25	085
04	08	3			4	0.96					-1.00	
04	08	4			2	0.47					-0.50	095
04	09	1			4	0.96					-0.75	
04	09	2			2	0.50					-0.25	085
04	09	3			4	0.96					-1.00	
04	09	4			2	0.49					-0.50	095
04	10	1			4	0.96	0.59	0.59	0.57	0.65	-0.75	
04	10	2			2	0.49	0.50	0.51	0.51	0.54	-0.25	085
04	10	3			4	0.96	0.59	0.61	0.63	0.65	-1.00	
04	10	4			2	0.49	0.53	0.52	0.54	0.53	-0.50	095
04	11	1	7.950	170	4	0.96	0.59	0.57	0.60	0.65	-0.25	
04	11	2	7.955	065	2	0.49	0.53	0.51	0.55	0.55	-0.50	085
04	11	3	7.850	085	4	1.08	0.55	0.59	0.67	0.65	-0.75	
04	11	4	7.800	175	2	0.49	0.49	0.54	0.53	0.55	-0.50	095
05	01	1	8.300	165	4	0.96	0.65	0.69	0.71	0.71	-1.50	
05	01	2	8.225	060	2	0.59	0.61	0.61	0.62	0.63	-0.50	150
05	01	3	8.225	160	4	0.96	0.67	0.67	0.73	0.71	-1.75	
05	01	4	8.125	060	2	0.59	0.63	0.65	0.67	0.67	-0.25	095
05	02	1			4							
05	02	2				0.59						
05	02	3			4							
05	02	4				0.61						
05	03	1			4							
05	03	2				0.60						
05	03	3			4							
05	03	4				0.61						
05	04	1			4							
05	04	2				0.59						
05	04	3			4							
05	04	4				0.60						
05	05	1			4							
05	05	2				0.60						
05	05	3			4							
05	05	4				0.60						
05	06	1			4							
05	06	2			2	0.60						
05	06	3			4							
05	06	4			2	0.60						
05	07	1			4							
05	07	2			2	0.60						
05	07	3			4							
05	07	4			2	0.61						
05	08	1			4	1.08					-1.50	
05	08	2			2	0.59					-0.75	160
05	08	3			4	1.16					-2.00	
05	08	4			2	0.61					0.00	000
05	09	1			4	0.96					-1.50	
05	09	2			2	0.53					-0.50	160

05	09	3			4	1.08						-2.00	
05	09	4			2	0.59						0.00	000
05	10	1			4	0.96	0.66	0.69	0.73	0.72		-1.50	
05	10	2			2	0.59	0.62	0.63	0.64	0.64		-0.50	160
05	10	3			4	1.08	0.69	0.69	0.76	0.75		-2.00	
05	10	4			2	0.61	0.63	0.64	0.65	0.65		0.00	000
05	11	1	8.300	165	4	1.08	0.63	0.66	0.71	0.71		-1.50	
05	11	2	8.225	065	2	0.58	0.59	0.61	0.63	0.63		-0.50	160
05	11	3	8.225	150	4	1.40	0.67	0.67	0.77	0.73		-2.00	
05	11	4	8.125	065	2	0.59	0.61	0.63	0.67	0.65		0.00	000
06	01	1	7.500	080	4	1.08	0.56	0.59	0.56	0.63		0.00	
06	01	2	7.475	165	2	0.49	0.51	0.50	0.52	0.53		-0.25	010
06	01	3	7.500	180	4	1.08	0.55	0.63	0.60	0.60		1.00	
06	01	4	7.375	085	2	0.49	0.50	0.58	0.53	0.59		-0.25	090
06	02	1			4								
06	02	2				0.48							
06	02	3			4								
06	02	4				0.48							
06	03	1			4								
06	03	2				0.51							
06	03	3			4								
06	03	4				0.51							
06	04	1			4								
06	04	2				0.49							
06	04	3			4								
06	04	4				0.50							
06	05	1			4								
06	05	2				0.49							
06	05	3			4								
06	05	4				0.49							
06	06	1			4								
06	06	2			2	0.49							
06	06	3			4								
06	06	4			2	0.50							
06	07	1			4								
06	07	2			2	0.49							
06	07	3			4								
06	07	4			2	0.49							
06	08	1			4	1.40						0.00	
06	08	2			2	0.49						-0.25	175
06	08	3			4	0.96						1.00	
06	08	4			2	0.48						-0.25	090
06	09	1			4	2.40						-0.25	
06	09	2			2	0.48						0.00	000
06	09	3			4	0.96						1.00	
06	09	4			2	0.48						0.00	000
06	10	1			4	2.40	0.55	0.57	0.58	0.62		-0.25	
06	10	2			2	0.48	0.51	0.51	0.52	0.52		0.00	000
06	10	3			4	0.96	0.55	0 61	0.59	0.62		1.00	
06	10	4			2	0.49	0.51	0.51	0.53	0.52		0.00	000
06	11	1	7.475	180	4	1.08	0.53	0.60	0.59	0.59		0.25	
06	11	2	7.350	085	1	0.48	0.51	0.50	0.51	0.57		-0.25	130
06	11	3	7.525	180	4	0.96	0.53	0.61	0.61	0.63		0.75	
06	11	4	7.350	095	1	0.49	0.51	0.51	0.54	0.53		-0.25	140
07	01	1	8.200	005	04	1.10	0.67	0.69	0.71	0.72		0.50	
07	01	2	8.125	094	2	0.58	0.61	0.61	0.63	0.62		-0.25	095
07	01	3	8.200	094	04	0.96	0.65	0.69	0.70	0.74		0.50	
07	01	4	8.075	003	2	0.59	0.59	0.60	0.65	0.63		-0.25	095
07	02	1			04								
07	02	2				0.59							
07	02	3			04								
07	02	4				0.58							
07	03	1			04								
07	03	2				0.59							
07	03	3			04								
07	03	4				0.58							
07	04	1			04								
07	04	2				0.57							
07	04	3			04								
07	04	4				0.57							

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07 05 1                 04
07 05 2                  2  0.59
07 05 3                 04
07 05 4                  2  0.59
07 06 1                 04
07 06 2                    0.58
07 06 3                 04
07 06 4                    0.58
07 07 1                 04
07 07 2                    0.58
07 07 3                 04
07 07 4                    0.57
07 08 1                 04  0.96                                          0.50
07 08 2                  2  0.57                                          0.00 000
07 08 3                 04  0.96                                          0.00
07 08 4                  2  0.58                                          0.00 000
07 09 1                 04  0.96                                          0.25
07 09 2                  2  0.58                                          0.00 000
07 09 3                 04  1.08                                          0.00
07 09 4                  2  0.57                                          0.00 000
07 10 1 8.200 075       04  1.16   0.67 0.67 0.71 0.71                     0.25
07 10 2 8.075 180        2  0.57   0.59 0.59 0.63 0.63                     0.00 000
07 10 3 8.200 180       04  1.08   0.63 0.67 0.71 0.69                     0.50
07 10 4 8.075 090        2  0.57   0.57 0.61 0.63 0.63                     0.00 000
07 11 1
07 11 2
07 11 3
07 11 4
08 01 1 7.575 000        4  0.96   0.63 0.64 0.65 0.68                     0.50
08 01 2 7.450 090        2  0.57   0.57 0.59 0.59 0.62                    -0.25 085
08 01 3 7.600 170        4  0.96   0.61 0.65 0.67 0.66                     0.75
08 01 4 7.575 095        1  0.57   0.58 0.58 0.60 0.61                     0.00 000
08 02 1                  4
08 02 2                    0.58
08 02 3                  4
08 02 4                    0.57
08 03 1                  4
08 03 2                    0.56
08 03 3                  4
08 03 4                    0.55
08 04 1                  4
08 04 2                    0.57
08 04 3                  4
08 04 4                    0.58
08 05 1                  4
08 05 2                    0.55
08 05 3                  4
08 05 4                    0.57
08 06 1                  4
08 06 2                  2  0.57
08 06 3                  4
08 06 4                  1  0.57
08 07 1                  4
08 07 2                  2  0.57
08 07 3                  4
08 07 4                  2  0.57
08 08 1                  4  1.08                                          0.50
08 08 2                  2  0.57                                         -0.25 085
08 08 3                  4  1.08                                          0.75
08 08 4                  1  0.58                                         -0.25 100
08 09 1                  4  2.40                                          0.50
08 09 2                  2  0.57                                         -0.25 085
08 09 3                  4  1.40                                          0.50
08 09 4                  2  0.58                                         -0.25 100
08 10 1                  4  1.16   0.61 0.67 0.65 0.65                     0.50
08 10 2                  2  0.58   0.59 0.58 0.60 0.61                    -0.25 095
08 10 3                  4  1.40   0.60 0.63 0.67 0.67                     0.50
08 10 4                  2  0.56   0.57 0.59 0.61 0.59                    -0.50 100
08 11 1 7.600 180        4  1.40   0.63 0.65 0.65 0.67                     0.25
08 11 2 7.475 080        2  0.57   0.58 0.59 0.59 0.60                    -0.25 090
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08 11 3 7.700 000   4  3.20   0.63 0.66 0.70 0.67          0.25
08 11 4 7.575 075   2  0.57   0.60 0.58 0.62 0.61         -0.25 100
09 01 1 7.850 005   4  0.96   0.68 0.75 0.78 0.76          0.50
09 01 2 7.825 090   2  0.60   0.62 0.63 0.63 0.64         -0.25 110
09 01 3 7.800 175   4  0.96   0.69 0.71 0.73 0.78          0.50
09 01 4 7.675 085   2  0.59   0.61 0.65 0.63 0.68          0.00 000
09 02 1
09 02 2
09 02 3
09 02 4
09 03 1
09 03 2
09 03 3
09 03 4
09 04 1
09 04 2
09 04 3
09 04 4
09 05 1
09 05 2
09 05 3
09 05 4
09 06 1
09 06 2
09 06 3
09 06 4
09 07 1             4
09 07 2                0.59
09 07 3             4
09 07 4                0.59
09 08 1
09 08 2
09 08 3
09 08 4
09 09 1
09 09 2
09 09 3
09 09 4
09 10 1 7.850 005   4  1.08   0.71 0.70 0.69 0.69          0.25
09 10 2 7.750 100   2  0.59   0.61 0.65 0.62 0.62          0.00 000
09 10 3 7.775 155   4  0.96   0.68 0.69 0.71 0.74          0.25
09 10 4 7.675 070   2  0.59   0.62 0.63 0.65 0.63          0.00 000
09 11 1 7.850 010   4  0.96   0.70 0.71 0.69 0.65          0.25
09 11 2 7.800 080   2  0.60   0.61 0.63 0.63 0.63         -0.25 110
09 11 3 7.825 180   4  0.96   0.67 0.69 0.71 0.73          0.25
09 11 4 7.775 080   2  0.59   0.62 0.61 0.63 0.65         -0.25 085
10 01 1 8.250 180   4  0.96   0.67 0.70 0.70 0.73          0.00
10 01 2 8.025 090   1  0.58   0.61 0.61 0.62 0.65         -0.25 180
10 01 3 8.225 175   4  0.96   0.65 0.71 0.69 0.75         -1.00
10 01 4 8.125 180   1  0.58   0.61 0.64 0.62 0.62         -0.25 015
10 02 1             4
10 02 2                0.59
10 02 3             4
10 02 4                0.58
10 03 1             4
10 03 2                0.59
10 03 3             4
10 03 4                0.58
10 04 1             4
10 04 2                0.59
10 04 3             4
10 04 4                0.60
10 05 1             4
10 05 2                0.60
10 05 3             4
10 05 4                0.59
10 06 1             4
10 06 2             1  0.58
10 06 3             4
10 06 4             1  0.60
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10	07	1			4								
10	07	2			1	0.57							
10	07	3			4								
10	07	4			1	0.58							
10	08	1			4	0.96						0.00	
10	08	2			1	0.57						-0.25	180
10	08	3			4	0.96						1.00	
10	08	4			1	0.57						-0.50	005
10	09	1			4	0.96						0.00	
10	09	2			4	0.58						-0.25	180
10	09	3			4	1.08						-1.00	
10	09	4			4	0.57						-0.50	005
10	10	1	8.275	180	4	0.96	0.65	0.71	0.64	0.75		0.00	
10	10	2	7.925	100	1	0.57	0.58	0.61	0.59	0.62		-0.25	180
10	10	3	8.250	175	4	0.96	0.61	0.67	0.71	0.69		-1.00	
10	10	4	8.050	085	1	0.57	0.59	0.61	0.61	0.63		-0.25	175
10	11	1	8.275	005	4	0.96	0.67	0.72	0.65	0.73		0.00	
10	11	2	7.975	090	1	0.59	0.61	0.62	0.61	0.69		-0.25	180
10	11	3	8.250	175	4	0.96	0.67	0.71	0.70	0.73		-1.00	
10	11	4	8.100	095	1	0.60	0.61	0.61	0.65	0.65		-0.25	175
11	01	1	8.400	005	4	1.08	0.61	0.58	0.60	0.65		0.00	
11	01	2	8.250	095	2	0.52	0.55	0.51	0.55	0.57		-0.25	115
11	01	3	8.425	075	4	0.96	0.60	0.59	0.65	0.69		0.25	
11	01	4	8.425	170	2	0.53	0.55	0.54	0.57	0.57		0.00	000
11	02	1			4								
11	02	2				0.54							
11	02	3			4								
11	02	4				0.55							
11	03	1			4								
11	03	2				0.53							
11	03	3			4								
11	03	4				0.52							
11	04	1			4								
11	04	2				0.53							
11	04	3			4								
11	04	4				0.53							
11	05	1			4								
11	05	2				0.55							
11	05	3			4								
11	05	4				0.55							
11	06	1			4								
11	06	2			2	0.51							
11	06	3			4								
11	06	4			2	0.51							
11	07	1			4								
11	07	2			2	0.52							
11	07	3			4								
11	07	4			2	0.51							
11	08	1			4	0.96						-0.25	
11	08	2			2	0.53						0.00	000
11	08	3			4	0.96						0.00	
11	08	4			2	0.52						0.00	000
11	09	1			4	0.96						-0.25	
11	09	2			2	0.52						0.00	000
11	09	3			4	0.96						-0.25	
11	09	4			2	0.51						0.00	000
11	10	1			4	0.96	0.61	0.57	0.61	0.67		0.00	
11	10	2			2	0.52	0.53	0.53	0.56	0.59		0.00	000
11	10	3			4	0.96	0.59	0.62	0.63	0.69		0.25	
11	10	4			2	0.51	0.54	0.55	0.56	0.57		-0.25	010
11	11	1	8.400	015	4	1.08	0.59	0.60	0.62	0.67		0.25	
11	11	2	8.275	085	2	0.51	0.53	0.52	0.57	0.56		0.00	000
11	11	3	8.425	175	4	0.96	0.59	0.59	0.65	0.67		0.25	
11	11	4	8.300	070	2	0.53	0.53	0.56	0.59	0.55		-0.25	020
12	01	1	7.800	165	4	1.16	0.65	0.67	0.73	0.70		-0.50	
12	01	2	7.625	075	2	0.53	0.58	0.59	0.57	0.63		-0.25	115
12	01	3	7.800	040	4	1.08	0.60	0.66	0.71	0.72		-0.50	
12	01	4	7.700	120	2	0.54	0.56	0.58	0.63	0.62		-0.50	060
12	02	1			4								
12	02	2				0.57							

12	02	3			4							
12	02	4				0.57						
12	03	1			4							
12	03	2				0.53						
12	03	3			4							
12	03	4				0.54						
12	04	1			4							
12	04	2				0.55						
12	04	3			4							
12	04	4				0.55						
12	05	1			4							
12	05	2				0.55						
12	05	3			4							
12	05	4				0.55						
12	06	1			4							
12	06	2			2	0.55						
12	06	3			4							
12	06	4			2	0.55						
12	07	1			4							
12	07	2			2	0.54						
12	07	3			4							
12	07	4			2	0.55						
12	08	1			4	0.96					0.50	
12	08	2			2	0.53					-0.25	135
12	08	3			4	0.96					-0.50	
12	08	4			2	0.54					-0.25	055
12	09	1			4	0.96					-0.75	
12	09	2			2	0.53					0.00	000
12	09	3			4	0.96					-0.50	
12	09	4			2	0.54					-0.25	055
12	10	1			4	1.08	0.63	0.63	0.69	0.67	-0.50	
12	10	2			2	0.53	0.55	0.59	0.58	0.59	0.00	000
12	10	3			4	1.08	0.57	0.65	0.70	0.70	-0.50	
12	10	4			2	0.54	0.55	0.59	0.59	0.61	-0.25	055
12	11	1	7.800	170	4	0.96	0.62	0.63	0.65	0.70	-0.50	
12	11	2	7.650	065	2	0.53	0.56	0.61	0.57	0.58	0.00	000
12	11	3	7.825	045	4	1.08	0.59	0.62	0.71	0.71	-0.50	
12	11	4	7.700	120	2	0.54	0.55	0.59	0.63	0.61	-0.25	055
13	01	1	7.800	165	4	1.40	0.60	0.68	0.66	0.73	0.25	
13	01	2	7.575	080	2	0.52	0.55	0.54	0.55	0.55	-0.25	175
13	01	3	7.850	005	4	1.08	0.61	0.63	0.68	0.71	0.25	
13	01	4	7.625	095	2	0.53	0.53	0.55	0.54	0.59	-0.25	015
13	02	1			4							
13	02	2				0.52						
13	02	3			4							
13	02	4				0.53						
13	03	1			4							
13	03	2				0.52						
13	03	3			4							
13	03	4				0.52						
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13	04	4				0.54						
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13	05	2				0.53						
13	05	3			4							
13	05	4				0.54						
13	06	1			4							
13	06	2			2	0.51						
13	06	3			4							
13	06	4			2	0.50						
13	07	1			4							
13	07	2			2	0.51						
13	07	3			4							
13	07	4			2	0.53						
13	08	1			4	1.84					0.25	
13	08	2			2	0.50					-0.25	180
13	08	3			4	1.84					-0.25	
13	08	4			2	0.50					0.00	000

13	09	1			4	1.08					0.25	
13	09	2			2	0.51					-0.25	005
13	09	3			4	1.16					0.00	
13	09	4			2	0.51					0.00	000
13	10	1	7.600	165	4	1.04	0.61	0.65	0.63	0.72	0.25	
13	10	2	7.500	075	2	0.52	0.54	0.55	0.55	0.56	0.00	000
13	10	3	7.850	005	4	1.16	0.59	0.63	0.65	0.72	0.00	
13	10	4	7.625	090	2	0.52	0.55	0.55	0.56	0.57	0.00	000
13	11	1	7.800	165	4	1.40	0.61	0.63	0.68	0.68	0.25	
13	11	2	7.500	070	2	0.52	0.55	0.52	0.57	0.57	0.00	000
13	11	3	7.850	005	4	4.60	0.57	0.63	0.69	0.69	0.00	
13	11	4	7.625	090	2	0.52	0.53	0.55	0.60	0.57	0.00	000
14	01	1	7.450	005	4	1.08	0.64	0.65	0.66	0.61	0.00	
14	01	2	7.300	100	1	0.56	0.56	0.55	0.59	0.58	0.00	000
14	01	3	7.450	180	4	1.08	0.60	0.65	0.68	0.61	10.25	
14	01	4	7.325	085	1	0.57	0.56	0.58	0.59	0.58	0.25	035
14	02	1			4							
14	02	2				0.57						
14	02	3			4							
14	02	4				0.58						
14	03	1			4							
14	03	2				0.57						
14	03	3			4							
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14	04	2				0.58						
14	04	3			4							
14	04	4				0.59						
14	05	1			4							
14	05	2				0.58						
14	05	3			4							
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14	06	2										
14	06	3										
14	06	4										
14	07	1										
14	07	2										
14	07	3										
14	07	4										
14	08	1			4	0.96					0.00	
14	08	2			1	0.58					-0.25	005
14	08	3			4	0.96					0.00	
14	08	4			1	0.59					0.00	000
14	09	1										
14	09	2										
14	09	3										
14	09	4										
14	10	1			4	1.08	0.63	0.67	0.65	0.71	0.00	
14	10	2			2	0.58	0.59	0.59	0.60	0.63	0.00	000
14	10	3			4	1.08	0.64	0.67	0.69	0.68	0.00	
14	10	4			2	0.57	0.63	0.59	0.65	0.64	0.00	000
14	11	1										
14	11	2										
14	11	3										
14	11	4										
15	01	1	7.450	165	4	0.96	0.56	0.50	0.55	0.60	-4.50	
15	01	2	7.325	180	2	0.48	0.49	0.48	0.52	0.51	-1.00	150
15	01	3	7.525	160	4	1.08	0.56	0.54	0.58	0.59	-5.25	
15	01	4	7.475	085	3	0.47	0.49	0.50	0.52	0.50	-1.00	010
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15	02	2				0.46						
15	02	3			4							
15	02	4				0.47						
15	03	1										
15	03	2										
15	03	3										
15	03	4										
15	04	1			4							
15	04	2				0.48						

15	04	3			4						-4.50	
15	04	4				0.49					-1.00	150
15	05	1			4						-5.00	
15	05	2				0.45					-1.00	010
15	05	3			4							
15	05	4				0.45						
15	06	1			4							
15	06	2				0.47						
15	06	3			4							
15	06	4				0.47						
15	07	1			4							
15	07	2				0.46						
15	07	3			4							
15	07	4				0.47						
15	08	1			4	0.96					-4.50	
15	08	2			2	0.47					-1.00	150
15	08	3			5	0.96					-5.00	
15	08	4			2	0.48					-1.00	010
15	09	1										
15	09	2										
15	09	3										
15	09	4										
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15	10	2										
15	10	3										
15	10	4										
15	11	1										
15	11	2										
15	11	3										
15	11	4										
16	01	1	8.150	025	4	0.96	0.66	0.74	0.72	0.77	0.25	
16	01	2	8.050	090	2	0.59	0.61	0.60	0.63	0.63	0.00	000
16	01	3	8.150	170	4	1.08	0.66	0.69	0.76	0.77	0.25	
16	01	4	8.050	075	2	0.59	0.61	0.62	0.66	0.66	0.00	000
16	02	1			4							
16	02	2				0.59						
16	02	3			4							
16	02	4				0.59						
16	03	1			4							
16	03	2				0.60						
16	03	3			4							
16	03	4				0.60						
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16	04	2				0.60						
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16	04	4				0.61						
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16	05	2				0.59						
16	05	3			4							
16	05	4				0.58						
16	06	1			4							
16	06	2			2	0.58						
16	06	3			4							
16	06	4			2	0.59						
16	07	1			4							
16	07	2			2	0.59						
16	07	3			4							
16	07	4			2	0.59						
16	08	1			4	0.96					0.25	
16	08	2			2	0.60					0.00	000
16	08	3			4	0.96					0.25	
16	08	4			2	0.59					0.00	000
16	09	1			4	0.96					0.25	
16	09	2			2	0.58					0.00	000
16	09	3			4	0.96					0.25	
16	09	4			2	0.59					0.00	000
16	10	1	8.125	010	4	0.96	0.67	0.67	0.71	0.75	0.25	
16	10	2	8.050	085	2	0.59	0.60	0.59	0.63	0.64	0.00	000
16	10	3	8.175	000	4	0.96	0.65	0.67	0.75	0.75	0.50	
16	10	4	8.000	100	2	0.60	0.61	0.62	0.64	0.63	-0.25	130

16	11	1	8.175	010	4	0.96	0.67	0.73	0.71	0.75	0.25	
16	11	2	8.025	090	2	0.60	0.61	0.63	0.63	0.65	0.00	000
16	11	3	8.175	175	4	1.08	0.65	0.71	0.76	0.77	0.25	
16	11	4	8.050	090	2	0.59	0.59	0.64	0.65	0.67	0.00	000
17	01	1	7.750	175	4	0.96	0.56	0.65	0.64	0.70	-0.25	
17	01	2	7.725	080	1	0.53	0.54	0.54	0.52	0.5o	-0.25	125
17	01	3	7.875	005	4	0.96	0.58	0.62	0.69	0.77	-0.25	
17	01	4	7.775	090	1	0.53	0.57	0.54	0.53	0.56	-0.25	070
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17	02	2				0.53						
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17	02	4				0.54						
17	03	1			4							
17	03	2				0.55						
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17	03	4				0.56						
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17	05	2				0.57						
17	05	3			4							
17	05	4				0.56						
17	06	1			4							
17	06	2				0.54						
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17	06	4				0.56						
17	07	1			4							
17	07	2				0.56						
17	07	3			4							
17	07	4				0.57						
17	08	1			4	1.08					-0.25	
17	08	2			2	0.57					-0.25	115
17	08	3			4	1.08					0.00	
17	08	4			2	0.56					-0.25	080
17	09	1			4	0.96					-0.25	
17	09	2			2	0.53					-0.25	115
17	09	3			4	0.96					-0.25	
17	09	4			2	0.54					-0.25	084
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17	10	2										
17	10	3										
17	10	4										
17	11	1										
17	11	2										
17	11	3										
17	11	4										
18	01	1	7.775	165	4	1.08	0.61	0.77	0.77	0.67	2.25	
18	01	2	7.650	060	2	0.55	0.56	0.60	0.60	0.61	0.00	000
18	01	3	7.750	020	5	1.16	0.62	0.69	0.74	0.72	3.25	
18	01	4	7.550	115	2	0.56	0.56	0.61	0.63	0.63	0.00	000
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18	02	2				0.55						
18	02	3			4							
18	02	4				0.55						
18	03	1			4							
18	03	2				0.57						
18	03	3			4							
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18	04	4				0.57						
18	05	1			4							
18	05	2				0.57						
18	05	3			4							
18	05	4				0.55						
18	06	1			4							
18	06	2			2	0.57						

18	06	3			4								
18	06	4			2	0.56							
18	07	1			4								
18	07	2			2	0.57							
18	07	3			4								
18	07	4			2	0.55							
18	08	1			4	0.96						2.00	
18	08	2			2	0.55						0.00	000
18	08	3			4	1.16						3.25	
18	08	4			2	0.56						-0.25	030
18	09	1			4	0.96						2.00	
18	09	2			2	0.55						0.00	000
18	09	3			5	1.16						3.25	
18	09	4			2	0.56						-0.25	035
18	10	1	7.850	175	4	1.08	0.63	0.69	0.65	0.77		2.00	
18	10	2	7.600	070	2	0.55	0.57	0.61	0.60	0.63		0.00	000
18	10	3	7.750	015	5	2.40	0.61	0.68	0.66	0.76		3.25	
18	10	4	7.575	115	2	0.55	0.55	0.59	0.54	0.61		-0.25	025
18	11	1	7.800	160	4	1.16	0.67	0.67	0.65	0.69		2.25	
18	11	2	7.625	060	2	0.55	0.57	0.59	0.63	0.60		-0.25	140
18	11	3	7.775	010	5	2.40	0.59	0.72	0.76	0.72		3.50	
18	11	4	7.575	100	2	0.56	0.56	0.61	0.62	0.62		-0.25	025
19	01	1	8.050	125	4	1.16	0.64	0.67	0.70	0.72		0.50	
19	01	2	8.025	025	2	0.57	0.59	0.61	0.61	0.61		-0.50	090
19	01	3	8.075	005	4	1.16	0.63	0.67	0.72	0.72		0.25	
19	01	4	8.025	100	2	0.57	0.57	0.61	0.62	0.63		-0.25	005
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19	04	3			4								
19	04	4				0.59							
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19	05	2				0.58							
19	05	3			4								
19	05	4				0.57							
19	06	1			4								
19	06	2			2	0.58							
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19	06	4			2	0.59							
19	07	1			4								
19	07	2			2	0.57							
19	07	3			4								
19	07	4			2	0.58							
19	08	1			4	1.16						0.25	
19	08	2			2	0.56						-0.50	110
19	08	3			4	1.16						0.25	
19	08	4			2	0.57						0.00	000
19	09	1			4	1.08						0.25	
19	09	2			2	0.57						-0.50	100
19	09	3			4	1.16						0.25	
19	09	4			2	0.57						0.00	000
19	10	1	8.125	110	4	1.40	0.63	0.67	0.69	0.73		0.25	
19	10	2	8.050	015	2	0.56	0.57	0.58	0.59	0.61		-0.25	100
19	10	3	8.100	165	4	1.08	0.61	0.69	0.73	0.72		0.25	
19	10	4	8.050	075	2	0.57	0.57	0.58	0.64	0.60		-0.25	040
19	11	1	8.125	105	4	1.16	0.65	0.69	0.67	0.69		0.25	
19	11	2	8.050	015	2	0.57	0.57	0.59	0.59	0.59		-0.25	090
19	11	3	8.125	165	4	1.16	0.63	0.68	0.75	0.73		0.50	
19	11	4	8.025	090	2	0.57	0.57	0.61	0.53	0.61		-0.50	005
20	01	1	7.950	005	4	0.96	0.65	0.63	0.65	0.71		-0.25	
20	01	2	7.800	095	2	0.58	0.61	0.59	0.59	0.61		-0.25	010
20	01	3	7.950	160	4	0.96	0.65	0.63	0.65	0.71		-0.50	
20	01	4	7.725	080	2	0.57	0.61	0.59	0.59	0.61		0.00	000

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20 02 4                    0.56
20 03 1                  4
20 03 2                    0.56
20 03 3                  4
20 03 4                    0.57
20 04 1                  4
20 04 2                    0.57
20 04 3                  4
20 04 4                    0.57
20 05 1                  4
20 05 2                    0.58
20 05 3                  4
20 05 4                    0.57
20 06 1                  4
20 06 2                  2 0.54
20 06 3                  4
20 06 4                  2 0.55
20 07 1                  4
20 07 2                  2 0.57
20 07 3                  4
20 07 4                  2 0.58
20 08 1                  4 0.96                                          0.00
20 08 2                  2 0.56                                         -0.25 010
20 08 3                  4 0.96                                          0.00
20 08 4                  2 0.57                                          0.00 000
20 09 1                  4 1.08                                          0.00
20 09 2                  2 0.55                                         -0.25 035
20 09 3                  4 0.96                                          0.00
20 09 4                  2 0.56                                          0.00 000
20 10 1 7.950 010        4 0.96   0.63 0.65 0.65 0.68                    0.00
20 10 2 7.800 100        2 0.55   0.55 0.55 0.56 0.60                    0.00 000
20 10 3 7.950 175        4 0.96   0.61 0.65 0.66 0.69                    0.00
20 10 4 7.800 080        2 0.55   0.59 0.55 0.57 0.59                    0.00 000
20 11 1
20 11 2
20 11 3
20 11 4
21 01 1 7.800 035        4 1.08   0.61 0.64 0.65 0.66                    0.50
21 01 2 7.725 100        1 0.54   0.56 0.55 0.56 0.56                   -0.25 080
21 01 3 7.800 170        4 1.08   0.59 0.67 0.70 0.69                    0.25
21 01 4 7.700 080        1 0.54   0.54 0.53 0.56 0.55                   -0.25 085
21 02 1                  4
21 02 2                    0.53
21 02 3                  4
21 02 4                    0.53
21 03 1                  4
21 03 2                    0.51
21 03 3                  4
21 03 4                    0.52
21 04 1                  4
21 04 2                    0.52
21 04 3                  4
21 04 4                    0.53
21 05 1                  4
21 05 2                    0.53
21 05 3                  4
21 05 4                    0.52
21 06 1                  4
21 06 2                  1 0.53
21 06 3                  4
21 06 4                  1 0.52
21 07 1                  4
21 07 2                  1 0.53
21 07 3                  4
21 07 4                  1 0.52
21 08 1                  4 1.08
21 08 2                  1 0.52
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21	08	4			1	0.53						
21	09	1			4	1.16					0.25	
21	09	2			2	0.51					-0.25	080
21	09	3			4	1.16					0.25	
21	09	4			2	0.53					-0.25	080
21	10	1	7.825	180	4	1.40	0.60	0.67	0.65	0.65	0.25	
21	10	2	7.725	090	2	0.51	0.53	0.54	0.56	0.57	-0.25	090
21	10	3	7.800	165	4	1.84	0.60	0.63	0.68	0.68	0.25	
21	10	4	7.725	070	2	0.53	0.53	0.53	0.57	0.57	-0.25	085
21	11	1	7.850	025	4	1.40	0.63	0.67	0.65	0.66	0.25	
21	11	2	7.725	095	1	0.51	0.54	0.54	0.55	0.57	0.00	000
21	11	3	7.825	175	4	1.84	0.61	0.66	0.67	0.68	0.50	
21	11	4	7.725	070	1	0.53	0.54	0.55	0.59	0.56	-0.25	080
22	01	1	7.875	180	4	0.96	0.63	0.69		0.70		
22	01	2	7.750	090	2	0.56	0.57	0.59	0.61	0.61		
22	01	3	8.100	140	4	0.96	0.61	0.63		0.71		
22	01	4	7.900	070	2	0.56	0.57	0.58	0.65	0.64		
22	02	1			4							
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22	08	3			4							
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22	09	1			4	0.96					2.00	
22	09	2			2	0.55					0.75	075
22	09	3			5	0.96					2.75	
22	09	4			2	0.56					0.75	075
22	10	1										
22	10	2										
22	10	3										
22	10	4										
22	11	1										
22	11	2										
22	11	3										
22	11	4										
23	01	1	8.225	010	4	0.96	0.68	0.69	0.68	0.72	1.00	
23	01	2	8.025	100	2	0.58	0.61	0.64	0.59	0.63	-0.25	045
23	01	3	8.275	180	4	1.08	0.64	0.69	0.71	0.71	0.50	
23	01	4	8.100	090	1	0.57	0.59	0.63	0.63	0.62	-0.25	165
23	02	1			4							
23	02	2				0.57						
23	02	3			4							
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23	07	2			2	0.58							
23	07	3			4								
23	07	4			1	0.57							
23	08	1			4	0.96						1.00	
23	08	2			2	0.56						-0.25	040
23	08	3			4	0.96						0.50	
23	08	4			2	0.57						-0.25	175
23	09	1			4	0.96						1.00	
23	09	2			3	0.57						-0.25	030
23	09	3			4	0.96						0.50	
23	09	4			3	0.58						-0.25	175
23	10	1			4	0.96	0.65	0.75	0.67	0.71		1.00	
23	10	2			2	0.55	0.61	0.63	0.59	0.60		-0.25	030
23	10	3			4	1.16	0.63	0.71	0.71	0.72		0.50	
23	10	4			2	0.55	0.60	0.63	0.63	0.62		-0.25	175
23	11	1	8.250	005	4	1.08	0.63	0.69	0.67	0.69		1.00	
23	11	2	8.075	100	2	0.57	0.59	0.58	0.59	0.61		-0.25	030
23	11	3	8.300	180	4	0.96	0.63	0.69	0.71	0.71		0.50	
23	11	4	8.100	085	2	0.57	0.59	0.61	0.63	0.63		-0.25	175
24	01	1	7.750	175	4	0.96	0.65	0.66	0.65	0.73		0.75	
24	01	2	7.700	095	2	0.56	0.59	0.59	0.60	0.61		-0.25	180
24	01	3	7.925	170	4	0.96	0.63	0.68	0.70	0.73		0.75	
24	01	4	7.775	075	2	0.57	0.57	0.64	0.62	0.65		-0.25	170
24	02	1			4								
24	02	2				0.56							
24	02	3			4								
24	02	4				0.55							
24	03	1			4								
24	03	2				0.57							
24	03	3			4								
24	03	4				0.58							
24	04	1			4								
24	04	2				0.58							
24	04	3			4								
24	04	4				0.57							
24	05	1			4								
24	05	2				0.59							
24	05	3			4								
24	05	4				0.59							
24	06	1			4								
24	06	2			2	0.57							
24	06	3			4								
24	06	4			2	0.59							
24	07	1			4								
24	07	2			2	0.60							
24	07	3			4								
24	07	4			2	0.60							
24	08	1			4	0.96						0.75	
24	08	2			2	0.57						0.00	000
24	08	3			4	0.96						-0.75	
24	08	4			2	0.59						-0.25	170
24	09	1			4	1.08						0.75	
24	09	2			2	0.57						0.00	000
24	09	3			4	0.96						0.75	
24	09	4			2	0.59						-0.25	170
24	10	1			4	0.96	0.66	0.67	0.67	0.71		0.75	
24	10	2			2	0.58	0.61	0.61	0.63	0.64		0.00	000

24	10	3			4	0.96	0.67	0.68	0.70	0.71			1.00		
24	10	4			2	0.59	0.61	0.61	0.63	0.64			-0.50	170	
24	11	1	7.825	010	4	1.16	0.69	0.69	0.69	0.73			0.75		
24	11	2	7.650	085	2	0.60	0.63	0.63	0.63	0.63			-0.25	010	
24	11	3	7.975	170	4	0.96	0.66	0.69	0.71	0.73			0.75		
24	11	4	7.800	065	2	0.60	0.59	0.62	0.63	0.63			-0.25	160	
25	01	1	7.800	173	4	1.16	0.65	0.65	0.68	0.70			1.00		
25	01	2	7.725	075	3	0.57	0.61	0.59	0.59	0.61			-0.25	100	
25	01	3	7.725	020	4	1.16	0.61	0.63	0.69	0.71			0.75		
25	01	4	7.675	100	3	0.57	0.58	0.58	0.61	0.63			-0.25	055	
25	02	1			4										
25	02	2				0.56									
25	02	3			4										
25	02	4				0.55									
25	03	1			4										
25	03	2				0.54									
25	03	3			4										
25	03	4				0.53									
25	04	1			4										
25	04	2				0.55									
25	04	3			4										
25	04	4				0.56									
25	05	1			4										
25	05	2				0.56									
25	05	3			4										
25	05	4				0.56									
25	06	1			4										
25	06	2			3	0.55									
25	06	3			4										
25	06	4			3	0.55									
25	07	1			4										
25	07	2			3	0.54									
25	07	3			4										
25	07	4			3	0.55									
25	08	1			4	1.40							0.75		
25	08	2			3	0.56							0.00	000	
25	08	3			4	1.84							0.75		
25	08	4			3	0.58							-0.25	030	
25	09	1			4	1.08	0.66	0.65	0.67	0.70			0.75		
25	09	2			2	0.55	0.60	0.59	0.60	0.60			-0.25	115	
25	09	3			4	1.08	0.61	0.64	0.70	0.71			0.50		
25	09	4			2	0.56	0.58	0.54	0.60	0.62			-0.25	055	
25	10	1	7.800	010	4	1.08	0.67	0.65	0.69	0.70			0.50		
25	10	2	7.725	090	2	0.58	0.60	0.59	0.61	0.59			-0.25	115	
25	10	3	7.775	015	4	1.08	0.62	0.65	0.71	0.71			0.75		
25	10	4	7.725	090	2	0.59	0.58	0.51	0.59	0.61			-0.25	055	
25	11	1	7.775	025	4	12.84	0.66	0.65	0.67	0.69			0.50		
25	11	2	7.750	100	2	0.57	0.59	0.59	0.61	0.61			-0.25	115	
25	11	3	7.850	010	4	12.84	0.63	0.67	0.67	0.71			0.75		
25	11	4	7.775	080	2	0.56	0.57	0.57	0.61	0.59			-0.25	060	
26	01	1	7.850	007	4	0.96	0.57	0.61	0.67	0.62	0.25		-1.00		
26	01	2	7.675	085	2	0.57	0.54	0.55	0.55	0.57	0.00	000	-0.25	110	
26	01	3	7.775	180	4	0.96	0.69	0.61	0.69	0.70	0.25		-1.25		
26	01	4	7.550	095	2	0.53	0.54	0.54	0.59	0.56	-0.25	015	-0.25	050	
26	02	1			4										
26	02	2				0.55									
26	02	3													
26	02	4				0.55									
26	03	1			4										
26	03	2				0.53									
26	03	3			5										
26	03	4				0.55									
26	04	1			4										
26	04	2				0.53									
26	04	3			4										
26	04	4				0.55									
26	05	1			4										
26	05	2				0.57									
26	05	3			5										
26	05	4				0.57									

26	06	1			4												
26	06	2			2	0.55											
26	06	3			5												
26	06	4			2	0.55											
26	07	1			4												
26	07	2			2	0.54											
26	07	3			4												
26	07	4			2	0.55											
26	08	1			4	0.96	1					0.25		-1.00			
26	08	2			2	0.54	4					-0.25	105	-0.25	110	1	
26	08	3			6	0.96	1					0.50		-1.50			
26	08	4			2	0.55	4					-0.75	025	-0.25	040	1	
26	09	1			4	0.96	1					0.50		-1.00			
26	09	2			2	0.56	4					-0.25	100	-0.50	090	1	
26	09	3			4	0.96	1					0.75		-1.50			
26	09	4			2	0.57	4					0.00	000	-0.50	055	1	
26	10	1	7.850	010	4	1.16	1	0.61	0.61	0.65	0.66	0.00		-1.25			
26	10	2	7.750	085	2	0.52	3	0.53	0.55	0.52	0.55	-0.25	135	-0.25	095	1	
26	10	3	7.800	175	5	1.84	1	0.59	0.59	0.67	0.63	0.50		-1.50			
26	10	4	7.675	085	2	0.54	3	0.54	0.55	0.57	0.58	-0.25	045	-0.25	055	1	
26	11	1	7.850	015	5	1.08	1	0.58	0.63	0.63	0.67	0.75		-1.25			
26	11	2	7.725	090	2	0.53	4	0.53	0.55	0.55	0.57	-0.50	045	-0.25	110	2	
26	11	3	7.800	005	4	1.08	1	0.60	0.59	0.64	0.71	0.25		-1.50			
26	11	4	7.625	085	2	0.55	4	0.53	0.54	0.57	0.58	0.00	000	-0.25	050	1	
27	01	1	8.000	015	4	1.16		0.60	0.60	0.68	0.67	0.25		-2.75			
27	01	2	7.625	105	2	0.56		0.55	0.60	0.57	0.59	0.00	000	-1.50	020		
27	01	3	7.975	015	4	0.96		0.64	0.59	0.64	0.68	0.25		-3.50			
27	01	4	7.600	100	2	0.55		0.58	0.57	0.58	0.60	-0.50	175	-1.00	015		
27	02	1			6												
27	02	2				0.61											
27	02	3			5												
27	02	4				0.60											
27	03	1			5												
27	03	2				0.56											
27	03	3			5												
27	03	4				0.57											
27	04	1			5												
27	04	2				0.57											
27	04	3			5												
27	04	4				0.57											
27	05	1			5												
27	05	2				0.58											
27	05	3			5												
27	05	4				0.57											
27	06	1			5												
27	06	2			2	0.59											
27	06	3			5												
27	06	4			2	0.59											
27	07	1			9												
27	07	2			2	0.57											
27	07	3			5												
27	07	4			2	0.57											
27	08	1			6	0.96	1					0.50		-2.75			
27	08	2			2	0.55	4					-0.25	085	-1.25	015	1	
27	08	3			4	1.08	1					0.00		-3.75			
27	08	4			2	0.56	1					-0.50	170	-1.00	020	1	
27	09	1			5	0.96	4					0.25		-2.75			
27	09	2			2	0.57	4					-0.75	025	-1.25	015	2	
27	09	3			5	1.08	1					0.75		-3.25			
27	09	4			2	0.56	4					-1.00	180	-1.00	010	2	
27	10	1			6	0.96	1	0.64	0.62	0.70	0.68	0.00		-3.25			
27	10	2			2	0.53	2	0.60	0.59	0.58	0.61	-1.00	020	-1.00	035	2	
27	10	3			5	1.08	1	0.65	0.61	0.62	0.62	0.25		-3.50			
27	10	4			2	0.55	5	0.58	0.58	0.59	0.59	-0.75	170	-1.00	015	2	
27	11	1	7.925	005	4	1.08	1	0.65	0.60	0.67	0.69	0.50		-3.50			
27	11	2	7.550	095	2	0.56	4	0.61	0.60	0.58	0.61	-0.75	020	-1.00	025	1	
27	11	3	7.925	015	5	1.16	1	0.65	0.64	0.70	0.70	0.00		-3.75			
27	11	4	7.650	105	2	0.56	3	0.63	0.61	0.61	0.65	-1.00	025	-1.00	015	1	
28	01	1	7.875	180	4	1.08		0.67	0.72	0.68	0.72	0.00		-3.00			1
28	01	2	7.675	085	2	0.59		0.61	0.63	0.62	0.59	0.00	000	0.00	000		

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28 01 3 7.825 165  4  0.96   0.65 0.78 0.66 0.73  0.25      -2.75      1
28 01 4 7.650 080  2  0.61   0.60 0.66 0.63 0.65 -0.25 150 -0.50 155
28 02 1            5
28 02 2               0.61
28 02 3            5
28 02 4               0.60
28 03 1            4
28 03 2               0.60
28 03 3            4
28 03 4               0.59
28 04 1            4
28 04 2               0.62
28 04 3            4
28 04 4               0.61
28 05 1            4
28 05 2               0.57
28 05 3            4
28 05 4               0.57
28 06 1            4
28 06 2            2  0.58
28 06 3            4
28 06 4            2  0.58
28 07 1            4
28 07 2            2  0.59
28 07 3            4
28 07 4            2  0.59
28 08 1            5  0.96 1                      0.00      -3.00
28 08 2            3  0.59 4                      0.00 000  0.00 000 1
28 08 3            5  0.96 1                      0.50      -2.75
28 08 4            3  0.59 4                     -0.50 155 -0.50 155 1
28 09 1            4  0.96 1                      0.00      -3.00
28 09 2               0.57 1                      0.00 000 -0.25 005 1
28 09 3            5  0.96 1                      0.50      -2.50
28 09 4               0.57 1                     -0.50 160 -0.50 155 1
28 10 1 7.850 170  5  0.96 1                      0.00      -3.00
28 10 2 7.650 035     .    4                     -0.25 175 -0.25 180 1
28 10 3 7.850 175  5  1.08 1                      0.00      -2.50
28 10 4 7.650 055     .    4                     -0.50 150 -0.25 165 1
28 11 1
28 11 2
28 11 3
28 11 4
29 01 1 7.350 005  4  0.96   0.59 0.64 0.70 0.66  0.25      -2.75
29 01 2 7.075 095  2  0.52   0.55 0.53 0.54 0.59 -0.50 175 -0.75 175
29 01 3 7.300 005  4  0.96   0.59 0.65 0.63 0.62  0.75      -4.50
29 01 4 6.975 100  2  0.53   0.56 0.53 0.56 0.54 -1.00 010 -1.25 010
29 02 1            5
29 02 2               0.56
29 02 3            4
29 02 4               0.53
29 03 1            5
29 03 2               0.52
29 03 3            5
29 03 4               0.52
29 04 1            4
29 04 2               0.56
29 04 3            5
29 04 4               0.56
29 05 1            6
29 05 2               0.54
29 05 3            5
29 05 4               0.55
29 06 1            6
29 06 2            2  0.54
29 06 3            5
29 06 4            2  0.55
29 07 1            4
29 07 2            2
29 07 3            9
29 07 4            2
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29	08	1			4	0.96	1						0.50		-2.75		
29	08	2			2	0.54	4						-0.75	165	-1.00	005	1
29	08	3			6	0.96	1						1.00		-4.75		
29	08	4			2	0.55	4						-1.25	015	-1.25	010	1
29	09	1			4	0.96	1						0.75		-3.00		
29	09	2			2	0.54	4						-1.00	180	-0.50	005	1
29	09	3			6	0.96	1						1.00		-4.75		
29	09	4			2	0.55	4						-1.50	005	-1.00	010	2
29	10	1			4	1.08	1	0.62	0.64	0.67	0.64		0.25		-5.00		
29	10	2			2	0.55	4	0.57	0.58	0.59	0.57		-1.00	170	-0.50	175	1
29	10	3			9	0.96	1	0.60	0.67	0.63	0.66		1.25		-5.00		
29	10	4			2	0.54	4	0.59	0.57	0.58	0.59		-1.75	020	-0.75	005	3
29	11	1															
29	11	2															
29	11	3															
29	11	4															
30	01	1	7.800	155	4	1.16		0.64	0.59	0.60	0.67		0.50		-4.25		
30	01	2	7.700	065	2	0.52		0.54	0.55	0.54	0.63		-0.50	105	-1.00	100	
30	01	3	7.800	020	4	1.16		0.59	0.61	0.64	0.68		0.25		-3.25		
30	01	4	7.725	115	1	0.54		0.54	0.56	0.58	0.57		-0.50	065	-0.75	065	
30	02	1			5												
30	02	2				0.51											
30	02	3			4												
30	02	4				0.52											
30	03	1			5												
30	03	2				0.53											
30	03	3			5												
30	03	4				0.55											
30	04	1			5												
30	04	2				0.53											
30	04	3			5												
30	04	4				0.53											
30	05	1			4												
30	05	2				0.55											
30	05	3			4												
30	05	4				0.56											
30	06	1			4												
30	06	2			2	0.53											
30	06	3			4												
30	06	4			1	0.54											
30	07	1			6												
30	07	2			2	0.51											
30	07	3			5												
30	07	4			1	0.52											
30	08	1			4	0.96	1						0.00		-3.25		
30	08	2			2	0.55	4						-0.25	165	-1.00	100	2
30	08	3			4	0.96	1						0.25		-3.25		
30	08	4			2	0.53	4						-0.50	065	-0.75	070	1
30	09	1			6	0.96	1						0.75		-4.25		
30	09	2			2	0.54	4						-0.75	160	-1.00	115	1
30	09	3			4	1.08	1						0.25		-3.50		
30	09	4			2	0.55	4						-0.25	080	-0.50	070	1
30	10	1			5	0.96	1	0.57	0.60	0.58	0.67		0.25		-4.50		
30	10	2			2	0.54	2	0.54	0.54	0.53	0.55		-0.50	160	-1.25	125	1
30	10	3			5	0.96	1	0.58	0.57	0.61	0.65		0.25		-3.50		
30	10	4			2	0.54	2	0.54	0.54	0.53	0.58		-0.50	065	-0.50	070	1
30	11	1	7.800	165	6	0.96	1	0.59	0.57	0.63	0.63		1.00		-3.50		
30	11	2	7.625	050	2	0.54	5	0.54	0.52	0.55	0.53		-0.50	180	-1.50	120	4
30	11	3	7.750	015	4	0.96	1	0.60	0.55	0.67	0.67		0.00		-3.50		
30	11	4	7.725	130	2	0.56	5	0.55	0.58	0.60	0.61		-0.25	090	-0.50	070	4
31	01	1	7.600	030	5	0.96		0.65	0.68	0.69	0.61		0.25		-3.50		
31	01	2	7.600	145	2	0.57		0.58	0.62	0.60	0.57		-0.25	100	-0.50	105	
31	01	3	7.556	015	4	1.08		0.68	0.65	0.63	0.68		0.25		-3.50		
31	01	4	7.500	080	2	0.59		0.64	0.60	0.59	0.61		-0.50	065	-0.50	065	
31	02	1			4												
31	02	2				0.59											
31	02	3			4												
31	02	4				0.60											
31	03	1			4												
31	03	2				0.60											

31	03	3			4													
31	03	4				0.59												
31	04	1			5													
31	04	2				0.59												
31	04	3			5													
31	04	4				0.60												
31	05	1			5													
31	05	2				0.59												
31	05	3			5													
31	05	4				0.61												
31	06	1			5													
31	06	2			2	0.59												
31	06	3			5													
31	06	4			2	0.61												
31	07	1			5													
31	07	2			2	0.60												
31	07	3			5													
31	07	4			2	0.60												
31	08	1			4	1.08	1							0.50		-3.00		
31	08	2			2	0.61	4							-0.25	105	-0.50	105	1
31	08	3			4	0.96	1							0.25		-3.25		
31	08	4			2	0.59	4							-0.25	065	-0.50	065	1
31	09	1			4	1.08	1							0.25		-2.75		
31	09	2			2	0.61	4							0.00	000	-0.50	105	1
31	09	3			5	0.96	1							0.25		-3.00		
31	09	4			2	0.61	4							-0.25	005	-0.25	055	1
31	10	1	7.725	005	4	0.96	1	0.69	0.63	0.69	0.68			0.25		-2.75		
31	10	2	7.650	090	2	0.59	2	0.61	0.59	0.60	0.61			-0.25	160	-0.50	105	1
31	10	3	7.650	180	4	0.96	3	0.66	0.69	0.63	0.67			0.00		-3.00		
31	10	4	7.600	100	2	0.59	4	0.59	0.62	0.61	0.63			-0.25	005	-0.50	065	1
31	11	1	7.600	004	5	0.96	1	0.69	0.66	0.64	0.64			0.25		-3.00		
31	11	2	7.575	095	2	0.59	5	0.66	0.61	0.63	0.63			0.00	000	-0.75	110	1
31	11	3	7.550	025	4	0.96	1	0.65	0.69	0.69	0.71			0.25		-3.25		
31	11	4	7.525	120	2	0.61	5	0.63	0.63	0.65	0.63			-0.25	050	0.00	000	1
32	01	1	8.075	005	4	0.96		0.65	0.63	0.71	0.76			0.25		-0.75		
32	01	2	8.075	095	2	0.56		0.62	0.59	0.61	0.63			0.00	000	-0.25	080	
32	01	3	8.025	165	4	1.08		0.65	0.65	0.73	0.64			0.25		-0.75		
32	01	4	7.900	080	2	0.57		0.59	0.63	0.64	0.63			-0.25	085	-0.25	075	
32	02	1			5													
32	02	2				0.57												
32	02	3			4													
32	02	4				0.59												
32	03	1			4													
32	03	2				0.58												
32	03	3			4													
32	03	4				0.60												
32	04	1			4													
32	04	2				0.58												
32	04	3			4													
32	04	4				0.58												
32	05	1			4													
32	05	2				0.58												
32	05	3			4													
32	05	4				0.60												
32	06	1			5													
32	06	2			2	0.57												
32	06	3			4													
32	06	4			2	0.58												
32	07	1			4													
32	07	2			2	0.57												
32	07	3			4													
32	07	4			2	0.56												
32	08	1			4	1.08	1							0.25		-0.75		
32	08	2			2	0.58	4							-0.25	035	-0.25	075	1
32	08	3			4	0.96	1							0.00		-0.75		
32	08	4			2	0.57	4							-0.25	150	-0.25	080	1
32	09	1			4	0.96	1							0.50		-1.00		
32	09	2			2	0.57	4							-0.25	035	0.00	000	1
32	09	3			4	1.08	1							0.25		-0.75		
32	09	4			2	0.57	4							-0.25	150	-0.25	045	1

```
32 10 1 8.025 010  4  0.96 1 0.67 0.69 0.67 0.69  0.25      -1.00
32 10 2 7.850 100  2  0.56 4 0.59 0.60 0.59 0.61 -0.25 050  0.00 000 1
32 10 3 8.000 175  4  0.96 1 0.67 0.66 0.71 0.67  0.00      -1.00
32 10 4 7.825 075  2  0.57 4 0.60 0.61 0.61 0.61 -0.25 170  0.00 000 1
32 11 1 8.000 035  4  1.16 1 0.62 0.59 0.63 0.67  0.00      -1.25
32 11 2 7.900 100  2  0.53 4 0.55 0.55 0.55 0.57  0.00 000  0.00 000 1
32 11 3 8.025 035  4  0.96 1 0.59 0.63 0.69 0.69  0.00      -1.00
32 11 4 7.925 125  2  0.54 4 0.53 0.59 0.59 0.57  0.00 000  0.00 000 1
33 01 1 7.775 005  4  1.08    0.58 0.63 0.67 0.68  0.00      -1.00
33 01 2 7.650 090  2  0.52    0.54 0.56 0.55 0.56  0.00 000 -0.25 125
33 01 3 7.750 005  4  1.08    0.58 0.63 0.64 0.64  0.00      -1.25
33 01 4 7.675 090  2  0.53    0.56 0.57 0.59 0.57  0.00 000 -0.25 165
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33 02 2               0.55
33 02 3            5
33 02 4               0.55
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33 03 2               0.56
33 03 3            5
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33 04 2               0.54
33 04 3            4
33 04 4               0.56
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33 05 2               0.56
33 05 3            4
33 05 4               0.57
33 06 1            6
33 06 2            2  0.57
33 06 3            4
33 06 4            2  0.58
33 07 1            4
33 07 2            2  0.56
33 07 3            4
33 07 4            2  0.55
33 08 1            4  0.96 1                          0.50      -1.00
33 08 2            2  0.55 4                         -0.25 025 -0.25 125 1
33 08 3            4  1.16 1                          0.25      -1.50
33 08 4            2  0.55 4                          0.00 000  0.00 000 1
33 09 1            4  1.08 1                          0.25      -1.00
33 09 2            2  0.54 5                         -0.25 015 -0.50 110 1
33 09 3            4  0.96 1                          0.50      -1.00
33 09 4            2  0.55 5                          0.00 000 -0.25 155 1
33 10 1            4  1.16 1 0.59 0.65 0.65 0.67  0.75      -1.00
33 10 2            2  0.53 4 0.53 0.57 0.56 0.57 -0.50 085 -0.50 110 1
33 10 3            4  1.40 1 0.58 0.61 0.61 0.64  0.50      -1.00
33 10 4            2  0.55 4 0.55 0.55 0.59 0.57 -0.50 040 -0.25 055 1
33 11 1 7.800 175  4  0.96 1 0.54 0.55 0.57 0.61  0.50      -1.00
33 11 2 7.650 070  2  0.50 4 0.52 0.51 0.53 0.54 -0.50 085 -0.50 110 1
33 11 3 7.750 010  4  0.96 1 0.53 0.55 0.63 0.61  0.50      -1.25
33 11 4 7.675 095  2  0.49 4 0.51 0.51 0.57 0.55 -0.50 040  0.00 000 1
34 01 1 8.150 180  4  1.84    0.59 0.56 0.66 0.66  0.25      -2.50
34 01 2 7.825 080  2  0.50    0.52 0.52 0.53 0.56 -0.50 180 -1.00 170
34 01 3 8.075 175  4  1.16    0.54 0.58 0.68 0.66  0.50      -2.50
34 01 4 7.750 085  2  0.51    0.53 0.53 0.56 0.54 -0.50 175 -1.25 170
34 02 1            4
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34 02 4               0.52
34 03 1            4
34 03 2               0.53
34 03 3            4
34 03 4               0.51
34 04 1            4
34 04 2               0.53
34 04 3            4
34 04 4               0.52
34 05 1            4
34 05 2               0.51
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34 06 3                    4
34 06 4                    2  0.51
34 07 1                    4
34 07 2                    2  0.51
34 07 3                    4
34 07 4                    2  0.51
34 08 1                    4  1.16 1                                    0.50       -2.50
34 08 2                    2  0.52 4                                   -0.50 010  -0.75 170 1
34 08 3                    4  1.16 1                                    1.00       -2.25
34 08 4                    2  0.51 4                                   -0.25 070  -1.25 175 1
34 09 1                    4  1.16 1                                    0.75       -2.50
34 09 2                    2  0.51 4                                   -0.50 120  -0.75 170 1
34 09 3                    4  1.08 1                                    0.75       -2.25
34 09 4                    2  0.51 4                                   -0.25 015  -1.00 175 1
34 10 1                    4  1.40 1  0.63 0.62 0.64 0.67               0.25       -2.50
34 10 2                    2  0.50 4  0.53 0.53 0.54 0.57              -0.50 140  -1.00 160 1
34 10 3                    4  1.16 1  0.61 0.66 0.65 0.68               0.50       -2.50
34 10 4                    2  0.51 4  0.53 0.53 0.55 0.57              -0.50 015  -1.00 175 1
34 11 1
34 11 2
34 11 3
34 11 4
35 01 1 8.325 175          4  1.08    0.71 0.69 0.71 0.75               0.00       -4.50
35 01 2 8.175 085          2  0.57    0.61 0.59 0.59 0.61               0.00 000    0.00 000
35 01 3 8.450 015          4  0.96    0.68 0.69 0.69 0.75               0.00       -4.50
35 01 4 8.300 100          2  0.59    0.62 0.63 0.64 0.64               0.00 000   -0.25 010
35 02 1                    6
35 02 2                      0.60
35 02 3                    4
35 02 4                      0.62
35 03 1                    4
35 03 2                      0.59
35 03 3                    5
35 03 4                      0.60
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35 04 2                      0.58
35 04 3                    4
35 04 4                      0.59
35 05 1                    4
35 05 2                      0.57
35 05 3                    4
35 05 4                      0.59
35 06 1                    4
35 06 2                    2  0.58
35 06 3                    4
35 06 4                    2  0.59
35 07 1                    4
35 07 2                    2  0.57
35 07 3                    4
35 07 4                    2  0.58
35 08 1                    4  0.96                                      0.00       -4.25
35 08 2                    2  0.58                                     -0.25 165  -0.25 155 1
35 08 3                    4  0.96                                      0.00       -4.25
35 08 4                    2  0.59                                     -0.25 075  -0.25 030 1
35 09 1                    4  0.96 1                                    0.25       -4.00
35 09 2                    2  0.56 4                                   -0.25 005  -0.25 155 1
35 09 3                    4  0.96 1                                    0.25       -4.00
35 09 4                    2  0.57 4                                   -0.25 020  -0.25 020 1
35 10 1 8.425 175          4  0.96 1  0.69 0.68 0.67 0.73               0.00       -4.00
35 10 2 8.300 070          2  0.58 3  0.63 0.64 0.61 0.63              -0.25 145  -0.25 145 1
35 10 3 8.550 005          4  0.96 1  0.67 0.67 0.71 0.74               0.00       -4.00
35 10 4 8.425 095          2  0.59 3  0.61 0.65 0.63 0.63              -0.25 150  -0.25 020 1
35 11 1
35 11 2
35 11 3
35 11 4
```

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36 01 1 7.850 005  4  1.08    0.63 0.66 0.72  0.50          -3.25
36 01 2 7.700 090  2  0.57    0.57 0.53 0.61 0.61 -0.75 005 -1.00 170
36 01 3 7.850 020  4  1.16    0.65 0.65 0.65 0.67  0.00     -3.75
36 01 4 7.700 095  2  0.59    0.59 0.51 0.61 0.61  0.00 000  0.00 000
36 02 1               5
36 02 2                  0.57
36 02 3               4
36 02 4                  0.59
36 03 1               6
36 03 2                  0.56
36 03 3               4
36 03 4                  0.58
36 04 1               5
36 04 2                  0.59
36 04 3               4
36 04 4                  0.59
36 05 1               5
36 05 2                  0.58
36 05 3               4
36 05 4                  0.59
36 06 1               6
36 06 2               2  0.58
36 06 3               4
36 06 4               2  0.57
36 07 1               5
36 07 2               2  0.58
36 07 3               4
36 07 4               2  0.59
36 08 1               6  0.96 1                        0.50      -3.00
36 08 2               2  0.57 4                       -0.75 010 -1.00 180 1
36 08 3               4  1.16 1                        0.25      -3.75
36 08 4               2  0.56 4                       -0.25 175  0.00 000 1
36 09 1               5  0.96 1                        0.25      -3.75
36 09 2               2  0.57 3                       -0.50 170 -0.75 175 1
36 09 3               5  1.08 1                       -0.25      -4.00
36 09 4               2  0.57 3                       -0.25 120 -0.25 015 1
36 10 1 7.850 005  5  1.40 1 0.63 0.65 0.69 0.69  0.25      -3.50
36 10 2 7.650 090  2  0.55 5 0.57 0.68 0.51 0.61 -0.50 015 -0.75 175 1
36 10 3 7.800 010  5  1.40 1 0.65 0.63 0.66 0.73 -0.50      -4.00
36 10 4 7.675 090  2  0.57 3 0.57 0.61 0.61 0.62  0.00 000  0.00 000 1
36 11 1 7.825 010  5  1.84 1 0.63 0.66 0.67 0.71  0.25      -3.75
36 11 2 7.650 080  2  0.55 3 0.62 0.59 0.61 0.61 -0.75 170 -0.50 165 1
36 11 3 7.750 045  6  1.16 1 0.64 0.63 0.68 0.71 -0.25      -4.00
36 11 4 7.700 110  2  0.57 3 0.58 0.61 0.61 0.63 -0.25 105  0.00 000 1
37 01 1 8.225 085  4  1.08    0.63 0.59 0.76 0.69  0.00      5.50
37 01 2 8.125 015  2  0.57    0.57 0.60 0.58 0.61  0.00 000  0.00 000
37 01 3 8.200 020  4  1.16    0.62 0.62 0.69 0.75  0.50     -4.25
37 01 4 8.125 105  2  0.59    0.58 0.63 0.64 0.64 -0.50 025 -0.75 015
37 02 1               5
37 02 2                  0.57
37 02 3               5
37 02 4                  0.57
37 03 1               5
37 03 2                  0.59
37 03 3               5
37 03 4                  0.60
37 04 1               4
37 04 2                  0.57
37 04 3               4
37 04 4                  0.57
37 05 1               4
37 05 2                  0.56
37 05 3               4
37 05 4                  0.59
37 06 1               5
37 06 2               2  0.59
37 06 3               5
37 06 4               2  0.59
37 07 1               5
37 07 2               2  0.57
```

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37	07	4			2	0.59											
37	08	1			4	1.08	1						0.00		-5.25		
37	08	2			2	0.56	2						0.00	000	0.00	000	
37	08	3			5	1.08	1						0.75		-4.00		
37	08	4			2	0.57	5						-0.25	125	-1.00	015	
37	09	1			5	0.96	1						0.50		-5.00		
37	09	2			2	0.56	5						0.00	000	-0.25	160	1
37	09	3			5	1.08	1						1.25		-3.75		
37	09	4			2	0.57	5						-0.25	160	-0.75	005	1
37	10	1	8.275	110	4	2.40	1	0.66	0.61	0.71	0.67		0.00		-5.25		
37	10	2	8.125	020	2	0.56	5	0.59	0.58	0.65	0.61		-0.25	030	0.00	000	1
37	10	3	8.225	050	5	2.40	1	0.65	0.64	0.71	0.71		1.50		-3.75		
37	10	4	8.200	170	2	0.57	3	0.58	0.61	0.63	0.62		-0.75	040	-0.50	005	1
37	11	1	8.225	125	4	4.60	1	0.65	0.62	0.74	0.73		0.25		-5.25		
37	11	2	8.075	040	2	0.55	2	0.57	0.55	0.60	0.61		-0.50	100	-0.25	150	1
37	11	3	8.250	060	5	3.20	1	0.63	0.65	0.67	0.75		0.75		-3.75		
37	11	4	8.175	120	2	0.56	5	0.61	0.63	0.62	0.62		-1.00	015	-0.75	010	1
38	01	1	8.175	000	4	1.16		0.67	0.68	0.68	0.72		0.75		-2.75		
38	01	2	7.875	090	2	0.58		0.61	0.63	0.59	0.67		-1.00	010	-1.75	005	
38	01	3	8.025	005	4	1.16		0.69	0.72	0.74	0.75		0.50		-1.50		
38	01	4	7.800	090	2	0.60		0.64	0.66	0.66	0.65		-0.75	170	-1.00	175	
38	02	1			5												
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38	02	3			5												
38	02	4				0.61											
38	03	1			5												
38	03	2				0.60											
38	03	3			5												
38	03	4				0.61											
38	04	1			5												
38	04	2				0.62											
38	04	3			4												
38	04	4				0.63											
38	05	1			5												
38	05	2				0.58											
38	05	3			4												
38	05	4				0.60											
38	06	1			5												
38	06	2			2	0.60											
38	06	3			4												
38	06	4			2	0.61											
38	07	1			5												
38	07	2			2	0.60											
38	07	3			4												
38	07	4			2	0.62											
38	08	1			5	1.08	1						0.75		-3.00		
38	08	2			2	0.61	4						-0.75	010	-1.00	005	1
38	08	3			5	1.08	1						0.75		-1.75		
38	08	4			2	0.60	4						-0.75	160	-1.00	005	1
38	09	1			5	0.96	1						0.50		-3.00		
38	09	2			2	0.57	4						-1.25	175	-1.00	005	1
38	09	3			4	1.08	1						0.50		-2.00		
38	09	4			2	0.59	4						-0.50	170	-0.50	020	1
38	10	1															
38	10	2															
38	10	3															
38	10	4															
38	11	1															
38	11	2															
38	11	3															
38	11	4															
39	01	1	8.175	020	4	0.96		0.62	0.67	0.63	0.67		0.00		-1.75		
39	01	2	8.075	110	2	0.55		0.56	0.56	0.56	0.58		0.00	000	0.00	000	
39	01	3	8.125	000	4	0.96		0.58	0.67	0.62	0.64		0.00		-1.25		
39	01	4	7.775	010	2	0.55		0.54	0.59	0.58	0.56		0.00	000	-0.25	045	
39	02	1			4												
39	02	2				0.57											
39	02	3			4												
39	02	4				0.56											

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39 03 4                   0.56
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39 04 3                5
39 04 4                   0.57
39 05 1                4
39 05 2                   0.60
39 05 3                4
39 05 4                   0.58
39 06 1                4
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39 06 3                4
39 06 4                2  0.56
39 07 1                5
39 07 2                2  0.56
39 07 3                5
39 07 4                2  0.55
39 08 1                4  1.08 1                                          0.50      -1.50
39 08 2                2  0.56 4                                         -0.25 075 -0.25 105 1
39 08 3                4  0.96 1                                          0.25      -1.25
39 08 4                2  0.57 3                                         -0.25 160 -0.25 060 1
39 09 1                4  0.96 1                                          0.50      -1.50
39 09 2                2  0.56 4                                         -0.25 080 -0.50 085 1
39 09 3                4  0.96 1                                          0.25      -1.50
39 09 4                2  0.57 4                                         -0.25 180  0.00 000 1
39 10 1                4  0.96 1  0.67 0.69 0.71 0.66                     0.25      -1.50
39 10 2                2  0.57 4  0.59 0.58 0.61 0.60                     0.00 000 -0.25 095 1
39 10 3                4  0.96 1  0.59 0.64 0.69 0.67                     0.00      -1.50
39 10 4                2  0.57 4  0.57 0.59 0.62 0.62                     0.00 000  0.00 000 1
39 11 1 8.250 085      4  1.08 1  0.65 0.65 0.64 0.68                     0.25      -1.25
39 11 2 8.225 135      2  0.56 3  0.59 0.61 0.57 0.61                    -0.25 035 -0.75 095 1
39 11 3 8.050 175      4  1.08 4  0.59 0.64 0.65 0.71                    -0.25      -1.56
39 11 4 7.925 080      2  0.55 2  0.57 0.60 0.61 0.59                    -0.75 175  0.00 000 1
40 01 1 7.875 125      4  1.08    0.61 0.58 0.63 0.65                     0.25      -5.25
40 01 2 7.825 030      1  0.49    0.53 0.53 0.57 0.57                     0.00 000 -0.25 105
40 01 3 7.800 010      4  1.08    0.57 0.60 0.63 0.57                     0.25      -6.75
40 01 4 7.750 105      1  0.51    0.55 0.56 0.57 0.56                     0.00 000 -0.25 165
40 02 1                5
40 02 2                   0.53
40 02 3                5
40 02 4                   0.55
40 03 1                5
40 03 2                   0.51
40 03 3                4
40 03 4                   0.51
40 04 1                5
40 04 2                   0.51
40 04 3                5
40 04 4                   0.51
40 05 1                5
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40 05 3                5
40 05 4                   0.53
40 06 1                5
40 06 2                1  0.52
40 06 3                5
40 06 4                1  0.52
40 07 1                5
40 07 2                1  0.54
40 07 3                5
40 07 4                1  0.53
40 08 1                5  1.16 1                                          0.50      -5.00
40 08 2                2  0.51 4                                         -0.25 115 -0.25 125 1
40 08 3                5  1.16 1                                          0.50      -6.00
40 08 4                2  0.50 4                                         -0.25 160 -0.25 150 1
40 09 1                5  1.08 1                                          0.50      -5.00
40 09 2                2  0.50 4                                         -0.25 115  0.00 000 1
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40	09	4			2	0.51	4					0.30	000	-0.25	015	1
40	10	1	7.900	145	5	1.16	1	0.56	0.58	0.59	0.67	0.50		-5.25		
40	10	2	7.850	025	2	0.51	4	0.53	0.53	0.53	0.57	-0.25	120	0.00	000	1
40	10	3	7.850	150	5	1.40	1	0.56	0.56	0.62	0.67	0.75		-6.00		
40	10	4	7.775	025	2	0.53	4	0.53	0.53	0.55	0.54	-0.25	010	-0.50	150	1
40	11	1	7.850	150	5	1.08	4	0.56	0.55	0.62	0.63	-0.25		-5.50		
40	11	2	7.800	015	2	0.52	5	0.53	0.53	0.57	0.55	-0.50	105	-0.25	085	1
40	11	3	7.875	145	6	1.08	1	0.55	0.57	0.63	0.64	0.25		-6.00		
40	11	4	7.800	035	2	0.53	5	0.53	0.55	0.57	0.53	-0.50	120	-0.75	135	1
41	01	1	7.725	010	4	0.96		0.63	0.63	0.66	0.67	0.25		-0.75		
41	01	2	7.650	095	2	0.55		0.56	0.57	0.59	0.61	0.00	000	-0.25	010	
41	01	3	7.650	010	4	0.96		0.62	0.63	0.67	0.69	0.00		-1.00		
41	01	4	7.575	090	2	0.55		0.56	0.58	0.61	0.61	0.00	000	-0.25	090	
41	02	1			4											
41	02	2				0.57										
41	02	3			4											
41	02	4				0.59										
41	03	1			4											
41	03	2				0.57										
41	03	3			4											
41	03	4				0.57										
41	04	1			4											
41	04	2				0.56										
41	04	3			4											
41	04	4				0.57										
41	05	1			5											
41	05	2				0.55										
41	05	3			5											
41	05	4				0.57										
41	06	1			5											
41	06	2			2	0.56										
41	06	3			5											
41	06	4			2	0.58										
41	07	1			5											
41	07	2			2	0.53										
41	07	3			5											
41	07	4			2	0.54										
41	08	1			6	0.96	1					0.00		-0.75		
41	08	2			2	0.54	4					0.00	000	-0.25	160	1
41	08	3			5	0.96	1					-0.25		-1.00		
41	08	4			2	0.56	4					0.00	000	-0.25	090	1
41	09	1			5	0.96	1					0.50		-0.75		
41	09	2			2	0.55	4					-0.25	145	-0.25	135	1
41	09	3			5	0.96	1					-0.25		-1.00		
41	09	4			2	0.57	4					-0.50	005	-0.50	085	1
41	10	1	7.675	175	4	0.96	1	0.63	0.64	0.65	0.67	0.50		-0.75		
41	10	2	7.600	070	2	0.55	4	0.55	0.58	0.59	0.57	-0.50	085	-0.25	160	1
41	10	3	7.650	030	5	0.96	1	0.60	0.63	0.69	0.69	-0.50		-1.00		
41	10	4	7.575	115	2	0.56	4	0.56	0.57	0.59	0.60	0.50	065	-0.25	070	1
41	11	1	7.700	005	4	1.40	1	0.63	0.65	0.69	0.67	0.25		0.00		
41	11	2	7.595	085	2	0.55	4	0.55	0.59	0.57	0.60	0.00	000	0.00	000	1
41	11	3	7.675	090	5	1.16	1	0.60	0.63	0.69	0.69	-0.50		-0.75		
41	11	4	7.575	180	2	0.56	4	0.56	0.57	0.59	0.60	0.00	000	-1.00	090	1
42	01	1	8.025	175	4	1.08		0.69	0.70	0.79	0.79	0.00		-3.75		
42	01	2	7.950	085	2	0.60		0.65	0.63	0.63	0.68	0.00	000	-0.25	150	
42	01	3	8.025	020	4	1.08		0.69	0.70	0.73	0.68	0.00		-4.00		
42	01	4	7.950	100	2	0.62		0.64	0.63	0.66	0.68	0.00	000	0.00	000	
42	02	1			4											
42	02	2				0.62										
42	02	3			6											
42	02	4				0.63										
42	03	1			4											
42	03	2				0.62										
42	03	3			4											
42	03	4				0.64										
42	04	1			4											
42	04	2				0.61										
42	04	3			4											
42	04	4				0.64										

42	05	1			4											
42	05	2				0.61										
42	05	3			4											
42	05	4				0.60										
42	06	1			4											
42	06	2			2	0.63										
42	06	3			4											
42	06	4			2	0.64										
42	07	1			5											
42	07	2			2	0.61										
42	07	3			4											
42	07	4			2	0.61										
42	08	1			4	1.08	1					0.00		-4.00		
42	08	2			2	0.60	4					-0.25	065	-0.25	150	1
42	08	3			4	0.96	1					0.00		-4.50		
42	08	4			2	0.61	4					-0.25	100	0.00	000	1
42	09	1			6	1.08	1					0.00		-3.75		
42	09	2			2	0.59	4					-0.50	060	0.00	000	1
42	09	3			4	1.40	1					0.00		-4.25		
42	09	4			2	0.61	4					-0.50	085	-0.25	085	1
42	10	1	7.950	000	5	1.08	1	0.70	0.67	0.77	0.73	0.25		-4.00		
42	10	2	7.900	105	2	0.60	2	0.64	0.63	0.63	0.69	0.00	000	0.00	000	1
42	10	3	7.950	175	4	0.96	1	0.67	0.69	0.74	0.77	0.00		-4.25		
42	10	4	7.900	075	2	0.61	4	0.65	0.63	0.65	0.67	-0.25	125	-0.25	160	1
42	11	1														
42	11	2														
42	11	3														
42	11	4														
43	01	1	7.550	160	5	1.40		0.60	0.65	0.64	0.64	0.25		-1.50		
43	01	2	7.400	060	2	0.50		0.51	0.53	0.55	0.55	-0.50	040	-0.75	055	
43	01	3	7.650	050	5	1.16		0.53	0.65	0.65	0.65	0.00		-3.25		
43	01	4	7.500	145	2	0.50		0.51	0.56	0.57	0.56	0.00	000	-0.25	090	
43	02	1			6											
43	02	2				0.51										
43	02	3			5											
43	02	4				0.53										
43	03	1			5											
43	03	2				0.52										
43	03	3			5											
43	03	4				0.52										
43	04	1			5											
43	04	2				0.51										
43	04	3			6											
43	04	4				0.53										
43	05	1			5											
43	05	2				0.51										
43	05	3			5											
43	05	4				0.53										
43	06	1			5											
43	06	2			2	0.52										
43	06	3			5											
43	06	4			2	0.53										
43	07	1			5											
43	07	2			2	0.50										
43	07	3			5											
43	07	4			2	0.50										
43	08	1			5	1.84	1					0.00		-1.75		
43	08	2			2	0.50	4					-0.50	005	-0.75	035	1
43	08	3			6	1.16	1					0.25		-3.25		
43	08	4			2	0.51	4					-0.25	090	0.25	100	1
43	09	1			5	0.96	1					0.00		-1.75		
43	09	2			2	0.50	4					-0.50	080	-0.75	030	1
43	09	3			5	1.16	1					-0.25		-3.50		
43	09	4			2	0.50	4					0.00	000	-0.25	105	1
43	10	1			5	1.84	1	0.59	0.64	0.61	0.63	0.00		-1.75		
43	10	2			2	0.50	4	0.51	0.51	0.53	0.53	-0.25	085	-0.75	050	1
43	10	3			6	1.16	1	0.61	0.64	0.64	0.65	0.25		-3.50		
43	10	4			2	0.51	3	0.53	0.53	0.57	0.55	-0.50	115	-0.25	105	1
43	11	1	7.600	075	5	1.40	1	0.59	0.65	0.59	0.63	0.00		-2.00		
43	11	2	7.450	120	2	0.49	5	0.55	0.53	0.55	0.53	-0.25	110	-1.00	040	1

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43 11 3 7.450 170  6  1.84 1 0.55 0.65 0.69 0.63 -0.50      -3.75
43 11 4 7.350 070  2  0.50 4 0.49 0.54 0.57 0.55 -0.25 170 -0.25 105 1
44 01 1 7.775 005  4  1.08   0.61 0.66 0.71 0.72  0.00      -3.25
44 01 2 7.575 085  2  0.56   0.58 0.59 0.61 0.60  0.00 000 -0.25 150
44 01 3 7.625 085  4  0.96   0.66 0.66 0.75 0.75  0.00      -3.75
44 01 4 7.600 175  2  0.57   0.57 0.61 0.64 0.63  0.00 000 -0.25 180
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44 02 3            4
44 02 4               0.58
44 03 1            4
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44 03 3            4
44 03 4               0.58
44 04 1            4
44 04 2               0.58
44 04 3            4
44 04 4               0.59
44 05 1            4
44 05 2               0.57
44 05 3            4
44 05 4               0.57
44 06 1            4
44 06 2            2  0.59
44 06 3            4
44 06 4            2  0.59
44 07 1            4
44 07 2            2  0.58
44 07 3            4
44 07 4            2  0.58
44 08 1            4  0.96 1                          0.00      -3.50
44 08 2            2  0.57 4                          0.00 000 -0.25 145 1
44 08 3            4  0.96 1                          0.25      -3.75
44 08 4            2  0.58 4                         -0.50 015 -0.25 055 2
44 09 1            4  0.96 1                          0.25      -3.25
44 09 2            2  0.57 5                          0.00 000  0.00 000 1
44 09 3           12  0.96 1                         -0.50      -3.50
44 09 4            2  0.58 5                          0.00 000  0.00 000 1
44 10 1            4  1.08 1 0.63 0.69 0.74 0.75  0.50      -3.25
44 10 2            2  0.57 4 0.59 0.61 0.63 0.61 -0.25 170  0.00 000 1
44 10 3            4  0.96 1 0.65 0.69 0.73 0.71  0.25      -3.75
44 10 4            2  0.58 5 0.59 0.62 0.63 0.61 -0.50 015 -0.25 045 2
44 11 1 7.775 010  4  0.96 1 0.63 0.66 0.69 0.69  0.25      -3.25
44 11 2 7.550 085  2  0.53 4 0.57 0.57 0.59 0.59  0.00 000  0.00 000 1
44 11 3 7.850 170  4  0.96 1 0.60 0.67 0.69 0.67  0.25      -3.50
44 11 4 7.600 075  2  0.54 5 0.55 0.59 0.61 0.59 -0.25 010  0.00 000 2
45 01 1 7.725 170  4  1.08   0.67 0.74 0.71 0.73  0.00      -4.25
45 01 2 7.525 085  3  0.58   0.61 0.61 0.65 0.61  0.00 000 -0.25 175
45 01 3 7.725 010  4  0.96   0.69 0.71 0.74 0.73  0.50      -4.50
45 01 4 7.550 105  3  0.58   0.59 0.61 0.64 0.63 -0.25 170 -0.50 180
45 02 1            4
45 02 2               0.60
45 02 3            4
45 02 4               0.59
45 03 1            5
45 03 2               0.59
45 03 3            5
45 03 4               0.60
45 04 1            4
45 04 2               0.61
45 04 3            5
45 04 4               0.59
45 05 1            5
45 05 2               0.61
45 05 3            4
45 05 4               0.60
45 06 1            4
45 06 2            3  0.59
45 06 3            4
45 06 4            3  0.60
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45 07 1                4
45 07 2                3  0.58
45 07 3                4
45 07 4                3  0.58
45 08 1                4  1.16 1                                    0.25       -4.25
45 08 2                2  0.58 3                                   -0.25 170  -0.25 175 1
45 08 3                4  1.08 1                                    0.00       -4.50
45 08 4                2  0.57 3                                   -0.25 165  -0.25 175 3
45 09 1                4  1.40 1                                   -0.25       -4.25
45 09 2                2  0.57 4                                    0.00 000  -0.25 015 1
45 09 3                4  0.96 1                                    0.25       -4.50
45 09 4                2  0.58 4                                   -0.25 130  -0.25 160 1
45 10 1                5  1.16 1  0.67 0.72 0.69 0.67             -0.25       -4.50
45 10 2                2  0.58 4  0.61 0.63 0.63 0.61             -0.25 055  -0.25 025 1
45 10 3                5  1.08 1  0.69 0.73 0.71 0.69              0.25       -4.75
45 10 4                2  0.59 3  0.59 0.63 0.61 0.62             -0.25 155  -0.25 175 1
45 11 1 7.750 175      4  1.40 1  0.67 0.73 0.67 0.69              0.25       -4.00
45 11 2 7.600 070      2  0.57 5  0.60 0.61 0.63 0.61              0.00 000  -0.25 005 2
45 11 3 7.750 030      4  1.84 1  0.65 0.70 0.71 0.69              0.25       -4.25
45 11 4 7.550 105      2  0.57 5  0.58 0.61 0.62 0.60              0.00 000  -0.25 175 1
46 01 1 7.875 015      4  1.16    0.65 0.64 0.69 0.71              0.00       -1.75
46 01 2 7.675 100      2  0.57    0.57 0.60 0.57 0.60              0.00 000  -0.25 015
46 01 3 7.825 175      4  1.16    0.63 0.64 0.71 0.71              0.00       -2.50
46 01 4 7.625 080      1  0.57    0.55 0.61 0.57 0.64              0.00 000  -0.25 165
46 02 1                5
46 02 2                   0.58
46 02 3                9
46 02 4                   0.58
46 03 1                5
46 03 2                   0.59
46 03 3                5
46 03 4                   0.58
46 04 1                5
46 04 2                   0.58
46 04 3                5
46 04 4                   0.59
46 05 1                5
46 05 2                   0.57
46 05 3                5
46 05 4                   0.58
46 06 1                5
46 06 2                2  0.57
46 06 3                5
46 06 4                1  0.58
46 07 1                5
46 07 2                2  0.57
46 07 3                5
46 07 4                1  0.58
46 08 1                4  1.16 1                                    0.25       -1.75
46 08 2                2  0.58 4                                   -0.50 140  -0.25 170 3
46 08 3                4  1.40 1                                    0.00       -2.50
46 08 4                2  0.57 4                                   -0.25 160  -0.50 170 1
46 09 1                4  1.16 1                                    0.25       -2.00
46 09 2                2  0.56 4                                   -0.25 170  -0.25 170 1
46 09 3                4  1.84 1                                    0.00       -2.50
46 09 4                2  0.57 4                                    0.00 000  -0.50 175 1
46 10 1 7.850 180      5  1.08 1  0.65 0.63 0.67 0.71              0.50       -2.25
46 10 2 7.625 085      2  0.57 4  0.59 0.61 0.61 0.61             -0.25 120  -0.25 175 1
46 10 3 7.800 005      6  1.16 1  0.64 0.62 0.68 0.69             -1.25       -2.75
46 10 4 7.625 090      2  0.57 4  0.59 0.61 0.61 0.61             -0.25 135  -0.50 005 1
46 11 1
46 11 2
46 11 3
46 11 4
47 01 1 8.250 180      4  0.96    0.65 0.66 0.64 0.70              0.25       -4.75
47 01 2 8.250 050      2  0.59    0.63 0.61 0.62 0.60             -0.25 090  -0.50 105
47 01 3 8.325 000      4  0.96    0.65 0.67 0.74 0.71              0.25       -5.50
47 01 4 8.125 095      2  0.58    0.61 0.62 0.61 0.63             -0.25 005  -0.50 015
47 02 1                4
47 02 2                   0.61
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47 02 3                4
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47 03 1                5
47 03 2                   0.62
47 03 3                4
47 03 4                   0.64
47 04 1                6
47 04 2                   0.62
47 04 3                4
47 04 4                   0.64
47 05 1                5
47 05 2                   0.60
47 05 3                5
47 05 4                   0.62
47 06 1                4
47 06 2                2  0.61
47 06 3                5
47 06 4                2  0.61
47 07 1                4
47 07 2                2  0.62
47 07 3                5
47 07 4                2  0.64
47 08 1                4  0.96 1                                          0.00       -4.75
47 08 2                2  0.61 5                                          0.00 000 -0.50 085 1
47 08 3                4  0.96 1                                          0.50       -5.50
47 08 4                2  0.61 5                                         -0.25 180 -0.50 025 1
47 09 1                5  0.96 1                                          0.25       -4.75
47 09 2                2  0.60 1                                         -0.25 090 -0.50 085 1
47 09 3                4  0.96 1                                          0.50       -5.75
47 09 4                2  0.61 1                                         -0.25 170  0.00 000 1
47 10 1                5  1.08 1  0.65 0.67 0.67 0.68                     0.25       -5.00
47 10 2                2  0.60 4  0.60 0.62 0.63 0.65                    -0.50 100 -0.75 085 1
47 10 3                5  1.08 4  0.65 0.69 0.70 0.71                     0.50       -5.50
47 10 4                2  0.61 4  0.64 0.64 0.63 0.66                     0.00 000 -0.25 180 1
47 11 1 8.225 040      5  0.96 1  0.63 0.69 0.70 0.71                     0.25       -5.00
47 11 2 8.225 125      2  0.60 3  0.60 0.61 0.63 0.63                    -0.50 095 -0.75 095 1
47 11 3 8.350 180      5  1.08 1  0.68 0.69 0.66 0.69                     0.25       -5.75
47 11 4 8.100 090      2  0.61 3  0.64 0.61 0.63 0.63                     0.00 000 -0.25 170 1
48 01 1 7.825 005      5  1.08    0.64 0.64 0.67 0.67                     0.25       -4.00
48 01 2 7.525 095      2  0.56    0.58 0.58 0.57 0.61                    -0.50 170 -0.75 175
48 01 3 7.850 175      5  1.08    0.59 0.64 0.69 0.67                     0.25       -1.00
48 01 4 7.500 085      2  0.55    0.55 0.58 0.60 0.60                    -0.50 175 -1.00 170
48 02 1                6
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48 02 3                5
48 02 4                   0.55
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48 03 2                   0.57
48 03 3                5
48 03 4                   0.58
48 04 1                6
48 04 2                   0.56
48 04 3                5
48 04 4                   0.59
48 05 1                6
48 05 2                   0.56
48 05 3                5
48 05 4                   0.57
48 06 1                5
48 06 2                2  0.55
48 06 3                5
48 06 4                2  0.55
48 07 1                5
48 07 2                2  0.55
48 07 3                6
48 07 4                2  0.56
48 08 1                5  1.08 1                                          0.25       -3.75
48 08 2                2  0.55 4                                         -0.50 180 -0.75 175 1
48 08 3                5  1.08 1                                          0.00       -0.75
48 08 4                2  0.54 4                                         -0.25 015 -1.25 170 1
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48	09	1			5	1.08	1					0.25		-3.75		
48	09	2			2	0.54	4					-0.50	160	-0.75	175	1
48	09	3			9	1.08	1					-1.00		-0.75		
48	09	4			2	0.56	4					0.00	000	-1.25	180	1
48	10	1	7.675	005	5	1.16	1	0.61	0.63	0.63	0.65	0.25		-4.00		
48	10	2	7.575	095	2	0.53	4	0.55	0.56	0.55	0.55	-0.75	160	-0.75	175	1
48	10	3	7.900	000	5	1.40	1	0.59	0.61	0.65	0.67	0.75		-0.75		
48	10	4	7.675	080	2	0.53	3	0.54	0.55	0.60	0.57	-0.75	180	-1.00	180	1
48	11	1	7.825	005	5	1.40	1	0.61	0.64	0.67	0.66	0.75		-4.00		
48	11	2	7.575	090	2	0.56	4	0.59	0.55	0.59	0.57	-1.25	170	-0.50	175	1
48	11	3	7.700	175	5	1.40	1	0.63	0.62	0.69	0.67	0.25		-1.00		
48	11	4	7.525	075	2	0.55	4	0.57	0.59	0.59	0.59	-0.25	170	-1.25	175	1
49	01	1	8.150	015	4	1.34		0.67	0.67	0.70	0.73	0.00		-2.00		
49	01	2	8.000	095	1	0.57		0.61	0.65	0.61	0.62	0.00	000	-0.25	085	
49	01	3	8.075	155	4	1.40		0.66	0.67	0.69	0.73	0.00		-2.50		
49	01	4	7.725	080	1	0.58		0.57	0.61	0.62	0.62	0.00	000	0.00	000	
49	02	1			5											
49	02	2				0.59										
49	02	3			4											
49	02	4				0.61										
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49	03	3			4											
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49	04	3			5											
49	04	4				0.57										
49	05	1			4											
49	05	2				0.59										
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49	07	4			1	0.59										
49	08	1			5	1.08	1					0.50		-2.25		
49	08	2			2	0.59	5					-0.50	055	-0.50	085	1
49	08	3			6	0.96	1					0.25		-2.50		
49	08	4			2	0.59	5					-0.50	115	-0.25	115	1
49	09	1			4	0.96	4					0.75		-2.25		
49	09	2			2	0.57	1					-0.75	060	-0.50	085	1
49	09	3			4	0.96	4					0.25		-2.50		
49	09	4			2	0.57	5					-0.50	105	-0.25	115	1
49	10	1	8.100	180	4	0.96	1	0.65	0.67	0.67	0.74	0.25		-1.75		
49	10	2	8.000	070	2	0.58	4	0.60	0.62	0.63	0.63	-0.25	120	-0.75	090	1
49	10	3	8.175	170	4	1.34	1	0.61	0.67	0.70	0.77	0.50		-2.50		
49	10	4	8.000	075	2	0.57	4	0.57	0.59	0.61	0.63	-0.25	120	-0.25	115	1
49	11	1	8.000	155	5	1.08	1	0.65	0.67	0.68	0.71	0.00		-2.25		
49	11	2	7.950	080	2	0.57	3	0.59	0.59	0.61	0.65	-0.50	090	-0.75	045	1
49	11	3	8.125	170	5	0.96	1	0.64	0.69	0.73	0.69	0.25		-2.75		
49	11	4	7.925	085	2	0.57	3	0.58	0.60	0.63	0.63	-0.50	115	-0.25	115	1
50	01	1	7.675	155	4	1.16		0.71		0.74		0.00	000	-2.50		
50	01	2	7.550	065	2	0.61		0.65	0.65	0.66	0.69	0.00	000	0.00	000	
50	01	3	7.650	010	4	0.96		0.65	0.78	0.73	0.77	0.00		-1.50		
50	01	4	7.475	120	2	0.61		0.63	0.63	0.68	0.67	0.00	000	-0.25	170	
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50	02	4				0.65										
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50	04	1			4											
50	04	2				0.61										

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50 06 3
50 06 4
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50 07 4                2  0.64
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50 08 4                2  0.61 1                                    0.00 000   -0.25 170 1
50 09 1                6  1.08 1                                    0.00        -2.50
50 09 2                2  0.61 2                                    0.00 000   -0.25 100 1
50 09 3                5  0.96 1                                    0.25        -1.50
50 09 4                2  0.61 5                                    0.00 000    0.00 000 1
50 10 1 7.700 165      5  1.40 1  0.69 0.67 0.70 0.75               0.00        -2.75
50 10 2 7.575 070      2  0.58 5  0.63 0.62 0.64 0.63              -0.25 025    0.00 000 1
50 10 3 7.700 015      5  1.40 1  0.67 0.72 0.73 0.79               0.00        -1.50
50 10 4 7.525 105      2  0.59 5  0.59 0.63 0.65 0.65               0.00 000    0.00 000 1
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50 11 2
50 11 3
50 11 4
51 01 1 3.175 175      4  0.96    0.56 0.63 0.64 0.65               0.25        -4.00
51 01 2 7.975 085      2  0.47    0.51 0.51 0.51 0.55              -0.25 010   -0.75 180
51 01 3 8.225 015      4  0.96    0.58 0.59 0.67 0.55               0.50        -3.75
51 01 4 8.050 090      2  0.49    0.49 0.52 0.54 0.55              -0.25 180   -0.75 175
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51 04 3                4
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51 06 3                5
51 06 4                2  0.53
51 07 1                5
51 07 2                2  0.52
51 07 3                5
51 07 4                2  0.52
51 08 1                4  0.96 1                                    0.50        -4.00
51 08 2                2  0.51 4                                    0.00 000   -0.75 180 1
51 08 3                5  0.96 1                                    0.25        -3.75
51 08 4                2  0.51 4                                   -0.50 180   -0.75 175 1
51 09 1                4  0.96 1                                    0.00        -4.00
51 09 2                2  0.50 4                                    0.00 000   -0.75 180 1
51 09 3                4  0.96 1                                    0.75        -3.75
51 09 4                2  0.51 4                                    0.00 000   -0.75 175 1
51 10 1                6  0.96 1  0.59 0.63 0.65 0.69               0.00        -4.25
51 10 2                2  0.51 2  0.53 0.55 0.56 0.56              -0.75 175   -0.75 180 1
51 10 3                4  0.96 1  0.59 0.65 0.63 0.69               0.50        -3.75
51 10 4                2  0.50 4  0.52 0.53 0.55 0.55               0.00 000   -0.25 175 1
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51 11 4 8.000 085  2  0.51 4 0.53 0.53 0.54 0.54 -0.75 170 -0.75 010 1
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52 01 2 7.975 085  1  0.54    0.56 0.56 0.61 0.61  0.00 000 -0.50 090
52 01 3 8.150 175  4  1.08    0.63 0.65 0.62 0.70  0.00      -1.50
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52 07 3                4
52 07 4                1  0.54
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52 08 3                4  0.96 1                         -0.25      -1.75
52 08 4                2  0.56 3                          0.00 000 -0.50 095 1
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52 09 3                4  0.96 1                          0.25      -1.50
52 09 4                2  0.54 5                         -0.50 155 -0.50 095 1
52 10 1 8.025 180  4  0.96 1 0.63 0.56 0.63 0.71  0.25      -1.50
52 10 2 7.850 095  2  0.53 2 0.57 0.53 0.55 0.58 -0.25 105 -0.25 105 1
52 10 3 8.175 180  4  0.96 1 0.59 0.67 0.67 0.73  0.00      -1.75
52 10 4 7.775 090  2  0.53 2 0.56 0.57 0.57 0.61 -0.25 090 -0.50 095 1
52 11 1 8.175 180  4  0.96 1 0.63 0.57 0.61 0.69  0.75      -1.50
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52 11 3 8.150 002  4  0.96 1 0.65 0.54 0.67 0.71  0.25      -1.75
52 11 4 8.100 075  2  0.53 2 0.52 0.52 0.57 0.59 -0.25 110 -0.75 095 1
53 01 1 7.950 010  5  1.40    0.75 0.72 0.66 0.74  0.25      -4.75
53 01 2 7.750 105  2  0.56    0.56 0.56 0.67 0.59 -0.25 010 -1.00 015
53 01 3 7.900 065  4  1.16    0.71 0.71 0.61 0.71  0.25      -4.75
53 01 4 7.825 080  2  0.57    0.58 0.57 0.60 0.62 -0.25 090 -0.50 090
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53 03 3                5
53 03 4                   0.57
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53 04 2                   0.57
53 04 3                6
53 04 4                   0.58
53 05 1                5
53 05 2                   0.56
53 05 3                5
53 05 4                   0.55
53 06 1                5
53 06 2                2  0.58
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53	07	2			2	0.55											
53	07	3			6												
53	07	4			2	0.54											
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53	08	3			5	0.96	4					0.75		-4.50			
53	08	4			2	0.55	5					-0.75	005	-0.75	090	1	
53	09	1			6	1.84	1					0.75		-4.50			
53	09	2			2	0.54	1					-0.25	010	-1.00	015	1	
53	09	3			6	1.08	1					-0.50		-4.50			
53	09	4			2	0.55	1					-0.75	095	-0.75	090	1	
53	10	1	8.000	015	5	2.40	1	0.62	0.65	0.73	0.71	0.75		-4.50			
53	10	2	7.800	100	2	0.53	1	0.57	0.57	0.61	0.61	-0.50	020	-1.00	015	1	
53	10	3	7.925	150	5	1.84	1	0.63	0.66	0.69	0.71	0.00		-4.50			
53	10	4	7.850	050	2	0.55	1	0.57	0.58	0.61	0.63	-0.75	110	-0.50	090	1	
53	11	1	7.900	020	5	1.40	1	0.63	0.65	0.63	0.68	0.25		-4.75			
53	11	2	7.725	105	2	0.54	1	0.57	0.55	0.57	0.56	-0.50	180	-1.00	020	1	
53	11	3	7.950	130	5	1.16	1	0.65	0.67	0.71	0.71	0.25		-4.75			
53	11	4	7.850	015	2	0.54	4	0.59	0.57	0.61	0.61	-0.75	115	-0.75	090	1	
54	01	1	8.400	140	4	0.96		0.63	0.71	0.68	0.66	0.00		-1.50			
54	01	2	8.300	045	2	0.57		0.58	0.59	0.61	0.61	0.00	000	-0.25	095		
54	01	3	8.375	025	4	1.08		0.63	0.67	0.69	0.68	0.00		-1.25			
54	01	4	8.300	115	2	0.57		0.58	0.57	0.61	0.63	0.00	000	-0.25	025		
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54	03	3			4												
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54	04	2				0.57											
54	04	3			4												
54	04	4				0.58											
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54	05	2				0.57											
54	05	3			4												
54	05	4				0.56											
54	06	1			5												
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54	06	3			5												
54	06	4			2	0.56											
54	07	1			5												
54	07	2			2	0.55											
54	07	3			5												
54	07	4			2	0.56											
54	08	1			6	0.96	1					0.25		-1.25			
54	08	2			2	0.55	4					-0.25	130	-0.25	130	1	
54	08	3			5	0.96	1					0.75		-1.00			
54	08	4			2	0.56	4					-0.50	085	-0.25	060	1	
54	09	1			5	1.08	1					0.50		-1.00			
54	09	2			2	0.54	4					-0.50	015	-0.50	105	1	
54	09	3			4	1.08	1					0.75		-0.75			
54	09	4			2	0.55	4					-0.50	080	-0.50	025	1	
54	10	1	8.350	165	5	1.16	1	0.63	0.66	0.64	0.71	0.50		-1.25			
54	10	2	8.350	040	2	0.55	4	0.57	0.57	0.60	0.59	-0.75	080	-0.50	110	1	
54	10	3	8.350	035	4	1.16	1	0.61	0.66	0.69	0.67	0.25		-0.75			
54	10	4	8.275	120	2	0.55	4	0.56	0.58	0.61	0.60	-0.25	045	-0.75	020	1	
54	11	1	8.425	085	4	0.96	1	0.63	0.66	0.70	0.67	0.50		-1.50			
54	11	2	8.375	175	2	0.53	1	0.57	0.57	0.59	0.57	-0.50	085	-0.25	070	1	
54	11	3	8.375	030	4	1.08	1	0.59	0.64	0.65	0.66	0.25		-1.25			
54	11	4	8.275	120	2	0.54	1	0.54	0.59	0.58	0.61	-0.25	085	-0.50	080	1	
55	01	1	7.925	180	4	1.84		0.68	0.72	0.65	0.70	0.50		-1.75			
55	01	2	7.725	090	2	0.58		0.59	0.64	0.60	0.66	-0.25	160	-0.50	165		
55	01	3	7.975	170	4	1.40		0.63	0.68	0.75	0.71	0.25		-3.00			
55	01	4	7.650	080	2	0.59		0.58	0.64	0.65	0.62	-0.25	160	-0.75	175		

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55 08 4                2  0.57 4                                         -0.25 015 -0.75 005 1
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55 09 3                5  1.08 1                                          0.50      -2.75
55 09 4                2  0.58 4                                         -0.75 180 -1.75 005 1
55 10 1 7.950 175      4  1.08 1 0.66 0.66 0.65 0.72                      0.50      -2.00
55 10 2 7.675 075      2  0.59 3 0.59 0.59 0.59 0.63                     -1.25 170 -0.75 150 4
55 10 3 8.050 180      6  1.08 1 0.66 0.67 0.71 0.73                      0.50      -2.75
55 10 4 7.725 085      2  0.59 3 0.61 0.61 0.62 0.63                     -1.25 175 -0.75 005 4
55 11 1 7.900 170      4  1.08 1 0.67 0.69 0.69 0.69                      0.00      -2.00
55 11 2 7.700 075      2  0.58 4 0.63 0.61 0.61 0.62                      0.00 000 -0.50 150 1
55 11 3 7.975 175      6  1.16 1 0.62 0.69 0.77 0.66                      0.00      -2.75
55 11 4 7.675 085      2  0.57 4 0.57 0.64 0.63 0.61                     -0.75 035 -0.25 020 1
56 01 1 8.025 005      4  1.16    0.74 0.78 0.75 0.75                     0.25      -4.75
56 01 2 7.800 095      3  0.59    0.65 0.64 0.64 0.67                     0.00 000 -0.25 175
56 01 3 8.025 180      4  1.08    0.68 0.76 0.74 0.78                     0.00      -3.50
56 01 4 7.800 090      3  0.60    0.62 0.65 0.64 0.67                     0.00 000 -0.25 010
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56 05 4                   0.62
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56 07 1                4
56 07 2                3  0.61
56 07 3                4
56 07 4                3  0.59
56 08 1               12  1.16 1                                          1.25      -5.00
56 08 2                2  0.61 2                                         -0.25 010  0.00 000 4
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56	09	2			2	0.60	4					-0.75	015	-0.50	015	1	
56	09	3			5	1.16	1					0.25		-3.50			
56	09	4			2	0.59	4					-0.50	180	-0.50	015	1	
56	10	1			5	1.16	1	0.69	0.75	0.73	0.78	0.25		-5.00			
56	10	2			2	0.61	2	0.66	0.63	0.67	0.67	-0.75	020	-0.50	010	1	
56	10	3			4	1.08	1	0.69	0.77	0.73	0.79	0.25		-3.75			
56	10	4			2	0.61	2	0.61	0.65	0.67	0.67	-0.50	005	0.00	000	1	
56	11	1	8.025	010	12	1.08	1	0.70	0.73	0.71	0.73	0.50		-4.75			
56	11	2	7.775	085	3	0.58	2	0.63	0.64	0.65	0.65	0.00	000	0.00	000	4	
56	11	3	8.000	005	5	1.16	1	0.70	0.73	0.79	0.75	0.50		-3.50			
56	11	4	7.675	085	3	0.61	3	0.63	0.65	0.65	0.66	-0.75	175	-0.75	180	1	
57	01	1	8.050	005	4	1.08		0.74	0.71	0.74	0.78	0.25		-2.50			
57	01	2	7.850	090	3	0.65		0.66	0.66	0.65	0.70	0.00	000	-0.50	175		
57	01	3	8.075	170	4	1.08		0.70	0.73	0.73	0.79	0.25		-2.25			
57	01	4	7.775	085	3	0.66		0.65	0.66	0.67	0.70	-0.25	170	-0.50	175		
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57	03	3			4												
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57	08	2			2	0.65	4					-0.25	005	-0.50	175	3	
57	08	3			4	2.40	4					0.25		-2.25			
57	08	4			2	0.65	4					-0.50	175	-0.50	165	3	
57	09	1			4	1.16	1					0.50		-2.25			
57	09	2			2	0.63	2					-0.50	175	-0.50	175	1	
57	09	3			4	1.16	1					0.50		-2.00			
57	09	4			2	0.64	2					-0.25	155	-0.50	165	1	
57	10	1	8.100	005	4	1.08	1	0.71	0.73	0.73	0.72	0.00		-2.25			
57	10	2	7.875	085	2	0.63	5	0.69	0.65	0.63	0.68	0.00	000	-0.50	170	1	
57	10	3	8.125	170	4	0.96	1	0.68	0.73	0.71	0.74	0.00		-2.00			
57	10	4	7.875	080	2	0.64	4	0.65	0.65	0.65	0.65	0.00	000	-0.25	160	3	
57	11	1	7.975	005	4	1.40	1	0.71	0.69	0.67	0.73	0.00		-2.25			
57	11	2	7.825	080	2	0.61	2	0.63	0.63	0.63	0.66	0.00	000	-0.50	175	4	
57	11	3	8.000	175	4	1.40	1	0.65	0.69	0.71	0.73	0.00		-2.00			
57	11	4	7.800	080	2	0.59	3	0.61	0.63	0.65	0.63	0.00	000	-0.50	165	1	
58	01	1	7.925	005	4	1.08		0.64	0.61	0.65	0.67	0.00		-1.25			
58	01	2	7.775	090	2	0.56		0.57	0.61	0.56	0.60	0.00	000	0.00	000		
58	01	3	7.925	010	4	0.96		0.59	0.63	0.65	0.66	0.00		-1.75			
58	01	4	7.850	105	2	0.56		0.54	0.59	0.56	0.59	0.00	000	-0.25	075		
58	02	1			4												
58	02	2				0.56											
58	02	3			4												
58	02	4				0.57											
58	03	1			4												
58	03	2				0.55											
58	03	3			5												
58	03	4				0.55											

58	04	1			4												
58	04	2				0.55											
58	04	3			4												
58	04	4				0.55											
58	05	1			4												
58	05	2				0.55											
58	05	3			4												
58	05	4				0.55											
58	06	1			4												
58	06	2			2	0.55											
58	06	3			4												
58	06	4			2	0.55											
58	07	1			4												
58	07	2			2	0.56											
58	07	3			4												
58	07	4			2	0.56											
58	08	1			4	0.96	1						0.00		-1.25		
58	08	2			2	0.56	4						0.00	000	-0.25	120	1
58	08	3			4	0.96	1						0.00		-1.75		
58	08	4			2	0.58	4						-0.25	085	-0.25	070	3
58	09	1			6	1.08	1						0.25		-1.25		
58	09	2			2	0.55	4						-0.25	095	0.00	000	1
58	09	3			6	1.08	1						-0.25		-1.75		
58	09	4			2	0.56	4						-0.25	070	-0.25	070	1
58	10	1	7.975	165	4	1.16	1	0.65	0.62	0.67	0.67		0.25		-1.25		
58	10	2	7.750	075	2	0.55	1	0.61	0.57	0.59	0.59		-0.25	095	0.00	000	1
58	10	3	7.900	005	5	1.40	1	0.59	0.65	0.63	0.69		-0.50		-1.75		
58	10	4	7.775	100	2	0.57	1	0.57	0.58	0.52	0.59		-0.25	065	-0.25	070	1
58	11	1	7.975	180	6	1.40	1	0.63	0.63	0.67	0.65		-0.50		-1.50		
58	11	2	7.750	090	2	0.55	4	0.56	0.57	0.57	0.57		0.00	000	-0.50	170	1
58	11	3	7.950	010	6	1.16	1	0.57	0.67	0.64	0.66		-0.50		-1.75		
58	11	4	7.800	090	2	0.55	4	0.51	0.57	0.60	0.59		0.00	000	0.00	000	1
59	01	1	8.025	165	4	0.96		0.61	0.61	0.64	0.63		0.00		-1.75		
59	01	2	7.950	065	3	0.51		0.53	0.56	0.56	0.55		0.00	000	0.00	000	
59	01	3	8.050	175	4	0.96		0.59	0.56	0.67	0.68		0.00		-2.50		
59	01	4	7.975	085	3	0.52		0.52	0.58	0.55	0.57		0.00	000	-0.25	020	
59	02	1			4												
59	02	2				0.52											
59	02	3			5												
59	02	4				0.53											
59	03	1			4												
59	03	2				0.57											
59	03	3			4												
59	03	4				0.58											
59	04	1			4												
59	04	2				0.53											
59	04	3			5												
59	04	4				0.56											
59	05	1			5												
59	05	2				0.54											
59	05	3			5												
59	05	4				0.55											
59	06	1			5												
59	06	2			3	0.54											
59	06	3			5												
59	06	4			3	0.54											
59	07	1			5												
59	07	2			3	0.53											
59	07	3			4												
59	07	4			3	0.54											
59	08	1			4	1.08	1						0.00		-1.75		
59	08	2			2	0.53	5						0.00	000	0.00	000	1
59	08	3			4	1.08	1						0.00		-2.25		
59	08	4			2	0.55	4						0.00	000	-0.25	050	1
59	09	1			4	0.96	1						0.00		-1.50		
59	09	2			3	0.52	4						-0.25	165	-0.25	090	1
59	09	3			4	1.08	1						0.00		-2.50		
59	09	4			3	0.54	4						0.00	000	0.00	000	2
59	10	1	8.025	175	4	1.08	1	0.61	0.61	0.63	0.63		0.00		-2.00		
59	10	2	7.975	075	2	0.52	4	0.57	0.55	0.55	0.55		-0.25	115	0.00	000	1

59	10	3	8.075	020	4	1.16	1	0.63	0.61	0.69	0.66	0.25		-2.50			
59	10	4	7.975	095	2	0.53	4	0.55	0.55	0.59	0.58	-0.50	040	-0.25	035	1	
59	11	1	8.075	180	5	6.64	1	0.63	0.59	0.64	0.69	0.75		-2.25			
59	11	2	8.000	095	3	0.53	3	0.54	0.56	0.53	0.55	-0.75	035	0.00	000	1	
59	11	3	8.075	005	5	2.40	4	0.57	0.59	0.67	0.67	0.50		-2.75			
59	11	4	7.925	100	3	0.53	5	0.51	0.55	0.56	0.54	-0.50	035	-0.25	040	1	
60	01	1	8.025	170	4	1.08		0.62	0.64	0.66	0.70	0.25		-2.75			
60	01	2	7.825	070	2	0.56		0.56	0.57	0.58	0.60	-0.25	090	-0.50	095		
60	01	3	8.075	175	4	1.08		0.62	0.66	0.65	0.71	0.25		-3.50			
60	01	4	7.875	085	2	0.54		0.56	0.59	0.57	0.59	0.00	000	-0.25	180		
60	02	1			5												
60	02	2				0.56											
60	02	3			5												
60	02	4				0.55											
60	03	1			4												
60	03	2				0.57											
60	03	3			4												
60	03	4				0.57											
60	04	1			4												
60	04	2				0.58											
60	04	3			4												
60	04	4				0.58											
60	05	1			4												
60	05	2				0.56											
60	05	3			4												
60	05	4				0.57											
60	06	1			5												
60	06	2			2	0.57											
60	06	3			4												
60	06	4			2	0.58											
60	07	1			5												
60	07	2			2	0.58											
60	07	3			4												
60	07	4			2	0.58											
60	08	1			4	1.84	1					-0.50		-2.50			
60	08	2			2	0.57	4					-0.25	175	-0.50	110	2	
60	08	3			4	1.40	1					0.25		-3.25			
60	08	4			2	0.57	4					-0.25	170	-0.25	005	1	
60	09	1			5	1.40	1					0.25		-2.25			
60	09	2			2	0.56	4					-0.25	060	-0.50	100	1	
60	09	3			4	1.16	1					0.50		-3.50			
60	09	4			2	0.55	4					-0.25	015	-0.50	010	1	
60	10	1			4	0.96	1	0.60	0.64	0.66	0.70	0.00		-2.50			
60	10	2			2	0.56	4	0.59	0.59	0.58	0.60	0.00	000	-0.25	110	1	
60	10	3			5	0.96	1	0.66	0.67	0.68	0.71	0.75		-3.50			
60	10	4			2	0.56	4	0.57	0.57	0.59	0.63	-0.50	020	-0.50	010	1	
60	11	1	8.050	165	4	1.40	1	0.64	0.65	0.69	0.71	0.25		-2.50			
60	11	2	7.900	080	2	0.59	3	0.59	0.59	0.61	0.62	-0.25	130	-0.25	125	1	
60	11	3	8.050	170	4	0.96	1	0.65	0.63	0.67	0.73	-0.50		-3.75			
60	11	4	7.925	080	2	0.59	3	0.58	0.59	0.61	0.63	-0.25	165	-0.25	010	1	
61	01	1	7.725	125	4	1.08		0.63	0.66	0.65	0.65	0.00		-4.25			
61	01	2	7.750	015	2	0.51		0.55	0.53	0.53	0.56	0.00	000	-0.25	055		
61	01	3	7.775	140	4	0.96		0.57	0.62	0.67	0.59	0.00		-3.50			
61	01	4	7.700	080	2	0.51		0.53	0.53	0.57	0.52	0.00	000	-0.25	085		
61	02	1			5												
61	02	2				0.52											
61	02	3			4												
61	02	4				0.50											
61	03	1			4												
61	03	2				0.52											
61	03	3			4												
61	03	4				0.52											
61	04	1			4												
61	04	2				0.53											
61	04	3			4												
61	04	4				0.54											
61	05	1			4												
61	05	2				0.50											
61	05	3			5												
61	05	4				0.51											

61	06	1			4													
61	06	2			2	0.50												
61	06	3			4													
61	06	4			2	0.51												
61	07	1			4													
61	07	2			2	0.52												
61	07	3			5													
61	07	4			2	0.51												
61	08	1			5	1.08	1						-0.25		-4.00			
61	08	2			2	0.49	4						-0.25	175	-0.25	085	2	
61	08	3			4	0.96	1						0.00		-3.25			
61	08	4			1	0.49	1						-0.25	056	-0.50	095	1	
61	09	1			5	1.16	1						-0.25		-4.00			
61	09	2			2	0.49	1						-0.25	140	-0.25	070	1	
61	09	3			5	0.96	1						0.25		-3.25			
61	09	4			1	0.49	1						-0.25	050	-0.50	085	1	
61	10	1	7.775	175	5	1.04	1	0.59	0.59	0.59	0.65		0.25		-4.25			
61	10	2	7.625	085	2	0.49	3	0.53	0.53	0.49	0.55		-0.25	135	0.00	000	1	
61	10	3	7.775	035	5	0.96	1	0.58	0.57	0.65	0.67		0.00		-3.50			
61	10	4	7.750	140	1	0.50	3	0.52	0.53	0.57	0.55		-0.25	055	-0.25	085	1	
61	11	1	7.725	030	4	0.96	1	0.61	0.59	0.63	0.63		0.25		-4.00			
61	11	2	7.700	095	2	0.51	3	0.53	0.52	0.59	0.53		0.00	000	-0.25	075	2	
61	11	3	7.725	090	5	0.96	1	0.63	0.59	0.65	0.63		0.00		-3.50			
61	11	4	7.725	180	2	0.50	3	0.53	0.52	0.55	0.55		-0.50	095	-0.50	080	1	
62	01	1	8.000	015	4	1.08		0.65	0.68	0.65	0.75		0.25		-2.00			
62	01	2	7.750	100	2	0.53		0.54	0.56	0.54	0.59		-0.25	005	-0.50	010		
62	01	3	7.975	170	4	0.96		0.65	0.66	0.72	0.75		0.25		-2.00			
62	01	4	7.900	080	2	0.56		0.57	0.55	0.60	0.59		0.00	000	-0.25	180		
62	02	1			5													
62	02	2				0.53												
62	02	3			4													
62	02	4				0.54												
62	03	1			5													
62	03	2				0.55												
62	03	3			4													
62	03	4				0.55												
62	04	1			4													
62	04	2				0.56												
62	04	3			4													
62	04	4				0.55												
62	05	1			4													
62	05	2				0.53												
62	05	3			4													
62	05	4				0.55												
62	06	1			4													
62	06	2			2	0.53												
62	06	3			4													
62	06	4			2	0.54												
62	07	1			4													
62	07	2			2	0.53												
62	07	3			4													
62	07	4			2	0.54												
62	08	1			4	0.96	1						0.25		-2.00			
62	08	2			2	0.55	3						0.00	000	-0.50	020	1	
62	08	3			4	0.96	1						0.00		-2.00			
62	08	4			2	0.55	4						0.00	000	0.00	000	1	
62	09	1			4	0.96	1						0.25		-2.25			
62	09	2			2	0.53	1						0.00	030	-0.25	050	1	
62	09	3			4	0.96	1						0.25		-2.00			
62	09	4			2	0.53	1						-0.25	100	-0.25	070	1	
62	10	1			4	1.40	1	0.62	0.67	0.70	0.75		1.00		-2.00			
62	10	2			2	0.56	1	0.55	0.56	0.61	0.59		-0.25	050	0.00	000	1	
62	10	3			4	1.40	1	0.63	0.67	0.71	0.75		0.00		-2.00			
62	10	4			2	0.55	4	0.58	0.57	0.61	0.60		-0.25	090	-0.25	070	1	
62	11	1	7.925	180	5	0.96	1	0.64	0.67	0.71	0.69		1.00		-2.25			
62	11	2	7.850	105	2	0.53	3	0.59	0.57	0.60	0.59		-0.50	065	-0.25	070	1	
62	11	3	7.950	170	6	0.96	1	0.59	0.71	0.73	0.71		-0.25		-2.25			
62	11	4	7.825	090	3	0.54	3	0.57	0.55	0.60	0.61		-0.25	100	-0.25	160	1	
63	01	1	7.925	010	4	1.16		0.71	0.68	0.71	0.75		0.50		-5.00			
63	01	2	7.800	100	2	0.58		0.60	0.64	0.64	0.62		-0.25	005	-0.50	010		

63	01	3	8.000	045	4	1.16		0.66	0.71	0.74	0.76	0.50		-3.50			
63	01	4	7.850	135	2	0.58		0.63	0.61	0.66	0.66	-0.50	035	-0.75	045		
63	02	1			5												
63	02	2				0.61											
63	02	3			5												
63	02	4				0.60											
63	03	1			5												
63	03	2				0.64											
63	03	3			6												
63	03	4				0.63											
63	04	1			5												
63	04	2				0.61											
63	04	3			5												
63	04	4				0.63											
63	05	1			6												
63	05	2				0.63											
63	05	3			6												
63	05	4				0.64											
63	06	1			6												
63	06	2			2	0.64											
63	06	3			6												
63	06	4			2	0.65											
63	07	1			5												
63	07	2			2	0.63											
63	07	3			6												
63	07	4			2	0.64											
63	08	1			6	1.08	1					0.75		-5.25			
63	08	2			2	0.63	4					-0.50	085	-0.25	135	1	
63	08	3			6	0.96	1					0.75		-3.75			
63	08	4			2	0.64	2					-0.75	045	-0.50	070	1	
63	09	1			6	0.96	1					1.00		-5.25			
63	09	2			2	0.64	1					-0.75	015	-0.25	010	1	
63	09	3			6	0.96	1					0.75		-3.75			
63	09	4			2	0.64	4					-1.00	055	-1.00	045	1	
63	10	1			9	0.96	1	0.79	0.70	0.75	0.66	0.75		-5.50			
63	10	2			2	0.63	1	0.71	0.65	0.64	0.65	-1.00	075	-0.25	115	1	
63	10	3			9	0.96	1	0.69	0.73	0.74	0.77	0.25		-4.00			
63	10	4			2	0.63	4	0.63	0.64	0.66	0.68	-1.00	065	-1.00	040	1	
63	11	1	7.925	005	6	0.96	1	0.69	0.71	0.69	0.77	0.00		-5.50			
63	11	2	7.750	085	2	0.63	2	0.65	0.66	0.63	0.67	-0.50	040	-0.75	175	1	
63	11	3	7.975	035	6	0.96	1	0.69	0.71	0.75	0.75	0.00		-4.00			
63	11	2	7.875	130	2	0.63	3	0.63	0.67	0.67	0.69	-0.75	045	-1.00	045	2	
64	01	1	7.775	015		0.96		0.63	0.54	0.64	0.64	0.25		-4.25			
64	01	2	7.525	105	3	0.53		0.54	0.52	0.56	0.56	-0.50	015	-0.75	025		
64	01	3	7.750	155		0.96		0.58	0.53	0.61	0.63	0.50		-4.50			
64	01	4	7.600	070	3	0.52		0.53	0.50	0.55	0.57	-0.50	130	-0.75	140		
64	02	1			5												
64	02	2				0.51											
64	02	3			4												
64	02	4				0.51											
64	03	1			5												
64	03	2				0.52											
64	03	3			5												
64	03	4				0.52											
64	04	1			5												
64	04	2				0.53											
64	04	3			5												
64	04	4				0.51											
64	05	1			5												
64	05	2				0.53											
64	05	3			4												
64	05	4				0.53											
64	06	1			5												
64	06	2			2	0.52											
64	06	3			4												
64	06	4			2	0.51											
64	07	1			5												
64	07	2			2	0.51											
64	07	3			5												
64	07	4			2	0.51											

64	08	1			5	0.96	1					0.25		-4.25		
64	08	2			2	0.51	4					0.00	000	-0.50	025	1
64	08	3			5	0.96	1					0.50		-4.50		
64	08	4			2	0.51	4					-0.75	130	-0.75	145	1
64	09	1			5	0.96	1					-0.25		-4.25		
64	09	2			2	0.50	4					0.00	030	-0.50	040	1
64	09	3			5	0.96	1					0.25		-4.50		
64	09	4			2	0.50	4					0.50	150	-0.75	145	1
64	10	1	7.750	005	5	0.96	1	0.59	0.55	0.59	0.63	0.00		-4.25		
64	10	2	7.550	100	2	0.48	3	0.53	0.51	0.53	0.55	-0.25	030	-0.75	175	1
64	10	3	7.675	180	5	1.16	1	0.56	0.55	0.59	0.63	0.00		-4.75		
64	10	4	7.425	070	2	0.49	3	0.51	0.50	0.55	0.55	-0.30	165	-0.50	150	2
64	11	1	7.725	015	5	0.96	1	0.57	0.53	0.63	0.67	-0.25		-4.50		
64	11	2	7.450	100	2	0.51	5	0.53	0.51	0.55	0.55	-0.25	020	0.00	000	1
64	11	3	7.650	165	5	0.96	1	0.59	0.57	0.60	0.59	-0.50		-4.50		
64	11	4	7.550	045	2	0.51	3	0.52	0.53	0.57	0.54	-0.50	120	-1.00	135	1
65	01	1	7.625	170	5	0.96		0.71	0.70	0.63	0.69	0.25		-1.75		
65	01	2	7.450	085	2	0.55		0.59	0.55	0.57	0.59	0.00	000	-0.50	150	
65	01	3	7.625	180	5	0.96		0.65	0.67	0.67	0.71	0.25		-4.00		
65	01	4	7.350	085	1	0.54		0.55	0.57	0.61	0.61	-0.25	180	-0.75	170	
65	02	1			6											
65	02	2				0.57										
65	02	3			6											
65	02	4				0.55										
65	03	1			5											
65	03	2				0.57										
65	03	3			6											
65	03	4				0.56										
65	04	1			6											
65	04	2				0.55										
65	04	3			6											
65	04	4				0.59										
65	05	1			6											
65	05	2				0.57										
65	05	3			6											
65	05	4				0.55										
65	06	1			5											
65	06	2			2	0.56										
65	06	3			6											
65	06	4			2	0.54										
65	07	1			5											
65	07	2			2	0.59										
65	07	3			6											
65	07	4			2	0.55										
65	08	1			6	0.96	1					0.50		-1.75		
65	08	2			2	0.57	2					0.00	000	-0.50	150	1
65	08	3			5	0.96	1					0.25		-4.50		
65	08	4			2	0.54	1					-1.25	170	-0.75	170	3
65	09	1			6	0.96	1					0.25		-1.75		
65	09	2			2	0.56	4					0.00	000	-0.50	175	1
65	09	3			5	0.96	1					0.25		-4.50		
65	09	4			2	0.53	1					-0.75	165	-1.00	165	1
65	10	1	7.575	165	6	0.96	1	0.69	0.67	0.66	0.69	0.00		-1.75		
65	10	2	7.425	065	2	0.55	2	0.59	0.57	0.60	0.59	-0.50	120	-0.75	160	1
65	10	3	7.550	180	6	0.96	1	0.61	0.68	0.65	0.69	0.25		-4.25		
65	10	4	7.325	085	2	0.54	5	0.56	0.56	0.57	0.59	-0.75	175	-1.00	180	1
65	11	1	7.700	160	6	0.96	1	0.67	0.65	0.63	0.67	0.75		-1.75		
65	11	2	7.475	065	2	0.55	2	0.61	0.57	0.59	0.59	-0.50	125	-0.50	165	1
65	11	3	7.575	180	6	0.96	1	0.55	0.61	0.65	0.67	0.50		-4.00		
65	11	4	7.350	090	2	0.55	5	0.53	0.51	0.57	0.53	-0.75	170	-1.00	180	1
66	01	1	8.175	180	4	1.16		0.56	0.66	0.67	0.67	0.50		-3.50		
66	01	2	7.950	080	2	0.54		0.58	0.57	0.63	0.62	0.00	000	-0.50	170	
66	01	3	8.150	180	4	1.16		0.63	0.69	0.71	0.70	0.50		-1.75		
66	01	4	7.750	080	2	0.56		0.57	0.57	0.62	0.61	-0.25	180	-0.75	005	
66	02	1			4											
66	02	2				0.58										
66	02	3			5											
66	02	4				0.58										
66	03	1			5											
66	03	2				0.57										

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66 03 3                5
66 03 4                   0.55
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66 04 2                   0.56
66 04 3                5
66 04 4                   0.55
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66 05 2                   0.56
66 05 3                5
66 05 4                   0.57
66 06 1                5
66 06 2                2  0.57
66 06 3                4
66 06 4                2  0.58
66 07 1                5
66 07 2                2  0.55
66 07 3                5
66 07 4                2  0.56
66 08 1                5  1.40 1                                    0.50      -3.25
66 08 2                3  0.56 1                                   -0.25 180  -0.50 120 1
66 08 3                5  1.40 1                                    0.50      -1.75
66 08 4                3  0.55 1                                   -0.25 025  -0.50 010 1
66 09 1                5  1.16 1                                    0.25      -3.00
66 09 2                2  0.57 3                                   -0.25 145  -0.50 150 1
66 09 3                5  1.40 1                                    0.25      -1.75
66 09 4                2  0.55 3                                   -0.75 005  -0.75 180 1
66 10 1 8.050 180      4  1.40 1 0.64 0.67 0.64 0.69                0.00      -3.00
66 10 2 7.850 085      2  0.55 2 0.57 0.57 0.58 0.59                0.00 000  -0.50 145 1
66 10 3 8.150 180      4  1.16 1 0.61 0.67 0.72 0.71                0.00      -1.75
66 10 4 7.825 090      2  0.55 1 0.55 0.58 0.59 0.59               -0.25 180  -0.75 180 1
66 11 1 8.075 170      4  1.34 1 0.67 0.67 0.69 0.67                0.25      -3.00
66 11 2 7.850 075      2  0.53 3 0.55 0.55 0.57 0.56               -0.25 010  -0.50 145 1
66 11 3 8.125 005      5  2.40 1 0.59 0.65 0.71 0.71                0.00      -1.75
66 11 4 7.750 085      2  0.54 2 0.55 0.56 0.59 0.57               -0.25 005  -0.75 005 1
67 01 1 8.200 170      4  1.16    0.67 0.65 0.73 0.74               0.00      -2.50
67 01 2 8.125 085      2  0.56    0.60 0.58 0.65 0.62               0.00 000   0.00 000
67 01 3 8.300 180      4  0.96    0.63 0.62 0.68 0.71               0.50      -1.25
67 01 4 8.075 095      2  0.58    0.58 0.60 0.60 0.60              -0.25 005  -0.75 005
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67 02 3                5
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67 03 3                4
67 03 4                   0.59
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67 04 2                   0.60
67 04 3                6
67 04 4                   0.61
67 05 1                4
67 05 2                   0.63
67 05 3                4
67 05 4                   0.64
67 06 1                4
67 06 2                2  0.61
67 06 3                4
67 06 4                2  0.62
67 07 1                4
67 07 2                2  0.64
67 07 3                5
67 07 4                2  0.63
67 08 1                4  0.96 1                                    0.25      -2.50
67 08 2                3  0.61 3                                   -0.25 175   0.00 000 1
67 08 3                4  1.08 1                                    0.50      -2.00
67 08 4                3  0.61 3                                   -0.50 010  -0.75 015 1
67 09 1                4  1.08 1                                    0.25      -2.50
67 09 2                2  0.59 2                                   -0.75 175   0.00 000 1
67 09 3                4  0.96 1                                    0.25      -1.50
67 09 4                2  0.60 1                                    0.00 000  -0.75 005 1
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67 10 1 8.200 010  4  1.08 1 0.69 0.66 0.77 0.75  0.25      -2.25
67 10 2 8.150 110  2  0.63 1 0.64 0.67 0.67 0.67 -0.50 130  0.00 000 1
67 10 3 8.275 005  4  0.96 1 0.66 0.67 0.73 0.75  0.25      -1.50
67 10 4 8.100 095  2  0.62 1 0.63 0.69 0.67 0.68 -0.25 110 -0.75 005 1
67 11 1 8.075 075  4  1.40 1 0.73 0.69 0.73 0.74  0.25      -2.75
67 11 2 8.050 175  2  0.63 2 0.67 0.65 0.67 0.66 -0.50 090 -0.50 090 1
67 11 3 8.275 005  4  1.40 1 0.68 0.69 0.77 0.74  1.00      -1.50
67 11 4 8.075 100  2  0.61 2 0.64 0.63 0.69 0.68 -0.75 020 -0.75 010 1
68 01 1 8.025 160  4  1.08    0.64 0.72 0.71 0.66  0.00      -1.75
68 01 2 7.850 030  2  0.59    0.65 0.63 0.63 0.65  0.00 000 -0.25 095
68 01 3 8.025 045  4  0.96    0.68 0.68 0.73 0.71  0.00      -2.50
68 01 4 7.925 140  2  0.60    0.62 0.65 0.63 0.63  0.00 000 -0.00 065
68 02 1            6
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68 02 3            5
68 02 4                 0.64
68 03 1            6
68 03 2                 0.64
68 03 3            6
68 03 4                 0.65
68 04 1            5
68 04 2                 0.64
68 04 3            4
68 04 4                 0.64
68 05 1            5
68 05 2                 0.65
68 05 3            4
68 05 4                 0.68
68 06 1            4
68 06 2            2    0.62
68 06 3            4
68 06 4            2    0.63
68 07 1            5
68 07 2            2    0.64
68 07 3            5
68 07 4            2    0.61
68 08 1            5    0.96 1                          0.25      -1.75
68 08 2            3    0.63 1                          0.00 000 -0.50 085 1
68 08 3            4    0.96 1                          0.25      -2.50
68 08 4            3    0.63 2                          0.00 000 -0.50 070 1
68 09 1            5    0.96 1                          0.75      -1.50
68 09 2            2    0.62 1                         -0.50 110 -0.75 090 1
68 09 3            4    0.96 1                          0.25      -2.75
68 09 4            2    0.62 1                         -0.25 070 -0.75 065 1
68 10 1            5    0.96 1 0.73 0.70 0.70 0.72      0.50      -1.75
68 10 2            2    0.62 3 0.65 0.67 0.65 0.67 -0.75 100 -0.75 100 1
68 10 3            5    0.96 1 0.69 0.68 0.71 0.77 -0.25      -2.75
68 10 4            2    0.63 3 0.65 0.65 0.65 0.66  0.00 000 -0.50 050 1
68 11 1 8.000 145  4  0.96 1 0.72 0.67 0.71 0.71  0.25      -2.00
68 11 2 7.925 040  2  0.61 3 0.63 0.63 0.62 0.66  0.00 000 -0.25 100 1
68 11 3 8.000 035  4  0.96 4 0.66 0.67 0.70 0.73  0.25      -2.75
68 11 4 7.900 130  2  0.60 1 0.61 0.63 0.63 0.65 -0.25 085 -0.50 050 1
69 01 1 8.025 180  4  1.08    0.68 0.72 0.75 0.75  0.00      -3.00
69 01 2 7.900 090  3  0.59    0.60 0.61 0.62 0.63  0.00 000  0.00 000
69 01 3 7.825 085  4  1.08    0.63 0.72 0.72 0.75  0.00      -2.50
69 01 4 8.000 180  3  0.60    0.60 0.61 0.68 0.65  0.00 000 -0.50 160
69 02 1            5
69 02 2                 0.58
69 02 3            9
69 02 4                 0.60
69 03 1            4
69 03 2                 0.59
69 03 3            4
69 03 4                 0.60
69 04 1            4
69 04 2                 0.61
69 04 3            5
69 04 4                 0.63
69 05 1            4
69 05 2                 0.59
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69	05	3			5												
69	05	4			2	0.59											
69	06	1			4												
69	06	2			2	0.62											
69	06	3			4												
69	06	4			2	0.61											
69	07	1			4												
69	07	2			2	0.59											
69	07	3			4												
69	07	4			2	0.60											
69	08	1			5	0.96	1						0.25		-3.00		
69	08	2			3	0.58	2						0.00	000	-0.25	050	1
69	08	3			4	0.96	1						-0.25		-2.50		
69	08	4			3	0.59	2						-0.25	145	-0.50	125	1
69	09	1			4	1.16	1						0.25		-2.75		
69	09	2			2	0.57	5						-0.50	135	-0.25	025	1
69	09	3			5	1.84	1						0.25		-2.75		
69	09	4			2	0.58	5						-0.50	155	-0.50	155	1
69	10	1	8.000	190	5	1.08	1	0.65	0.67	0.72	0.75		0.00		-2.75		
69	10	2	7.825	080	2	0.57	5	0.61	0.59	0.60	0.64		-0.25	165	-0.25	025	1
69	10	3	7.750	170	5	1.16	1	0.67	0.69	0.77	0.78		0.00		-2.75		
69	10	4	7.750	080	2	0.59	5	0.63	0.61	0.64	0.66		-0.50	170	-0.50	150	1
69	11	1	8.025	180	5	2.40	1	0.69	0.66	0.73	0.76		0.00		-3.00		
69	11	2	7.750	090	2	0.61	3	0.61	0.61	0.62	0.63		-0.50	015	-0.50	170	1
69	11	3	8.025	175	5	2.40	1	0.67	0.71	0.75	0.79		0.50		-2.75		
69	11	4	7.725	090	2	0.61	3	0.61	0.61	0.66	0.69		-0.75	170	-0.75	170	1
70	01	1	7.825	015	4	1.08		0.64	0.69	0.73	0.73		0.25		-2.50		
70	01	2	7.650	100	2	0.57		0.61	0.61	0.63	0.63		0.00	000	-0.50	035	
70	01	3	7.825	180	4	1.08		0.71	0.65	0.69	0.72		0.25		-4.00		
70	01	4	7.575	090	2	0.58		0.61	0.60	0.62	0.60		-0.50	010	-0.75	005	
70	02	1			6												
70	02	2				0.59											
70	02	3			5												
70	02	4				0.58											
70	03	1			6												
70	03	2				0.61											
70	03	3			5												
70	03	4				0.60											
70	04	1			5												
70	04	2				0.61											
70	04	3			5												
70	04	4				0.60											
70	05	1			5												
70	05	2				0.60											
70	05	3			5												
70	05	4				0.59											
70	06	1			5												
70	06	2			2	0.59											
70	06	3			5												
70	06	4			2	0.59											
70	07	1			5												
70	07	2			2	0.57											
70	07	3			5												
70	07	4			2	0.58											
70	08	1			4	1.16	1						0.50		-2.50		
70	08	2			2	0.57	4						-0.50	025	-0.50	030	1
70	08	3			4	1.16	1						1.25		-3.75		
70	08	4			2	0.57	4						-1.00	180	-1.00	175	1
70	09	1			5	1.16	1						0.50		-2.50		
70	09	2			2	0.58	4						-0.25	050	-0.50	035	1
70	09	3			6	1.16	1						0.75		-3.75		
70	09	4			2	0.59	4						-1.25	160	-1.00	175	1
70	10	1			4	1.16	1	0.63	0.66	0.69	0.69		0.25		-2.75		
70	10	2			2	0.59	4	0.58	0.59	0.60	0.59		-0.25	040	-0.25	175	1
70	10	3			5	1.16	1	0.64	0.67	0.71	0.65		0.75		-4.00		
70	10	4			2	0.59	4	0.63	0.59	0.60	0.61		-1.00	005	-1.00	005	1
70	11	1	7.825	020	4	1.40	1	0.65	0.69	0.72	0.69		0.00		-2.75		
70	11	2	7.575	110	2	0.56	4	0.60	0.59	0.59	0.59		-0.75	045	-0.50	175	1
70	11	3	7.800	180	4	1.16	1	0.67	0.70	0.75	0.73		0.75		-4.00		
70	11	4	7.500	085	2	0.57	4	0.61	0.63	0.64	0.63		-0.25	120	-0.75	005	2

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71 01 1 8.075 015  4  0.96    0.65 0.58 0.69 0.73  0.00      -2.50
71 01 2 7.950 105  3  0.56    0.58 0.59 0.58 0.61  0.00 000  0.00 000
71 01 3 8.075 175  4  0.96    0.65 0.60 0.67 0.71  0.00      -1.75
71 01 4 7.950 080  3  0.57    0.56 0.61 0.63 0.61  0.00 000 -0.25 150
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71 03 3            4
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71 04 3            5
71 04 4                 0.61
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71 05 2                 0.58
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71 05 4                 0.60
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71 06 3            4
71 06 4            2    0.58
71 07 1            5
71 07 2            2    0.57
71 07 3            4
71 07 4            2    0.57
71 08 1            5    0.96 1                        -0.25      -2.75
71 08 2            3    0.59 4                        -0.25 175 -0.25 010 1
71 08 3            4    0.96 1                         0.25      -1.75
71 08 4            3    0.58 4                        -0.25 135 -0.25 150 1
71 09 1            5    0.96 4                        -0.25      -2.75
71 09 2            2    0.56 6                        -0.25 030 -0.25 010 1
71 09 3            4    0.96 4                         0.25      -2.25
71 09 4            2    0.55 6                        -0.25 135 -0.25 135 1
71 10 1 8.050 015  4  0.96 4 0.67 0.61 0.65 0.68  0.25      -3.00
71 10 2 7.900 100  2  0.59 5 0.59 0.59 0.62 0.60  0.00 000  0.00 000 1
71 10 3 8.025 005  4  0.96 1 0.63 0.60 0.67 0.72  0.50      -2.25
71 10 4 7.825 091  2  0.58 1 0.59 0.58 0.63 0.61 -0.25 140 -0.25 135 3
71 11 1 8.025 020  5  1.08 1 0.66 0.62 0.69 0.73  0.25      -2.50
71 11 2 7.925 100  2  0.59 5 0.60 0.61 0.62 0.61  0.00 000  0.00 000 1
71 11 3 8.025 180  4  1.08 1 0.62 0.61 0.67 0.71  0.00      -2.06
71 11 4 7.850 080  2  0.58 5 0.58 0.59 0.62 0.63 -0.25 100 -0.25 125 1
72 01 1 8.375 090  4  0.96    0.60 0.58 0.61 0.68  0.00      -1.75
72 01 2 8.325 175  2  0.54    0.54 0.53 0.55 0.57  0.00 000 -0.50 105
72 01 3 8.275 090  4  1.08    0.57 0.56 0.65 0.68  0.00      -1.25
72 01 4 8.275 175  2  0.54    0.55 0.53 0.59 0.59  0.00 000  0.00 000
72 02 1            5
72 02 2                 0.59
72 02 3            5
72 02 4                 0.58
72 03 1            5
72 03 2                 0.58
72 03 3            6
72 03 4                 0.57
72 04 1            5
72 04 2                 0.59
72 04 3            5
72 04 4                 0.57
72 05 1            5
72 05 2                 0.56
72 05 3            5
72 05 4                 0.57
72 06 1            5
72 06 2            2    0.57
72 06 3            4
72 06 4            2    0.59
72 07 1            4
72 07 2            2    0.57
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72	07	3			5											
72	07	4			2	0.58										
72	08	1			4	0.96	1					0.00		-1.75		
72	08	2			2	0.55	3					-0.50	090	-0.50	105	1
72	08	3			4	0.96	1					0.25		-1.25		
72	08	4			2	0.57	3					-0.25	110	-0.25	100	1
72	09	1			5	0.96	1					0.00		-1.50		
72	09	2			2	0.56	1					-0.25	120	-0.50	105	1
72	09	3			4	0.96	1					0.25		-1.25		
72	09	4			2	0.57	1					-0.25	125	-0.25	120	1
72	10	1			4	0.96	1	0.63	0.57	0.65	0.67	0.00		-1.75		
72	10	2			2	0.55	1	0.57	0.55	0.59	0.57	-1.00	085	-0.50	090	1
72	10	3			4	0.96	1	0.63	0.58	0.71	0.69	0.25		-1.50		
72	10	4			2	0.56	1	0.54	0.59	0.60	0.59	0.00	000	-0.25	115	1
72	11	1	8.400	070	5	0.96	1	0.63	0.61	0.66	0.68	0.25		-0.75		
72	11	2	8.200	175	2	0.54	2	0.59	0.57	0.56	0.61	0.00	000	-0.25	075	1
72	11	3	8.325	010	4	0.96	1	0.61	0.59	0.69	0.69	0.00		-1.25		
72	11	4	8.300	090	2	0.56	5	0.57	0.58	0.61	0.61	-0.25	115	0.00	000	1
73	01	1	7.900	175	4	0.96		0.67	0.65	0.75	0.75	0.00		-5.75		
73	01	2	7.675	070	2	0.58		0.59	0.62	0.62	0.61	-0.00	000	-0.25	145	
73	01	3	7.800	005	4	0.96		0.63	0.67	0.70	0.79	0.00		-6.00		
73	01	4	7.625	085	2	0.59		0.61	0.61	0.65	0.63	0.00	000	-0.25	025	
73	02	1			4											
73	02	2				0.59										
73	02	3			6											
73	02	4				0.60										
73	03	1			4											
73	03	2				0.62										
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73	03	4				0.62										
73	04	1			4											
73	04	2				0.60										
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73	04	4				0.60										
73	05	1			5											
73	05	2				0.59										
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73	05	4				0.60										
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73	06	3			4											
73	06	4			2	0.59										
73	07	1			4											
73	07	2			2	0.57										
73	07	3			4											
73	07	4			2	0.59										
73	08	1			4	0.96	1					0.25		-5.75		
73	08	2			2	0.57	3					-0.25	165	-0.25	150	1
73	08	3			4	1.16	1					0.00		-5.75		
73	08	4			2	0.59	4					0.00	000	-0.25	040	1
73	09	1			4	0.96	1					0.25		-5.75		
73	09	2			2	0.57	4					-0.25	170	-0.25	150	1
73	09	3			4	1.16	1					0.00		-5.75		
73	09	4			2	0.58	4					0.00	000	-0.25	040	1
73	10	1	7.850	170	4	1.08	1	0.67	0.65	0.73	0.72	0.25		-5.75		
73	10	2	7.675	075	2	0.57	4	0.60	0.63	0.63	0.65	-0.25	170	-0.25	150	1
73	10	3	7.850	180	4	1.16	4	0.59	0.68	0.59	0.74	0.00		-5.75		
73	10	4	7.625	080	2	0.58	6	0.60	0.62	0.63	0.64	0.00	000	-0.25	040	1
73	11	1	7.850	165	4	0.96	1	0.66	0.65	0.72	0.71	0.25		-5.75		
73	11	2	7.700	075	2	0.57	5	0.61	0.64	0.63	0.63	-0.25	070	-0.25	150	1
73	11	3	7.800	165	4	0.96	1	0.67	0.63	0.71	0.71	-0.25		-5.75		
73	11	4	7.675	080	2	0.59	5	0.59	0.62	0.63	0.61	0.00	000	-0.50	025	3
74	01	1	7.875	090	4	0.96		0.58	0.57	0.61	0.66	0.00		-2.00		
74	01	2	7.675	180	2	0.51		0.51	0.53	0.52	0.56	0.00	000	-0.25	180	
74	01	3	7.700	085	4	0.96		0.58	0.58	0.62	0.67	0.00		-2.00		
74	01	4	7.625	170	2	0.51		0.52	0.52	0.55	0.57	0.00	000	-0.25	180	
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74	03	4				0.54								
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74	04	2				0.55								
74	04	3			4									
74	04	4				0.55								
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74	05	3			4									
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74	06	1			4									
74	06	2			2	0.54								
74	06	3			4									
74	06	4			2	0.54								
75	01	1	8.000	170	4	1.08	0.59	0.58	0.60	0.69	0.25		-3.25	
75	01	2	7.925	085	2	0.53	0.56	0.53	0.53	0.57	0.00	000	-0.75	050
75	01	3	8.075	090	5	0.96	0.59	0.58	0.61	0.70	0.50		-3.00	
75	01	4	8.000	175	2	0.53	0.55	0.54	0.57	0.57	-0.50	090	-1.00	095
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75	02	3			5									
75	02	4				0.56								
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75	06	3			5									
75	06	4			2	0.55								
75	07	1			4									
75	07	2			2	0.54								
75	07	3			4									
75	07	4			2	0.54								
76	01	1	8.000	070	4	1.08	0.63	0.67	0.64	0.66	0.00		-3.00	
76	01	2	7.800	165	2	0.54	0.56	0.56	0.56	0.56	0.00	000	0.00	000
76	01	3	8.050	186	4	1.08	0.63	0.66	0.65	0.67	0.00		-3.50	
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76	02	4				0.56								
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76	06	1			4									
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76	06	3			4									
76	06	4			2	0.56								
76	07	1			4									
76	07	2			2	0.55								

```
76 07 3                    4
76 07 4                    2   0.56
77 01 1 8.000 010              1.08   0.61 0.67 0.69 0.71
77 01 2 7.850 090          2   0.56   0.57 0.57 0.59 0.61
77 01 3 7.950 005              0.96   0.63 0.62 0.72 0.69
77 01 4 7.825 100          2   0.55   0.56 0.58 0.58 0.61
77 02 1                    4
77 02 2                        0.59
77 02 3                    5
77 02 4                        0.58
77 03 1                    5
77 03 2                        0.57
77 03 3                    5
77 03 4                        0.57
```

APPENDIX 3.8 (c)

Key to Secondary Clinical File

Each data point occupies a set of two lines, thus for each patient there are ten lines of data in this file, which contains values recorded at visits 1, 8, 9, 10 and 11.

Line	Columns	Variable recorded
1	1 - 2	Patient number
	4	Visit number
	6	Card number
	8 - 9	Apparent limbal depth 0 degrees, right
	11 - 12	Apparent limbal depth 90 degrees, right
	14 - 15	Apparent limbal depth 180 degrees, right
	17 - 18	Apparent limbal depth 270 degrees, right
	20	Injection, right
	22	Vascularization, right
	24	Oedema, right
	26	Evidence of fluorescein staining, right
	28	Depth of fluorescein staining, right
	30	Area of fluorescein staining, right
	32	Evidence of Rose Bengal staining, right
	34	Area of Rose Bengal staining, right
	36	Anterior chamber disturbance, right
	38	Presence of cysts, right
	40	Distribution of cysts, right
	42	Density of cysts, right

Line	Column	Variable recorded
1 continued	44	Degree of corneal cystic involvements, right
	46	Number of unlooped vessels, right
2	1 - 2	Patient number
	4	Visit number
	6	Card number
	8 - 9	Apparent limbal depth 0 degrees, left
	11 - 12	Apparent limbal depth 90 degrees, left
	14 - 15	Apparent limbal depth 180 degrees, left
	17 - 18	Apparent limbal depth 270 degrees, left
	20	Injection, left
	22	Vascularization, left
	24	Oedema, left
	26	Evidence of fluorescein staining, left
	28	Depth of fluorescein staining, left
	30	Area of fluorescein staining, left
	32	Evidence of Rose Bengal staining, left
	34	Area of Rose Bengal staining, left
	36	Anterior chamber disturbance, left
	38	Presence of cysts, left
	40	Distribution of cysts, left
	42	Density of cysts, left
	44	Degree of corneal cystic involvement, left
	46	Number of unlooped vessels, left

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15	9	2																		
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APPENDIX 3.8 (d)

Key to Questionnaire File

Each data point occupies one line thus for each patient there are four lines in this file, questionnaires being completed at visits 8, 9, 10 and 11.

Columns	Variable recorded
1 - 2	Patient number
4 - 5	Visit number
8	Comfort, right
10	Comfort, left
12	Subjective haloes, right
14	Subjective haloes, left
16	Burning sensation, right
18	Burning sensation, left
20	Photophobia, right
22	Photophobia, left
24	Quality of distance vision, right
26	Quality of distance vision, left
28	Quality of near vision, right
30	Quality of near vision, left
32	Stability of vision, right
34	Stability of vision, left
36	Ocular discharge, right
38	Ocular discharge, left

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28	11																
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40	9																
40	10																
40	11																

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68	9	2	2	1	1	1	1	1	1	1	1	1	1	2	2	1	1
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73	10																
73	11																

APPENDIX 3.8 (e)

Key to Survey File

Each patient occupies two lines on the file.

Line	Column	Variables recorded
1	1 - 2	Patient number
	4	Card number
	6	Presence of cysts, right
	8	Distribution of cysts, right
	10	Density of cysts, right
	12	Degree of corneal cystic involvement, right
	14	Patient sex
	16 - 17	Years of contact lens wear
	19	Cleaning regime
	20 - 25	Lens power right
	27	Fine cysts observed centrally, right
	29	Cysts, various size, peripherally, right
	31	Numerous cysts, mid-peripherym nasal or temporal cornea, right
	33	Numerous cysts, mid-periphery, superior or inferior cornea, right
	35	Proportion of cyts staining with 2% fluorescein, right
	37	Presence of oedema, right
	39	Presence of sub-epithelial infiltrates in cystic area, right

Line	Column	Variables recorded
1 continued	41	Presence of limbal blood vessel congestion which could have been associated with cystic areas, right
	43	Presence of limbal blood vessel encroachment which could have been associated with cystic areas, right
2	1 - 2	Patient number
	4	Card number
	6	Presence of cysts, left
	8	Distribution of cysts, left
	10	Density of cysts, left
	12	Degree of corneal involvement, left
	14	Lens type
	16 - 17	Daily hours of wear
	20 - 25	Lens power, left
	27	Fine cysts observed centrally, left
	29	Cysts, various sizes, peripherally, left
	31	Numerous cysts, mid-periphery, nasal or temporal cornea, left
	33	Numerous cysts, mid-periphery, superior or inferior cornea, left
	35	Proportion of cysts staining with 2% fluorescein, left
	37	Presence of oedema, left
	39	Presence of sub-epithelial infiltrates in cystic area, left

41 Presence of limbal blood vessel congestion which could have been associated with cystic areas, left

43 Presence of limbal blood vessel which could have been associated with cystic areas,left.

The variable "Proportion of cysts staining with 2% fluorescein" takes values of 1, 2 and 3. These equate to less than 25%, 25% to 50%, and 50% or more respectively.

```
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02 1 1 1 1 1 M 02 2 -2.25 0 1 1 0 3 0 0 1 0
02 2 1 1 1 1 H 10   -2.25 0 1 0 0 2 0 0 1 0
03 1 1 1 1 1 F 01 2 -3.75 0 1 0 0 1 0 0 0 0
03 2 1 1 1 1 H 14   -3.75 1 1 0 0 1 0 0 0 0
04 1 1 1 1 1 F 02 2 -4.50 1 1 0 0 2 0 0 0 0
04 2 1 1 1 1 H 10   -4.50 0 1 1 0 3 0 0 1 0
05 1 1 1 1 1 F 01 2 -2.50 1 1 0 0 1 0 0 0 0
05 2 1 1 1 1 H 16   -2.50 1 1 0 0 1 0 0 0 0
06 1 1 1 1 1 F 02 2 -1.75 1 1 1 0 3 0 0 1 0
06 2 1 1 1 1 H 16   -1.75 1 1 1 0 3 0 0 1 0
07 1 1 1 1 1 F 02 2 -3.50 0 1 1 0 3 0 0 1 0
07 2 1 1 1 1 H 14   -3.50 0 1 1 0 3 0 0 1 0
08 1 1 1 2 1 F 01 2 -2.00 0 1 1 0 3 0 0 1 0
08 2 1 1 1 1 H 12   -2.00 0 1 1 0 3 0 0 0 0
09 1 1 1 1 1 F 02 2 -4.00 1 1 0 0 1 0 0 0 0
09 2 0 0 0 0 H 08   -4.00 0 0 0 0 0 0 0 0 0
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10 2 1 1 1 1 H 10   -3.00 1 0 0 0 1 0 0 0 0
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12 2 1 2 2 1 H 12   -3.25 1 1 0 0 2 0 0 1 0
13 1 1 1 1 1 F 02 2 -4.25 1 1 0 0 1 0 0 0 0
13 2 1 1 1 1 H 10   -4.25 1 1 0 0 1 0 0 0 0
14 1 1 1 1 1 F 03 2 -4.50 1 1 1 0 3 0 0 1 0
14 2 1 1 1 1 H 12   -4.50 1 1 1 0 3 0 0 1 0
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15 2 1 1 1 1 H 14   -4.00 1 0 0 0 1 0 0 0 0
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16 2 1 1 1 1 H 10   -2.25 1 1 0 0 1 0 0 0 0
17 1 1 1 1 1 M 01 2 -3.25 0 1 0 0 2 0 0 0 0
17 2 1 1 1 1 H 16   -3.25 0 1 0 0 2 0 0 0 0
18 1 1 1 1 1 F 02 2 -3.50 1 1 0 0 2 0 0 0 0
18 2 1 1 1 1 H 14   -3.50 1 1 0 0 2 0 0 0 1
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19 2 1 1 1 1 H 14   -3.75 0 1 1 0 3 0 0 1 0
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20 2 1 1 1 1 H 16   -2.25 0 1 0 0 2 0 0 1 0
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21 2 1 1 1 1 H 14   -3.50 1 1 0 0 1 0 0 0 0
22 1 1 1 1 1 F 02 2 -3.00 1 0 0 0 1 0 0 0 0
22 1 1 1 1 1 H 12   -3.00 1 0 0 0 1 0 0 0 0
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24 2 1 2 2 1 H 12   -3.50 0 1 1 0 3 0 0 1 0
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29 2 1 1 1 1 H 12   -2.00 1 1 1 0 2 0 0 1 0
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30 2 1 2 1 1 E 24   13.00 1 1 0 1 2 0 0 0 1
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31	2	1	1	1	1	E	24		13.00	1	0	0	0	2	0	0	0	0
32	1	0	0	0	0	M	02	1	15.50	0	0	0	0	0	0	0	0	0
32	2	1	1	1	1	E	24		15.50	1	1	0	0	1	0	0	0	1
33	1	1	1	1	1	M	02	2	-2.25	1	1	0	0	1	0	0	1	0
33	2	1	1	1	1	S	18		-2.25	1	1	0	0	1	0	0	1	0
34	1	1	1	1	1	F	02	2	-2.00	1	1	0	0	1	0	0	1	0
34	2	1	1	1	1	S	18		-2.00	1	1	0	0	1	0	0	1	0
35	1	1	1	1	1	M	02	2	-2.00	1	1	0	1	1	0	1	0	1
35	2	1	1	1	1	S	18		-2.00	1	1	0	1	1	0	1	0	1
36	1	1	1	1	1	F	02	2	-2.50	0	1	0	0	1	0	0	1	0
36	2	1	1	1	1	S	14		-2.50	0	1	0	0	1	0	0	1	0
37	1	1	1	1	1	M	02	2	-4.00	1	1	0	0	1	0	0	1	0
37	2	1	1	1	1	S	08		-4.00	1	1	0	1	1	0	0	1	0
38	1	1	1	1	1	M	01	2	-2.00	0	1	0	0	1	0	0	0	0
38	2	1	1	1	1	S	12		-2.00	1	0	0	0	1	0	0	0	0
39	1	1	1	1	1	F	02	2	-1.75	1	1	0	0	1	0	0	1	0
39	2	1	1	1	1	S	10		-1.75	1	1	0	0	1	0	0	1	0
40	1	1	1	1	1	M	03	2	-2.50	1	1	0	0	1	0	0	0	0
40	2	1	1	1	1	S	16		-2.50	0	1	0	0	1	0	0	0	0
41	1	1	1	1	1	F	01	2	-3.00	1	1	0	0	1	0	0	0	0
41	2	1	1	1	1	S	14		-3.00	1	0	0	0	1	0	0	0	0
42	1	1	1	1	1	M	01	2	-4.00	1	1	0	0	1	0	0	0	0
42	2	1	1	1	1	S	14		-4.00	1	1	0	0	1	0	0	0	0
43	1	1	1	1	1	M	01	2	-3.00	1	1	0	0	1	0	0	0	0
43	2	1	1	1	1	S	14		-3.00	1	1	0	0	1	0	0	0	0
44	1	1	1	1	1	F	02	2	-3.00	1	1	0	0	1	0	0	0	0
44	2	1	1	1	1	S	16		-3.00	1	1	0	0	1	0	0	0	0
45	1	1	1	1	1	M	01	2	-1.75	0	1	0	0	1	0	0	1	0
45	2	1	1	1	1	S	16		-1.75	0	1	0	0	1	0	0	1	0
46	1	1	1	1	1	M	03	2	-4.50	1	1	0	0	1	0	0	1	0
46	2	1	1	1	1	S	16		-7.00	1	1	0	0	1	0	0	1	0
47	1	1	4	4	1	F	01	2	4.00	1	0	1	0	1	0	0	1	0
47	2	1	2	2	1	S	16		4.00	1	0	1	0	1	0	0	1	0
48	1	1	1	1	1	F	02	2	-1.00	1	0	0	0	1	0	0	0	0
48	2	1	1	1	1	S	18		-1.00	1	0	0	0	1	0	0	0	0
49	1	1	1	1	1	F	02	2	-2.50	1	1	0	0	1	0	0	1	0
49	2	1	1	1	1	S	12		-2.50	1	1	0	0	1	0	0	1	0
50	1	1	1	1	1	F	01	2	-3.00	1	0	0	0	1	0	0	0	0
50	2	1	1	1	1	S	08		-3.00	1	0	0	0	1	0	0	0	0
51	1	1	1	1	1	F	03	2	-2.50	1	1	0	0	1	0	1	1	0
51	2	1	1	1	3	S	12		-2.50	1	1	0	0	1	0	1	1	0
52	1	1	1	1	1	F	06	2	-5.00	1	1	0	0	1	0	0	1	0
52	2	1	1	1	1	S	14		-5.00	1	1	0	0	1	0	0	1	0
53	1	1	1	1	1	F	02	2	3.00	1	0	0	0	1	0	0	0	0
53	2	1	1	1	1	S	08		3.00	1	0	0	0	1	0	0	0	0
54	1	1	1	1	1	F	01	2	-2.50	0	1	0	0	1	0	0	0	0
54	2	1	1	1	1	S	16		-2.50	1	1	0	0	1	0	0	0	0
55	1	1	1	1	1	M	02	2	3.50	1	0	0	0	1	0	0	0	0
55	2	1	1	2	1	S	18		3.50	1	0	0	1	1	0	0	1	0
56	1	1	1	1	1	M	02	2	-2.00	0	1	0	0	1	0	0	0	0
56	2	1	1	1	1	S	16		-2.00	0	1	0	0	1	0	0	0	0
57	1	1	1	1	1	F	03	2	-3.75	1	1	0	0	1	0	0	1	0
57	2	1	1	1	1	S	16		-3.75	1	1	0	0	1	0	0	1	0
58	1	1	1	1	1	M	04	2	-2.00	1	1	0	1	2	0	0	1	0
58	2	1	2	1	1	S	14		-2.00	1	1	0	1	2	0	0	1	0
59	1	1	2	1	1	F	02	2	-6.25	1	0	0	1	1	0	0	0	0
59	2	1	2	1	1	S	12		-5.75	1	0	0	1	1	0	0	0	0
60	1	1	1	1	1	F	02	2	-1.50	1	0	0	0	1	0	0	0	0
60	2	1	1	1	1	S	16		-1.50	1	0	0	0	1	0	0	0	0

61	1	1	1	1	1	F	02	2	-2.00	0	1	0	0	1	0	0	0	0
61	2	1	1	1	1	S	16		-2.00	1	0	0	0	1	0	0	0	0
62	1	1	1	1	1	M	01	2	-3.00	0	1	0	0	1	0	0	1	0
62	2	1	1	1	1	S	18		-3.00	0	1	0	0	1	0	0	1	0
63	1	1	1	1	1	F	01	2	-2.50	1	0	0	0	1	0	0	0	0
63	2	1	1	1	1	S	18		-2.50	1	0	0	0	1	0	0	0	0
64	1	1	1	1	1	F	01	2		1	0	0	0	1	0		0	0
64	2	1	1	1	1	S	18			1	0	0	0	1	0	0	0	0
65	1	1	1	1	1	F	05	2	-3.25	0	1	0	0	1	0	0	1	0
65	2	1	1	1	1	S	18		-1.00	0	1	0	0	1	0	0	1	0
66	1	1	1	1	1	F	04	2	-2.50	1	1	0	0	1	0	0	0	1
66	2	1	1	1	1	S	18		-2.50	1	1	0	0	1	0	0	0	1
67	1	1	1	1	1	M	02	2	-3.00	0	1	0	0	1	0	0	0	0
67	2	1	1	1	1	S	18		-3.00	1	0	0	0	1	0	0	0	0
68	1	1	1	1	1	F	01	2		1	0	0	0	1	0	0	0	0
68	2	1	1	1	1	S	10			1	0	0	0	1	0	0	0	0
69	1	1	1	1	1	F	01	2		1	0	0	0	1	0	0	0	0
69	2	1	1	1	1	S	18			1	0	0	0	1	0	0	0	0
70	1	1	1	1	1	M	01	2	9.00	1	1	1	0	1	0	1	0	1
70	2	1	1	1	1	S	18		10.00	1	1	1	0	1	0	1	0	1
71	1	1	1	1	1	F	02	2	-8.50	1	1	0	0	1	0	0	0	0
71	2	1	1	1	1	S	18		-8.50	1	1	0	0	1	0	0	0	0
72	1	1	2	1	1	F	02	2	-1.25	1	0	0	1	1	0	0	1	0
72	2	1	2	1	1	S	18		-5.00	1	0	0	1	1	0	0	1	0
73	1	1	1	1	1	M	04	2	-2.00	1	0	0	0	1	0	0	0	0
73	2	1	1	1	1	S	12		-2.00	1	0	0	0	1	0	0	0	0
74	1	1	1	1	1	F	03	2		1	1	0	1	1	0	0	0	1
74	2	1	1	1	1	S	08			1	1	0	1	1	0	0	0	1
75	1	1	1	1	1	F	02	2	-4.00	1	1	0	1	1	0	0	0	1
75	2	1	1	1	1	S	16		-4.00	1	1	0	1	1	0	0	0	1
76	1	1	1	1	1	F	01	2	-3.25	1	1	0	1	1	0	0	1	0
76	2	1	1	1	1	S	07		-3.25	1	1	0	1	1	0	0	1	0
77	1	1	1	1	1	F	02	2	-3.50	1	1	0	0	1	0	0	0	1
77	2	1	1	1	1	S	18		-3.50	1	1	0	0	1	0	0	0	1
78	1	1	2	1	1	F	04	2	-5.00	1	1	0	1	2	0	0	0	1
78	2	1	1	1	1	S	18		-5.00	1	1	0	1	2	0	0	0	1
79	1	1	1	1	1	F	04	2	-5.00	1	1	0	0	1	0	0	0	0
79	2	1	1	1	1	S	12		-5.00	1	1	0	0	1	0	0	0	0
80	1	1	1	1	1	M	01	2	-1.50	1	0	1	0	1	0	0	0	0
80	2	1	1	1	1	S	18		-1.50	1	0	0	0	1	0	0	0	0
81	1	1	1	1	1	F	02	2	-3.50	1	1	0	1	1	0	0	1	0
81	2	1	1	1	1	S	12		-3.50	1	1	0	1	1	0	0	1	0
82	1	1	1	1	1	F	02	2	0.75	1	0	0	0	1	0	0	0	0
82	2	1	1	1	1	S	12		0.50	1	0	0	0	1	0	0	0	0
83	1	1	1	1	1	F	02	2	7.00	1	1	0	0	1	0	0	0	0
83	2	1	1	1	1	S	12		6.50	0	1	1	0	1	0	0	0	0
84	1	1	1	1	1	F	02	2		1	1	0	0	1	0	0	0	1
84	2	1	1	1	1	S	12			1	1	0	0	1	0	0	0	1
85	1	1	1	1	1	F	02	2	-11.00	1	1	0	0	1	0	0	1	0
85	2	1	1	1	1	S	12		-7.25	1	1	0	0	1	0	0	1	1
86	1	1	2	1	1	F	03	2	-5.00	1	1	0	0	1	0	0	0	1
86	2	1	2	1	1	S	12		-5.00	1	1	0	0	1	0	0	0	1
87	1	1	1	1	1	M	01	2	-5.00	1	1	0	0	2	0	1	1	0
87	2	1	1	1	1	S	12		-5.00	1	1	0	0	2	0	1	1	0
88	1	1	1	1	1	F	05	2	-3.50	0	1	0	1	1	0	0	0	1
88	2	1	1	1	1	S	12		-3.50	1	1	0	1	1	0	0	0	1
89	1	1	1	1	1	F	01	2	-2.00	1	0	0	0	1	0	0	0	0
89	2	1	1	1	1	S	12		-1.00	1	0	0	0	1	0	0	0	0
90	1	1	1	1	1	F	03	2	-6.00	1	1	0	1	1	0	0	1	0
90	2	1	1	1	1	S	12		-6.00	1	1	0	1	1	0	0	1	0

91	1	1	1	1	1	F		2	-3.00	0	1	0	1	1	0	0	0	0
91	2	1	1	1	1	S			-3.00	0	1	0	1	1	0	0	0	0
92	1	1	1	1	1	F	03	2	-4.50	1	0	0	0	1	0	0	0	0
92	2	1	1	1	1	S	12		-4.75	1	0	0	0	1	0	0	0	0
93	1	1	1	1	1	F	02	2	-1.25	0	1	0	1	1	0	0	1	0
93	2	1	1	1	1	S	12		-1.25	0	1	0	1	1	0	0	1	0
94	1	1	1	1	1	M	01	2	-2.25	1	0	0	0	1	0	0	1	0
94	2	1	1	1	1	S	12		-2.25	1	0	0	0	1	0	0	1	0
95	1	1	2	3	1	F	01	2	4.25	1	1	0	1	1	0	0	1	0
95	2	1	2	2	1	S	08		5.00	1	1	0	1	1	0	0	1	0
96	1	1	2	1	1	M	03	2	-3.00	1	1	0	0	1	0	0	0	1
96	2	1	2	1	1	S	08		-3.00	1	1	0	0	1	0	0	0	1
97	1	1	1	1	1	M	11	2	-5.00	1	1	0	0	1	0	0	0	1
97	2	1	1	1	1	S	18		-5.00	1	1	0	0	1	0	0	0	1
98	1	1	1	1	1	F	03	2	3.75	0	1	0	0	1	0	1	1	0
98	2	1	1	1	1	S	13		3.75	1	1	0	0	1	0	0	1	0
99	1	1	1	1	1	F	01	2	-4.75	1	1	0	0	1	0	0	0	0
99	2	1	1	1	1	S	18		-4.75	1	1	0	0	1	0	0	0	0
1001	1	1	1	1	M	03	2	-3.00	1	1	0	0	2	0	0	0	1	
1002	1	2	2	1	S	18		-3.00	1	1	0	0	2	0	0	0	1	
1011	1	1	1	1	F	01	1		1	1	0	0	1	0	0	0	1	
1012	1	1	1	1	S	06			1	1	0	0	1	0	0	0	1	
1021	1	1	1	1	F	02	2		1	1	0	0	1	0	0	1	0	
1022	1	1	1	1	S	18			1	1	0	0	1	0	0	1	0	
1031	1	1	1	1	F	02	2	2.25	1	0	0	0	1	0	0	0	0	
1032	1	1	1	1	S	06		2.25	1	0	0	0	1	0	0	0	0	
1041	1	2	1	1	F	03	2	-0.75	1	1	0	0	1	0	0	0	1	
1042	1	2	1	1	S	06		-0.75	1	1	0	0	1	0	0	0	1	
1051	1	1	1	1					1	1	0	0	1	0	0	0	0	
1052	0	0	0	0					0	0	0	0	1	0	0	0	0	
1061	1	1	1	1					1	1	0	0	1	0	0	0	0	
1062	1	1	1	1					1	1	0	0	1	0	0	0	0	
1071	1	1	1	1					1	0	0	0	1	0	0	0	0	
1072	1	1	1	1					1	0	0	0	1	0	0	0	0	
1081	1	1	1	1					1	0	0	0	1	0	0	0	0	
1082	0	0	0	0					0	0	0	0	0	0	0	0	0	
1091	1	1	1	1					1	0	0	0	1	0	0	0	0	
1092	1	1	1	1					1	0	0	0	1	0	0	0	0	
1101	1	1	1	1					1	0	0	0	1	0	0	0	0	
1102	1	1	1	1					1	0	0	0	1	0	0	0	0	
1111	1	1	1	1					0	1	0	0	1	0	0	0	0	
1112	1	1	1	1					0	1	0	0	1	0	0	0	0	
1121	1	1	1	1					1	0	0	0	1	0	0	0	0	
1122	1	1	1	1					1	0	0	0	1	0	0	0	0	
1131	1	1	1	1					1	0	0	0	1	0	0	0	0	
1132	1	1	1	1					1	0	0	0	1	0	0	0	0	
1141	1	1	1	1					1	0	0	0	1	0	0	0	0	
1142	1	1	1	1					1	0	0	0	1	0	0	0	0	
1151	1	1	1	1					1	1	0	0	1	0	0	0	0	
1152	1	1	1	1					1	1	0	0	1	0	0	0	0	
1161	1	1	1	1					1	1	0	0	1	0	0	0	0	
1162	1	1	1	1					1	1	0	0	1	0	0	0	0	
1171	1	1	1	1					1	1	0	0	1	0	0	0	0	
1172	1	1	1	1					1	1	0	0	1	0	0	0	0	
1181	1	1	1	1					1	0	0	0	1	0	0	0	0	
1182	1	1	1	1					1	0	0	0	1	0	0	0	0	
1191	1	1	1	1					1	1	0	0	1	0	0	0	0	
1192	1	1	1	1					1	1	0	0	1	0	0	0	0	
1201	1	1	1	1					1	0	0	0	1	0	0	0	0	
1202	1	1	1	1					1	0	0	0	1	0	0	0	0	

1211	1	1	1	1	1	0	0	0	1	0	0
1212	1	1	1	1	1	0	0	0	1	0	0
1221	1	1	1	1	1	0	0	0	1	0	0
1222	1	1	1	1	1	0	0	0	1	0	0
1231	1	1	1	1	1	0	0	0	1	0	0
1232	1	1	1	1	1	0	0	0	1	0	0
1241	1	1	1	1	1	0	0	0	1	0	0
1242	1	1	1	1	1	0	0	0	1	0	0
1251	1	1	1	1	1	0	0	0	1	0	0
1252	1	1	1	1	1	0	0	0	1	0	0
1261	1	1	1	1	1	0	0	0	1	0	0
1262	1	1	1	1	1	0	0	0	1	0	0
1271	1	1	1	1	1	0	0	0	1	0	0
1272	1	1	1	1	1	0	0	0	1	0	0
1281	1	1	1	1	1	0	0	0	1	0	0
1282	1	1	1	1	1	0	0	0	1	0	0
1291	1	1	1	1	1	0	0	0	1	0	0
1292	1	1	1	1	1	0	0	0	1	0	0
1301	1	1	1	1	1	0	0	0	1	0	0
1302	1	1	1	1	1	0	0	0	1	0	0
1311	1	1	1	1	1	0	0	0	1	0	0
1312	1	1	1	1	1	0	0	0	1	0	0
1321	1	1	1	1	1	0	0	0	1	0	0
1322	1	1	1	1	1	0	0	0	1	0	0
1331	1	1	1	1	1	0	0	0	1	0	0
1332	1	1	1	1	1	0	0	0	1	0	0
1341	1	1	1	1	1	0	0	0	1	0	0
1342	1	1	1	1	1	0	0	0	1	0	0

APPENDIX 3.8(f)

Photographic blood vessel data.

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Cargill

Group: C

Data Point: Baseline

SCALE: 20 Div. 13.650 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A 8.600	0.785	0.790	0.820	0.880	0.940	
B 3.380	0.980	0.970	1.090	1.000	1.040	
C 7.680	1.110	1.020	1.065	1.100	1.180	
D 4.120	0.640	0.665	0.720	0.760	0.770	
E 11.240	0.760	0.760	0.820	0.840	0.770	0.891
						0.1541

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	12.2	12.4	12.1	12.2	12.1	
B	7.0	7.1	7.1	7.2	7.2	
C	13.0	13.3	13.1	13.2	13.1	
D	9.6	9.8	9.8	9.6	9.7	
E	8.6	8.6	8.7	8.5	8.7	9.876
						2.988

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	5	5	3	5	5	4.6
Partially filled	7	7	9	7	7	7.4
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Cargill

Group: C

Data Point: 3/12

SCALE: 20 Div. 13.645 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	0.870	0.910	0.880	0.835	0.910	
B	0.900	0.920	0.980	0.990	1.110	
C	0.900	1.075	1.065	1.080	1.100	
D	0.815	0.830	1.170	1.200	1.250	
E	0.800	0.820	0.880	0.950	0.900	0.9656
						0.1297

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	11.5	11.4	11.3	11.5	11.6	
B	6.8	6.9	7.0	6.9	7.0	
C	6.8	6.9	6.7	6.9	6.8	
D	4.5	4.6	4.6	4.7	4.7	
E	4.7	5.0	5.0	4.7	4.7	6.928
						2.5153

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	5	5	2	2	5	3.8
Partially filled	3	3	6	6	3	4.2
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: A Chalklin

Group: C

Data Point: Baseline

SCALE: 20 Div. 13.760 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A 5.160	0.440	0.440	0.385	0.400	0.445	
B 2.750	0.610	0.610	0.645	0.665	0.680	
C 2.260	0.430	0.480	0.465	0.480	0.530	
D 2.500	0.615	0.630	0.860	0.840	0.860	0.5735
E						
						0.1538

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	15.6	15.7	15.5	15.7	15.5	
B	17.3	17.6	17.4	17.3	17.4	
C						
D	12.6	12.8	12.8	12.7	12.7	15.06
E						
						2.4686

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	2	1	0	0	0	0.6
Partially filled	16	17	17	17	16	16.6
Empty	0	0	1	1	2	0.8

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: A Chalklin

Group: C

Data Point: 3/12

SCALE: 20 Div = 13.775 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as baseline			EMPTY			
B	0.860	0.880	0.920	0.930	0.930	
C	0.660	0.680	0.660	0.710	0.780	
D	0.720	0.785	0.730	0.780	0.785	0.5905
E						
						0.3594

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A						
B	10.5	10.8	10.6	10.7	10.5	
C						
D	17.6	17.5	17.2	17.1	17.1	13.96
E						
						3.5252

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	2	1	1	2	2	1.6
Partially filled	14	15	15	14	13	14.2
Empty	1	1	1	1	2	1.2

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: A Chalklin

Group: C

Data Point: 6/12

SCALE: 20 Div.=13.790 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as Baseline	0.665	0.690	0.730	0.750	0.780	
B	0.610	0.640	0.640	0.715	0.690	
C	0.770	0.780	0.800	0.810	0.800	
D	0.855	0.880	0.980	0.975	0.980	0.777
E						
						0.1125

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A						
B	14.6	14.7	14.8	14.8	14.9	
C						
D	17.2	17.3	17.3	17.4	17.3	16.03
E						
						1.3417

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	1	1	2	2	1	1.4
Partially filled	16	16	15	15	15	15.4
Empty	2	2	2	2	3	2.2

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Collins

Group: C

Data Point: Baseline

SCALE: 20 Div. 13.725 cm.

1) DIAMETERS

REFERENCE		1	2	3	4	5	mean Std. Dev.
A	8.200	0.465	0.430	0.500	0.565	0.565	
B	1.715	0.550	0.585	0.650	0.625	0.650	
C	2.210	0.640	0.630	0.770	0.700	0.660	
D	3.140	0.550	0.540	0.540	0.560	0.540	
E	7.230	0.510	0.530	0.570	0.560	0.565	0.578
							0.0742

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	16.3	16.1	16.2	16.1	16.3	
B	8.2	7.9	8.1	8.0	8.2	
C	5.7	5.6	5.7	5.8	5.7	
D	12.4	12.0	12.3	12.1	12.3	
E	17.4	17.8	17.6	17.7	17.5	11.96
						4.658

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	0	0	2	2	2	1.2
Partially filled	28	28	26	23	23	25.6
Empty	0	0	0	3	3	1.2

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Collins

Group: C

Data Point: 3/12

SCALE: 20 Div. 13.720 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A as base	0.525	0.480	0.480	0.580	0.530	
B	0.480	0.495	0.520	0.520	0.520	
C	0.440	0.400	0.480	0.440	0.440	
D	0.530	0.565	0.530	0.630	0.610	
E	0.580	0.595	0.580	0.620	0.685	0.5302
						0.0689

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	19.1	19.4	19.0	19.2	19.4	
B	10.9	10.5	10.4	10.6	10.4	
C	8.5	8.3	8.1	8.5	8.5	
D	11.6	11.2	11.3	11.3	11.2	
E	17.0	17.3	17.5	17.8	17.8	13.392
						4.2893

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	1	1	0	0	0	0.4
Partially filled	19	17	16	16	17	17
Empty	0	2	4	4	3	2.6

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: S Cotton

Group: C

Data Point: Baseline

SCALE: 20 Div. = 13.740 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A 4.280	0.880	0.900	0.990	1.050	0.995	
B 4.000	0.590	0.560	0.535	0.530	0.560	
C 12.000	0.615	0.650	0.660	0.730	0.670	
D 6.650	0.515	0.480	0.470	0.500	0.530	
E 6.150	0.730	0.720	0.660	0.690	0.710	0.6768
						0.1684

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	15.7	15.5	15.6	15.4	15.4	
B	14.5	14.0	14.1	14.6	14.6	
C	17.0	17.4	17.2	17.1	17.0	
D	18.3	18.5	18.4	18.6	18.6	
E	12.9	12.7	12.7	12.6	12.7	15.644
						2.0727

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	2	1	2	2	4	2.2
Partially filled	19	20	19	19	17	18.8
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: S Cotton

Group: C Data Point: 3/12

SCALE: 20 Div.=13.730 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as Baseline	0.675	0.690	0.775	0.820	0.770	
B	0.620	0.605	0.580	0.595	0.615	
C	0.790	0.785	0.815	0.825	0.845	
D	0.590	0.595	0.680	0.675	0.690	
E	0.585	0.680	0.675	0.580	0.590	0.6858
						0.0910

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	19.4	19.3	19.2	19.3	19.2	
B	13.0	13.2	13.3	13.2	13.9	
C	15.5	15.7	15.6	15.7	15.7	
D	15.0	15.2	15.1	15.2	15.0	
E	11.7	11.8	11.8	1.5	11.8	15.012
						2.5999

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	6	5	5	6	6	5.6
Partially filled	16	17	17	16	16	16.4
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: S Cotton

Group: C Data Point: 6/12

SCALE: 20 Div= 13.740 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as Baseline	0.865	0.860	0.900	0.870	0.880	
B	0.440	0.445	0.530	0.550	0.560	
C	0.690	0.685	0.710	0.720	0.725	
D	0.370	0.330	0.480	0.495	0.390	
E	0.670	0.670	0.755	0.730	0.665	0.6894
						0.1716

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	18.7	18.8	18.5	18.7	18.7	
B	13.6	13.4	13.5	13.4	13.5	
C	18.3	18.3	18.5	18.5	18.4	
D	20.8	20.6	20.7	20.8	20.8	
E	11.1	11.3	11.2	11.3	11.1	16.500
						3.6397

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	6	4	5	6	8	58
Partially filled	18	20	20	18	16	18.4
Empty	1	1	0	1	1	0.8

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Craine

Group: C

Data Point: Baseline

SCALE: 20 Div.= 13.720 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A 7.520	0.880	0.920	1.030	0.930	0.940	
B 3.380	1.075	1.090	1.150	1.145	1.095	
C 2.700	0.970	0.995	1.065	1.135	0.980	
D 3.570	0.575	0.575	0.560	0.570	0.565	
E 12.150	0.590	0.625	0.650	0.695	0.650	0.8558
						0.2265

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	20.3	20.2	20.4	20.3	20.1	
B	18.2	18.3	18.2	18.1	18.3	
C	20.2	20.4	20.6	20.5	20.6	
D	19.4	19.7	19.4	19.6	19.7	
E	16.1	16.5	16.3	16.5	16.5	

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	6	6	7	6	6	6.2
Partially filled	10	10	9	10	10	9.8
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Craine

Group: C

Data Point: 3/12

SCALE: 20 Div.= 13.740 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A as Baseline	0.700	0.740	0.710	0.720	0.700	
B	0.650	0.640	0.700	0.650	0.665	
C	0.700	0.715	0.700	0.700	0.715	
D	0.580	0.600	0.615	0.660	0.680	
E	0.750	0.710	0.730	0.750	0.710	0.6896
						0.0047

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	15.0	15.1	15.3	15.1	15.1	
B	7.3	7.0	7.1	7.1	7.3	
C	14.8	14.9	14.7	14.8	14.9	
D	15.0	15.3	15.5	15.5	15.3	
E	13.3	13.5	13.3	13.4	13.3	13.156
						3.1415

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	0	0	0	1	1	0.4
Partially filled	15	15	15	14	13	14.4
Empty	2	2	2	2	3	2.2

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Craine

Group: C Data Point: 6/12

SCALE: 20 Div = 13.770 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as Baseline	0.950	1.025	0.985	1.300	0.965	
B	0.755	1.040	0.980	0.950	0.800	
C	0.755	0.780	0.850	0.875	0.890	
D	0.460	0.435	0.515	0.580	0.500	
E	0.820	0.860	0.850	0.800	0.815	0.8214
						0.2022

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	17.7	17.4	17.6	17.7	17.6	
B	6.7	6.5	6.7	6.6	6.7	
C	18.2	18.1	18.3	18.3	18.1	
D	16.9	16.7	16.8	16.9	16.7	
E	18.2	17.9	17.9	18.2	1	15.468
						4.5347

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	2	1	1	1	3	1.6
Partially filled	11	12	10	10	9	10.4
Empty	0	0	2	2	1	1

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Culverwell

Group: C Data Point: Baseline

SCALE: 20 Div. 13.730 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A 3.400	0.465	0.460	0.480	0.460	0.475	
B 1.375	0.570	0.600	0.620	0.610	0.600	
C 3.865	0.510	0.550	0.525	0.510	0.575	
D 7.100	0.470	0.500	0.530	0.565	0.515	
E 9.350	0.515	0.520	0.550	0.520	0.525	0.5264
						0.4715

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	16.1	16.2	16.1	16.3	16.1	
B	16.2	16.3	16.1	16.3	16.1	
C	11.6	11.7	11.7	11.6	11.8	
D	10.9	11.2	11.0	11.1	10.9	
E	22.8	22.6	22.8	22.7	22.8	15.56
						4. 2824

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	1	1	2	4	3	
Partially filled	18	18	17	15	16	16.8
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Culverwell

Group: C Data Point: 3/12

SCALE: 20 Div. 13.700 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A as base	0.495	0.530	0.525	0.630	0.520	
B	0.560	0.580	0.560	0.490	0.525	
C	0.480	0.480	0.620	0.585	0.550	
D	0.485	0.560	0.580	0.595	0.530	
E	0.600	0.575	0.595	0.635	0.640	0.5546
						0.050331

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	15.8	15.7	15.9	16.0	16.1	
B	13.0	12.8	12.9	13.1	13.0	
C	12.5	12.7	12.8	12.7	12.7	
D	10.2	9.8	9.9	9.8	10.1	
E	22.2	22.1	22.0	22.1	22.3	14.728
						4.2426

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	3	4	5	7	4	4.6
Partially filled	20	20	19	17	19	19
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Edyvean

Group: C Data Point: Baseline

SCALE: 20 Div. 13.635 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A 10.15	0.950	1.020	0.990	1.030	1.010	
B 10.91	0.790	0.790	0.820	0.870	0.930	
C 3.15	0.415	0.440	0.450	0.400	0.390	
D 7.150	0.540	0.550	0.440	0.490	0.525	
E 8.800	0.680	0.695	0.710	0.730	0.715	0.6948
						0.2194

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	23 0	23.0	23.2	23.4	23.2	
B	24.9	25.0	24.8	24.8	24.9	
C	19.1	18.9	19.1	19.1	19.0	
D	19.8	19.9	19.7	19.7	19.9	21.72
E						

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	3	2	4	4	4	3.4
Partially filled	9	10	8	8	8	8.6
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Edyvean

Group: C Data Point: 3/12

SCALE: 20 Div. 13.655 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	0.790	0.710	0.690	0.785	0.750	
B	0.595	0.610	0.635	0.640	0.625	
C	0.560	0.535	0.560	0.565	0.560	
D	0.395	0.440	0.380	0.435	0.400	
E	0.615	0.610	0.590	0.585	0.590	0.586
						0.1129

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	23.6	23.7	23.7	23.5	23.5	
B	28.3	28.1	28.4	28.4	28.3	
C	19.4	19.2	19.5	19.5	19.4	
D	18.8	18.6	18.8	18.7	18.8	22.51
E						3.9281

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	0	0	1	1	0	0.4
Partially filled	14	14	13	13	13	13.6
Empty	2	2	2	2	2	2

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Faulkner

Group: C Data Point: Baseline

SCALE: 20 Div = 13.735 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A 2.150	0.370	0.315	0.420	0.320	0.320	
B 3.440	0.570	0.540	0.595	0.610	0.560	
C 7.000	0.365	0.365	0.425	0.440	0.410	
D 6.180	0.660	0.695	0.710	0.685	0.700	
E 3.500	0.890	0.835	0.890	0.835	0.845	0.5748
						0.1933

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	15.1	14.9	15.2	15.2	15.1	
B	11.2	11.3	11.8	11.7	11.7	
C	10.8	10.6	10.6	10.8	10.8	
D	13.7	13.6	13.8	13.8	13.6	
E	13.6	13.8	13.6	13.8	13.7	12.952
						1.6333

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	1	1	1	1	1	1
Partially filled	13	12	12	12	12	12.2
Empty	0	1	1	1	1	0.8

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Faulkner

Group: C Data Point: 3/12

SCALE: 20 Div≡ 13.730 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as Baseline	0.640	0.625	0.680	0.685	0.640	
B	0.520	0.590	0.620	0.620	0.565	
C	0.700	0.735	0.685	0.690	0.700	
D	0.600	0.670	0.665	0.650	0.665	
E	0.520	0.590	0.590	0.600	0.600	0.6342
						0.0557

2) APPARENT LIMBAL DCPTH

REFERENCE	1	2	3	4	5	
A	15.0	14.9	15.1	15.1	15.0	
B	14.9	15.0	14.8	14.9	14.8	
C	13.2	13.1	13.3	13.2	13.2	
D	9.4	9.3	9.2	9.4	9.5	
E	12.3	12.4	12.4	12.1	12.3	12.952
						2.1125

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	3	2	2	2	2	2.2
Partially filled	10	11	10	9	10	10
Empty	2	2	3	4	3	2.8

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Faulkner

Group: C Data Point: 6/12

SCALE: 20 Div≡ 13.730 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A 2.150	0.590	0.610	0.635	0.590	0.600	
B 2.440	0.820	0.770	0.710	0.680	0.685	
C 7.000	0.330	0.340	0.345	0.330	0.350	
D 6.180	0.840	0.880	0.900	0.915	0.930	
E 3.500	0.645	0.680	0.625	0.600	0.620	0.6408
						0.1879

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	8.9	9.1	9.0	8.9	8.8	
B	12.1	12.0	11.9	11.9	12.1	
C	8.4	8.2	8.2	8.3	8.4	
D	12.5	12.4	12.6	12.6	12.4	
E	10.5	10.7	10.8	10.8	10.6	10.484
						1.6834

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	1	0	1	0	0	0.4
Partially filled	12	13	12	12	12	12.2
Empty	0	0	0	1	1	0.4

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Furness

Group: C

Data Point: Baseline

SCALE: 20 Div. = 13.790 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A 3.700	0.515	0.565	0.590	0.560	0.570	
B 9.550	0.350	0.415	0.430	0.340	0.365	
C 3.070	0.625	0.645	0.600	0.575	0.630	
D 9.300	0.690	0.695	0.720	0.710	0.680	
E 7.060	0.680	0.625	0.580	0.595	0.625	0.575
						0.1129

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	8.1	8.6	8.2	8.5	8.5	
B	15.2	15.1	15.3	15.3	15.1	
C	13.0	13.1	13.1	12.9	13.0	
D	21.3	21.2	21.4	21.3	21.3	14.475
E						

3) ENGORGEMENT 4.7691

Classification	1	2	3	4	5	
Filled	1	1	1	2	1	1.2
Partially filled	14	14	15	13	15	14.2
Empty	3	3	4	5	4	3.8

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Furness

Group: C

Data Point: 3/12

SCALE: 20 Div= 13.770 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as Baseline	0.300	0.260	0.300	0.330	0.310	
B	0.385	0.400	0.420	0.480	0.410	
C	0.700	0.735	0.695	0.680	0.710	
D	0.570	0.500	0.505	0.565	0.590	
E	0.520	0.510	0.490	0.485	0.490	0.4936
						0.1396

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	5.80	5.6	5.7	5.4	5.4	
B	11.9	12.0	12.0	11.9	11.8	
C	12.4	12.5	12.5	12.4	12.3	
D	19.2	19.1	19.1	19.2	19.2	12.27
E						

3) ENGORGEMENT 4.9314

Classification	1	2	3	4	5	
Filled	1	1	3	3	2	2
Partially filled	16	17	15	13	13	14.8
Empty	6	5	5	7	8	6.2

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Furness

Group: C Data Point: 6/12

SCALE: 20 Div. = 13.790 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as Baseline	0.490	0.485	0.510	0.590	0.520	
B	0.480	0.460	0.620	0.495	0.615	
C	0.620	0.640	0.600	0.615	0.635	
D	0.565	0.560	0.610	0.630	0.625	
E	0.510	0.535	0.495	0.560	0.560	0.561
						0.0585

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	7.2	7.1	7.3	7.4	7.2	
B	13.6	13.3	13.6	13.6	13.6	
C	14.8	14.5	14.9	14.9	14.9	
D	18.8	18.9	18.8	18.9	19.0	13.615
E						

3) ENGORGEMENT 4.2813

Classification	1	2	3	4	5	
Filled	1	0	0	0	0	0.2
Partially filled	16	14	14	13	13	14
Empty	0	3	3	4	4	2.8

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Harrison

Group: C Data Point: Baseline

SCALE: 20 Div. 13.745 cm.

1) DIAMETERS

REFERENCE		1	2	3	4	5	mean Std. Dev.
A	1.940	0.470	0.495	0.450	0.455	0.470	
B	8.500	0.670	0.650	0.730	0.675	0.660	
C	10.530	0.630	0.600	0.660	0.665	0.630	
D	3.320	0.920	0.910	0.980	0.990	0.900	
E	7.720	0.465	0.525	0.520	0.520	0.500	0.6456
							0.1721

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	9.6	9.7	9.8	9.8	9.9	
B	11.8	11.6	11.7	11.8	11.8	
C	9.6	9.7	9.5	9.6	9.6	
D	13.1	12.9	12.9	13.0	13.0	
E	13.1	12.9	13.0	12.8	13.0	11.408

3) ENGORGEMENT 1.5146

Classification	1	2	3	4	5	
Filled	1	1	1	1	2	1.2
Partially filled	9	9	9	9	10	9.2
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Harrison

Group: C

Data Point: 3/12

SCALE: 20 Div. 13.740 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	0.690	0.600	0.595	0.620	0.610	
B	0.700	0.670	0.675	0.670	0.690	
C	0.700	0.725	0.730	0.720	0.715	
D	0.650	0.680	0.620	0.615	0.630	
E	0.465	0.500	0.520	0.540	0.515	0.6338
						0.0763

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	9.5	9.3	9.6	9.3	9.6	
B	11.6	11.7	11.5	11.6	11.6	
C	14.7	14.9	15.0	14.6	14.7	
D	14.6	14.7	14.6	14.7	14.7	
E	13.1	13.2	13.7	13.6	13.5	12.784
						2.0645

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	1	0	0	0	0	0.2
Partially filled	15	16	16	15	15	15.4
Empty	0	0	0	1	1	0.4

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Henderson

Group: C

Data Point: Baseline

SCALE: 20 Div. 13.760 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A 3.650	0.680	0.675	0.700	0.725	0.675	0.691
B						0.0216
C						
D						
E						

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	3.8	3.6	3.7	3.8	3.6	3.7
B						0.1
C						
D						
E						

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	1	1	0	2	2	12
Partially filled	6	6	7	5	5	5.8
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Henderson

Group: C Data Point: 3/12

SCALE: 20 Div. 13.700 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A as base	0.715	0.760	0.770	0.765	0.755	0.753
B						0.0220
C						
D						
E						

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	4.0	4.2	4.1	4.0	4.1	4.08
B						0.0837
C						
D						
E						

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	1	2	0	1	1	1
Partially filled	7	6	8	7	7	7
Empty	0	0	0	0	0	1

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Hodges

Group: C Data Point: Baseline

SCALE: 20 Div. 13.720 cm.

1) DIAMETERS

REFERENCE		1	2	3	4	5	mean / Std. Dev.
A	5.180	1.680	1.620	1.625	1.630	1.620	
B	7.000	0.720	0.730	0.800	0.775	0.730	
C	3.400	0.680	0.660	0.745	0.700	0.710	
D	4.910	1.510	1.550	1.420	1.535	1.530	
E	4.650	1.510	1.665	1.615	1.600	1.670	1.2412
							0.4345

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	5.1	5.0	5.2	5.1	5.2	
B	5.6	5.4	5.5	5.7	5.6	
C	12.0	11.9	12.1	12.2	12.0	
D	8.7	8.6	8.8	8.7	8.6	
E	11.9	11.7	11.8	11.9	12.0	8.652

3) ENGORGEMENT 3.0224

Classification	1	2	3	4	5	
Filled	0	0	0	0	0	0
Partially filled	11	11	10	10	10	10.4
Empty	0	0	1	1	1	0.6

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Hodges

Group: C

Data Point: 3/12

SCALE: 20 Div. 13.720 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	1.360	1.395	1.330	1.400	1.385	
B	1.000	1.060	1.085	1.020	1.000	
C	0.950	0.915	1.000	0.935	0.940	
D	1.020	1.150	1.165	1.150	1.150	
E	1.610	1.630	1.710	1.645	1.630	1.2254
						0.2616

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	9.6	9.4	9.7	9.6	9.7	
B	9.7	9.8	9.7	9.6	9.7	
C	16.4	16.2	16.7	16.2	16.2	
D	9.8	9.7	9.7	9.8	9.7	
E	11.9	12.0	12.1	11.9	11.9	11.468
						2.6474

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	1	1	1	1	0	0.8
Partially filled	11	11	9	9	10	10
Empty	0	0	2	2	2	1.2

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Jones

Group: C

Data Point: Baseline

SCALE: 20 Div. 13.760 cm.

1) DIAMETERS

REFERENCE		1	2	3	4	5	mean Std. Dev.
A	14.850	0.940	0.935	1.010	0.950	0.930	
B	2.340	0.925	0.990	1.050	0.985	0.980	
C	11.950	0.530	0.565	0.625	0.580	0.560	
D	3.120	0.800	0.760	0.830	0.860	0.830	
E	4.000	0.720	0.790	0.835	0.730	0.735	0.8178
							0.1558

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	18.4	18.1	18.5	18.3	18.5	
B	12.0	12.3	12.2	12.3	12.2	
C	24.8	25.0	25.1	24.8	24.8	
D	10.9	11.0	10.8	10.8	10.9	
E	13.6	13.8	13.7	13.6	13.8	16.008
						5.2199

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	2	1	0	1	1	5
Partially filled	8	9	10	9	7	8.6
Empty	0	0	0	0	2	0.4

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Jones

Group: C

Data Point: 3/12

SCALE: 20 Div. = 13.72 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as Baseline	1.100	1.060	1.180	1.060	1.050	
B	1.320	1.320	1.400	1.300	1.330	
C	0.895	0.860	0.980	0.855	0.860	
D	0.810	0.900	0.920	0.885	0.900	
E	0.900	0.915	0.880	0.865	0.870	1.0166
						0.1852

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	18.7	18.8	18.5	18.6	18.8	
B	20.0	19.8	19.9	19.8	20.0	
C	20.4	20.3	20.5	20.5	20.3	
D	61.4	16.3	16.4	16.3	16.5	
E	15.7	15.6	15.7	15.8	15.7	18.212
						1.9127

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	2	1	1	1	2	1.4
Partially filled	9	10	9	9	9	9.2
Empty	0	0	1	1	0	0.4

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Jones

Group: C

Data Point: 6/12

SCALE: 20 Div. = 13.720 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as Baseline	0.880	0.915	0.980	1.000	0.930	
B	0.800	0.865	0.830	0.855	0.879	
C	0.725	0.765	0.680	0.765	0.725	
D	0.720	0.770	0.760	0.775	0.765	
E	0.800	0.825	0.795	0.840	0.815	0.8184
						0.0807

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	15.7	15.6	15.8	15.7	15.6	
B	10.7	10.6	10.8	10.7	10.6	
C	16.3	16.4	16.5	16.3	16.4	
D	10.1	9.9	10.2	10.2	10.0	
E	6.4	6.3	6.4	6.4	6.4	11.84
						3.8091

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	1	2	0	2	2	1.4
Partially filled	10	9	11	9	9	9.6
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Matthews

Group: C

Data Point: Baseline

SCALE: 20 Div = 13.740 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A 1.250	0.510	0.565	0.595	0.600	0.565	
B 0.950	0.685	0.700	0.735	0.740	0.700	
C 6.350	0.845	0.835	0.780	0.785	0.800	
D 3.300	0.930	1.050	0.910	1.030	0.935	
E 5.250	0920	0.960	0.865	0.880	0.885	0.7922
						0.1501

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	9.0	9.2	9.2	9.0	8.8	
B	12.1	12.2	12.1	12.0	12.0	
C	14.5	14.6	14.5	14.4	14.5	
D	15.7	15.6	15.7	15.7	15.7	
E	20.9	21.2	21.4	21.4	21.3	14.508
						4.1472

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	0	1	0	0	1	0.4
Partially filled	16	15	15	15	15	15.2
Empty	0	0	1	1	0	0.4

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Matthews

Group: C

Data Point: 3/12

SCALE: 20 Div. = 13.720 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as Baseline	0.890	0.925	0.880	.020	0.925	
B	1.005	0.985	0.990	1.015	1.020	
C	0.580	0.630	0.675	0.640	0.635	
D	0.715	0.785	0.700	0.695	0.720	
E	0.800	0.830	0.835	0.860	0.865	0.8248
						0.1409

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	11.5	11.1	11.6	11.6	11.6	
B	6.9	6.8	6.8	6.7	6.9	
C	11.3	11.4	11.3	11.3	11.3	
D	12.2	12.1	12.4	12.1	12.3	
E	23.5	23.3	23.7	23.6	23.6	13.076
						5.6839

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	3	3	1	1	1	1.8
Partially filled	17	17	18	18	19	17.8
Empty	0	0	1	1	0	0.4

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Matthews

Group: C

Data Point: 6/12

SCALE: 20 Div = 13.70 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as Baseline	0.630	0.560	0.615	0.645	0.610	
B	0.750	0.785	0.760	0.770	0.765	
C	0.600	0.625	0.665	0.580	0.645	
D	0.735	0.720	0.735	0.740	0.720	
E	0.485	0.465	0.400	0.460	0.450	0.6366
						0.1147

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	10.0	10.2	9.9	9.9	10.0	
B	6.2	6.3	6.3	6.2	6.1	
C	12.7	12.6	12.8	12.8	12.6	
D	13.7	13.4	13.8	13.8	13.8	
E	22.5	22.6	22.0	22.1	22.4	12.988
						5.4489

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	1	1	1	1	1	1
Partially filled	17	17	13	14	14	15
Empty	2	2	6	5	5	4

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Medlock

Group: C

Data Point: Baseline

SCALE: 20 Div = 13.820 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A 2.950	0.645	0.700	0.730	0.710	0.695	
B 6.650	1.420	1.480	1.460	1.380	1.420	
C 4.000	1.700	1.700	1.680	1.660	1.660	1.2693
D						
E						
						0.4335

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	9.2	9.3	9.2	9.3	9.2	
B	8.9	9.0	9.1	8.9	8.9	
C	13.5	13.3	13.4	13.5	13.6	10.553
D						
E						
						2.1324

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	2	4	1	0	2	1.8
Partially filled	8	6	9	10	8	8.2
Empty	1	1	1	1	1	1

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Medlock

Group: C Data Point: 3/12

SCALE: 20 Div = 13.810 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as Baseline	0.800	0.840	0.865	0.790	0.830	
B	1.215	1.290	1.300	1.320	1.320	
C	1.675	1.695	1.650	1.730	1.675	1.2663
D						
E						
						0.3652

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	10.9	10.8	11.0	11.1	10.8	
B	7.0	7.2	6.9	6.9	7.0	
C	10.5	10.6	10.6	10.3	10.4	9.46
D						
E						
						1.8188

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	2	3	5	2	3	3
Partially filled	7	6	4	7	6	6
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Medlock

Group: C Data Point: 6/12

SCALE: 20 Div = 13.810 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as Baseline	0.920	1.050	1.060	1.030	1.040	
B	1.230	1.185	1.125	1.140	1.160	
C	1.585	1.600	1.565	1.550	1.590	1.2553
D						
E						
						0.2475

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	11.1	10.8	10.9	11.0	10.8	
B	5.4	5.0	5.1	5.3	5.3	
C	13.4	13.7	13.5	13.6	13.5	9.893
D						
E						
						3.5975

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	1	0	0	0	0	0.2
Partially filled	6	7	7	7	7	6.8
Empty	1	1	1	1	1	1

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Mills

Group: C

Data Point: Baseline

SCALE: 20 Div. 13.740 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A 9.410	0.610	0.0	0.685	0.670	0.640	
B 5.600	0.810	0.867	0.885	0.815	0.830	
C 1.770	1.080	1.050	0.990	1.070	1.055	
D 3.640	0.565	0.580	0.600	0.575	0.550	
E 6.100	6.30	0.635	0.550	0.560	0.610	0.7416
						0.1863

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	10.9	10.8	10.7	10.7	10.9	
B	10.6	10.7	10.5	10.7	10.7	
C	9.0	8.7	8.8	8.9	8.7	
D	11.2	11.7	11.5	11.3	11.2	
E	12.1	11.8	12.2	12.2	12.1	

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	2	3	1	1	1	1.6
Partially filled	18	17	19	18	18	1.8
Empty	0	0	1	1	1	0.4

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Mills

Group: C

Data Point: 3/12

SCALE: 20 Div: 13.760 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	0.870	0.850	0.900	0.865	0.830	
B	0.710	0.680	0.685	0.720	0.700	
C	1.160	1.150	1.095	1.095	1.150	
D	0.420	0.485	0.500	0.410	0.500	
E	0.430	0.400	0.400	0.455	0.450	0.7164
						0.2679

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	13.5	12.9	13.3	13.4	13.3	
B	14.2	13.8	14.1	14.0	14.0	
C	11.4	11.3	11.6	11.3	11.4	
D	11.1	11.3	11.0	10.8	11.0	
E	9.8	10.1	10.0	9.9	9.9	11.936
						1.5364

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	5	3	3	0	0	2.2
Partially filled	10	12	12	15	15	12.8
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Neely

Group: C Data Point: Baseline

SCALE: 20 Div.= 13.755 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A 2.520	0.870	0.860	0.775	0.780	0.860	
B 4.890	0.640	0.610	0.625	0.600	0.595	
C 1.600	0.945	0.975	1.010	1.030	1.010	
D 4.640	1.090	1.135	1.09	1.080	1.095	
E 3.980	0.960	1.000	1.020	1.010	0.995	0.9064
						0.1755

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	19.2	19.1	19.3	19.4	19.1	
B	6.2	6.1	6.2	6.2	6.3	
C	13.8	14.0	14.1	13.7	13.8	
D	13.9	13.6	13.7	13.8	13.7	
E	7.1	7.7	7.3	7.5	7.7	12.1
						4.8519

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	5	5	2	4	4	4.0
Partially filled	8	8	11	9	9	9.0
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Neely

Group: C Data Point: 3/12

SCALE: 20 Div= 13.765 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as Baseline	0.880	0.900	0.935	0.870	0.910	
B	0.800	0.865	0.850	0.935	0.870	
C	0.720	0.765	0.780	0.800	0.765	
D	0.845	0.865	0.885	0.890	0.880	
E	1.390	1.360	1.320	1.300	0.310	0.9476
						0.2058

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	18.7	18.5	18.6	18.8	18.8	
B	14.1	14.2	14.0	14.0	14.1	
C	4.2	4.1	4.2	4.3	4.2	
D	8.8.	8.7	8.9	8.9	8.8	
E	6.7	7.0	6.7	6.7	6.7	10.508
						5.3282

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	4	5	4	2	4	3.8
Partially filled	6	5	6	8	6	6.2
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Neely

Group: C Data Point: 6/12

SCALE: 20 Div = 13.765 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as Baseline			Empty			
B	0.740	0.735	0.765	0.740	0.735	
C	0.660	0.685	0.710	0.745	0.700	
D	1.230	1.200	1.265	1.265	1.280	
E	0.800	0.865	0.800	0.850	0.800	0.7028
						0.4107

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	21.1	20.9	21.0	21.1	21.1	
B	5.8	5.9	5.7	5.9	5.8	
C	5.7	5.5	5.8	5.8	5.8	
D	13.7	13.5	13.8	13.8	13.7	
E	12.1	12.0	12.3	12.3	12.0	11.684
						5.8062

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	5	4	4	2	2	3.4
Partially filled	5	6	5	6	6	5.6
Empty	0	0	0	2	2	0.8

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Owens

Group: C Data Point: Baseline

SCALE: 20 Div. 13.720 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A 1.500	0.700	0.765	0.685	0.790	0.785	
B 1.820	0.500	0.540	0.535	0.560	0.565	
C 3.540	0.540	0.515	0.540	0.465	0.545	
D 2.910	0.510	0.570	0.550	0.590	0.565	
E 8.210	0.685	0.650	0.690	0.695	0.685	0.6088
						0.0949

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	7.4	7.1	7.3	7.4	7.5	
B	7.2	7.1	7.4	7.1	7.2	
C	10.6	10.5	10.7	10.5	10.7	
D	5.6	5.9	5.7	5.7	5.8	
E	12.5	12.6	12.7	12.6	12.5	8.692
						2.5650

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	2	2	1	1	2	1.6
Partially filled	16	16	17	17	17	16.6
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Owens

Group: C Data Point: 3//2

SCALE: 20 Div. 13.710 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	0.570	0.545	0.610	0.520	0.550	
B	0.640	0.620	0.590	0.610	0.645	
C	0.470	0.460	0.500	0.540	0.475	
D	0.590	0.540	0.595	0.580	0.585	
E	0.940	0.960	0.910	0.900	0.910	0.6318
						0.1576

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	9.4	9.3	9.5	9.4	9.3	
B	8.6	8.5	8.5	8,8	8,6	
C	14.4	14.3	14.4	14.5	14.5	
D	15.4	15.3	15.5	15.5	15.4	
E	18.7	18.6	18.8	18.8	18.6	13.304
						3.8838

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	0	1	1	1	0	0.6
Partially filled	17	16	16	17	18	16.8
Empty	0	1	1	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Ryhs Evans

Group: C Data Point: Baseline

SCALE: 20 Div. 13.755 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A 1.920	0.675	0.700	0.690	0.720	0.700	
B 1.400	0.780	0.830	0.795	0.780	0.795	
C 1.380	0.425	0.410	0.385	0.415	0.455	
D 6.800	0.725	0.625	0.640	0.665	0.650	
E 4.560	0.730	0.680	0.715	0.690	0.685	0.6544
						0.1311

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	4.2	4.3	4.3	4.2	4.2	
B	4.5	4.6	4.3	4.6	4.3	
C	4.4	4.6	4.7	4.6	4.5	
D	12.1	12.2	12.1	12.2	12.2	
E	17.7	17.8	17.6	17.7	17.6	8.62
						5.5658

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	6	5	7	4	5	5.4
Partially filled	9	10	8	11	10	9.6
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Rhys Evans

Group: C

Data Point: 3/12

SCALE: 20 Div. 13.775 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	0.510	0.520	0.520	0.515	0.520	
B	0.540	0.490	0.550	0.565	0.565	
C	0.470	0.450	0.500	0.445	0.450	
D	0.640	0.695	0.620	0.645	0.640	
E	0.715	0.710	0.700	0.700	0.715	0.5756
						0.0934

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	5.2	5.1	5.2	5.2	5.2	
B	4.2	3.9	4.0	4.0	4.2	
C	5.3	5.2	5.3	5.3	5.2	
D	12.7	13.8	13.6	13.6	13.7	
E	16.5	16.4	16.6	16.5	16.5	8.936
						5.2270

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	8	7	4	4	8	6.2
Partially filled	10	11	14	14	10	11.8
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Savage

Group: C

Data Point: Baseline

SCALE: 20 Div. 13.755 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A 1.450	0.780	0.830	0.795	0.815	0.785	
B 12.750	1.750	1.230	1.260	1.235	1.210	
C 3.750	0.790	0.810	0.745	0.790	0.785	
D 1.680	0.525	0.500	0.535	0.490	0.520	
E 3.230	0.775	0.810	0.765	0.755	0.780	0.8466
						0.2905

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	24.3	24.8	24.6	24.5	24.6	
B						
C	16.6	16.7	16.8	16.8	16.6	
D	12.9	12.6	12.9	13.0	13.0	
E	16.0	16.1	16.1	15.9	15.9	17.535
						4.4170

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	1	1	0	2	0	0.8
Partially filled	18	18	19	17	19	18.2
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Savage

Group: C

Data Point: 3/12

SCALE: 20 Div. 13.760 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	0.780	0.795	0.790	0.780	0.795	
B	0.860	0.855	0.780	0.860	0.845	
C	0.725	0.780	0.700	0.780	0.795	
D	0.655	0.645	0.680	0.610	0.664	
E	0.760	0.690	0.710	0.725	0.720	0.7512
						0.0701

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	25.0	25.1	25.0	25.0	24.9	
B						
C	15.9	15.7	15.7	15.8	15.9	
D	9.4	9.6	9.7	9.4	9.5	
E	19.5	19.6	19.5	19.4	19.5	17.455
						5.7775

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	0	0	0	0	0	0
Partially filled	15	15	13	13	15	14.2
Empty	3	3	5	5	3	3.8

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Scott

Group: C

Data Point: Baseline

SCALE: 20 Div. 13.730 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A 2.500	1.045	1.040	1.000	1.020	1.035	
B 11.680	0.800	0.820	0.865	0.855	0.820.	
C 9.100	0.710	0.730	0.780	0.740	0.750	
D 3.630	0.650	0.660	0.690	0.710	0.685	
E 2.600	0.940	0.930	0.935	1.030	0.940	0.8472
						0.1348

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	19.0	18.6	18.8	18.9	18.9	
B	22.0	21.9	21.9	22.0	22.0	
C	21.4	21.3	21.4	21.5	21.4	
D	21.2	21.2	21.1	21.1	21.2	
E	28.2	28.0	28.0	28.3	28.3	22.304
						3.1814

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	1	2	5	3	3	2.8
Partially filled	19	18	15	17	17	17.2
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Scott

Group: C

Data Point: 3/12

SCALE: 20 Div≅ 13.775 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A As Baseline	0.975	1.010	1.040	1.000	0.995	
B	0.535	0.510	0.550	0.490	0.500	
C	0.765	0.710	0.765	0.770	0.750	
D	0.790	0.790	0.810	0.815	0.790	
E	0.810	0.865	0.890	0.895	0.890	0.7884
						0.1651

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	26.2	26.2	26.3	26.2	26.2	
B	31.6	31.4	31.7	31.7	31.6	
C	27.1	27.0	26.9	27.1	27.1	
D	21.7	21.5	21.5	21.8	21.8	
E	16.5	16.5	16.3	16.6	16.6	24.604
						5.2417

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	2	4	2	0	0	1.6
Partially filled	21	19	21	21	21	20.6
Empty	0	0	0	2	2	0.8

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Scott

Group: C

Data Point: 6/12

SCALE: 20 Div≅ 13.765 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as Baseline	0.980	1.000	1.060	1.080	1.060	
B	0.620	0.670	0.620	0.655	0.760	
C	0.935	0.920	0.885	0.880	0.875	
D	0.835	0.840	0.850	0.850	0.855	
E	0.900	0.890	0.920	0.895	0.905	0.8696
						0.1266

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	25.7	25.6	25.7	25.7	25.6	
B	32.0	32.1	32.0	32.0	31.9	
C	30.3	30.4	30.3	30.5	30.5	
D	22.2	22.0	22.1	22.1	22.0	
E	24.6	24.7	24.6	24.7	24.7	26.96
						3.7653

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	2	3	3	4	4	3.2
Partially filled	18	17	16	16	14	15.2
Empty	0	0	1	0	2	0.6

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Tait

Group: C

Data Point: Baseline

SCALE: 20 Div. 13.740 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A 3.380	0.940	0.910	0.975	0.965	0.970	
B 4.640	0.670	0.600	0.615	0.630	0.600	
C 9.750	0.835	0.800	0.835	0.850	0.800	
D 5.220	0.620	0.660	0.685	0.645	0.630	
E 2.620	0.800	0.840	0.800	0.815	0.800	0.7716
						0.1264

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	21.1	21.0	21.0	21.1	21.0	
B	20.2	20.1	20.3	20.3	20.2	
C	11.1	11.2	11.0	11.2	11.2	
D	15.5	15.7	15.7	15.5	15.6	
E	14.6	14.1	14.1	14.5	14.5	16.472
						3.7814

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	4	2	3	2	3	2.8
Partially filled	11	13	12	13	12	12.8
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Tait

Group: C

Data Point: 3/12

SCALE: 20 Div. 13.780 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	1.100	1.105	1 120	1.095	1.080	
B	0.785	0.720	0.730	0.725	0.765	
C	0.800	0.795	0.780	0.835	0.780	
D	0.935	0.890	0.895	0.935	0.965	
E	1.060	1.040	0.985	0.965	0.985	0.9148
						0.1359

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	17.7	17.6	17.8	17.6	17.8	
B	17.5	17.3	17.6	17.6	17.5	
C	10.7	10.5	10.6	10.6	10.6	
D	6.8	6.8	6.6	6.9	6.9	
E	12.7	12.7	12.8	12.6	12.8	13.064
						4.2485

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	1	2	2	1	3	1.8
Partially filled	10	9	9	10	8	9.2
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Bell

Group: B

Data Point: Baseline

SCALE: 20 Div. 13.765 cm.

1) DIAMETERS

REFERENCE		1	2	3	4	5	mean Std. Dev.
A	8.950	0.590	0.565	0.590	0.600	0.660	
B	3.295	0.420	0.450	0.490	0.500	0.570	
C	5.720	0.640	0.645	0.650	0.620	0.650	
D	6.680	0.625	0.660	0.690	0.700	0.720	0.6122
E	2.180	0.610	0.630	0.690	0.700	0.720	0.6122
							0.0821

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	19.0	19.2	19.1	18.9	19.0	
B	18.8	18.7	18.6	18.6	18.6	
C	18.5	18.7	18.6	18.5	18.5	
D	15.8	15.6	15.7	15.8	15.8	
E	2.7	2.6	2.6	2.7	2.7	14.932
						6.3774

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	0	3	2	4	2	2.2
Partially filled	24	22	22	20	22	22
Empty	2	1	2	2	2	1.8

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Bell

Group: B

Data Point: 3/12

SCALE: 20 Div.13.780 cm.

1) DIAMETERS

REFERENCE		1	2	3	4	5	mean Std. Dev.
A	8.950	0.480	0.490	0.500	0.620	0.630	
B	3.295	0.710	0.730	0.720	0.900	1.055	
C	5.720	0.415	0.390	0.490	0.425	0.500	
D	6.680	0.820	0.835	0.760	0.790	0.900	
E	2.180	0.700	0.760	0.775	0.920	0.970	0.6914
							0.1894

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	14.6	14.9	14.7	14.7	14.6	
B	12.8	13.2	12.9	13.0	12.9	
C	10.6	10.8	10.8	10.9	10.9	
D	9.3	9.4	9.6	9.4	9.5	
E	6.0	6.3	6.2	6.0	6.0	10.8
						3.0236

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	0	0	0	1	1	0.4
Partially filled	16	17	16	16	15	16
Empty	3	2	3	2	3	2.6

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Booth

Group: B

Data Point: Baseline

SCALE: 20 Div. 13.750 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A 3.000	0.455	0.450	0.4530	0.520	0.450	
B 3.200	0.445	0.370	0.450	0.580	0.590	
C 5.300	0.440	0.490	0.620	0.660	0.670	
D 1.780	0.410	0.480	0.420	0.510	0.500	
E 8.68	0.535	0.565	0.550	0.835	0.820	0.5338
						0.1167

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	5.20	5.30	5.20	5.2	5.2	
B	7.3	7.4	7.3	7.2	7.2	
C	20.6	20.8	20.5	20.6	20.7	
D	8.2	8.3	8.1	8.2	8.2	
E	11.1	10.8	10.9	11.1	11.0	10.464
						5.5267

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	2	2	5	5	6	4
Partially filled	14	14	11	11	10	12
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Booth

Group: B

Data Point: 3/12

SCALE: 20 Div. 13.710 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A 3.00	0.460	0.435	0.440	0.455	0.450	
B 3.20	0.420	0.455	0.460	0.565	0.610	
C 5.30	0.660	0.680	0.740	0.750	0.760	
D 1.780	0.610	0.610	0.590	0.610	0.595	
E 8.680	0.610	0.640	0.765	0.780	0.785	0.5974
						0.1231

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	6.2	5.9	6.0	5.9	6.0	
B	12.8	12.7	12.6	12.9	12.9	
C	26.5	26.6	26.4	26.5	26.5	
D	10.1	10.1	10.2	10.1	10.0	
E	17.2	17.3	16.9	17.2	17.3	14.512
						7.1561

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	5	4	4	8	7	5.6
Partially filled	20	21	21	17	18	19.4
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Booth

Group: B Data Point: 6/12

SCALE: 20 Div. 13.670 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	0.400	0.485	0.450	0.510	0.500	
B	0.450	0.400	0.550	0.545	0.545	
C	0.655	0.644	0.655	0.650	0.640	
D	0.455	0.460	0.550	0.535	0.510	
E	0.630	0.650	0.690	0.780	0.785	0.5648
						0.1079

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	5.5	5.6	5.7	5.5	5.6	
B	12.1	12.3	12.0	12.2	12.0	
C	19.7	19.6	19.4	19.7	19.6	
D	13.9	13.9	13.5	13.4	13.4	
E	15.6	15.5	15.4	15.5	15.4	13.276
						4.6977

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	1	1	1	1	2	1.2
Partially filled	13	13	14	14	15	13.8
Empty	1	1	0	0	0	0.4

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Bethel

Group: B Data Point: Baseline

SCALE: 20 Div. 13.735 cm.

1) DIAMETERS

REFERENCE		1	2	3	4	5	mean Std. Dev.
A	7.520	0.440	0.400	0.450	0.535	0.530	
B	3.900	0.610	0.630	0.665	0.695	0.720	
C	5.930	0.550	0.575	0.590	0.635	0.655	
D	5.000	0.745	0.820	0.850	0.880	0.920	
E	3.000	0.780	0.875	0.840	0.800	0.840	0.6812
							0.1506

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	17.3	17.2	17.0	17.1	17.1	
B	11.0	10.8	11.1	11.0	11.1	
C	18.9	18.7	18.4	18.5	18.4	
D	22.3	22.6	22.4	22.0	22.2	
E	15.3	15.1	15.2	15.1	15.3	16.84
						3.8082

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	2	3	5	5	3	3.4
Partially filled	11	10	8	8	10	9.4
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Bethel

Group: B Data Point: 3/12

SCALE: 20 Div. 13.780 cm.

1) DIAMETERS

REFERENCE		1	2	3	4	5	mean / Std. Dev.
A	7.520	0.620	0.650	0.790	0.800	0.830	
B	3.900	0.500	0.520	0.600	0.640	0.680	
C	5.930			EMPTY			
D				EMPTY			
E	3.000	0.340	0.380	0.530	0.380	0.570	0.3508
							0.3149

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	22.6	22.8	22.7	22.8	22.7	
B	17.7	17.8	17.7	17.7	17.2	
C						
D	21.7	22.2	21.8	21.7	21.7	
E	13.6	13.4	13.5	13.6	13.4	18.91
						3.7719

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	1	1	0	0	0	0.4
Partially filled	9	8	9	9	8	8.6
Empty	1	2	2	2	3	2

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Carr

Group: B Data Point: Baseline

SCALE: 20 Div. 13.700 cm.

1) DIAMETERS

REFERENCE		1	2	3	4	5	mean / Std. Dev.
A	5.41	0.445	0.450	0.500	0.540	0.550	
B	6.43	0.695	0.640	0.685	0.695	0.760	
C	2.30	0.730	0.800	0.830	0.875	0.850	
D	8.10	0.520	0.500	0.540	0 .680	0.550	
E	7.05	0.590	0.520	0 . 580	0.625	0.640	0.6316
							0.1251

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	4.0	3.9	3.8	4.0	3.7	
B	12.0	11.9	12.1	12.0	12.2	
C	8.3	8.1	8.2	8.1	8.0	
D	10.6	10.8	10.6	10.7	10.7	
E	9.1	9.1	9.3	9.3	9.2	8.788
						2.9480

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	1	2	1	1	1	1.2
Partially filled	11	10	11	11	11	10.8
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Carr

Group: B Data Point: 3/12

SCALE: 20 Div. 13.685 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A as base	0.640	0.660	0.750	0.735	0.750	
B	0.530	0.540	0.680	0. 650	0.680	
C	0.650	0.630	0.630	0.690	0.690	
D	0.620	0.650	0.740	0.700	0.670	
E	0.785	0.740	0.760	0.780	0.790	0.6856
						0.0691

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	6.9	6.7	6.6	6.5	6.6	
B	12.1	11.9	12.0	12.1	12.1	
C	8.4	8.5	8.5	8.7	8.6	
D	6.3	6.2	6.2	6.0	6.2	
E	10.1	10.2	10.1	10.4	10.2	8.724
						2.2359

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	0	1	0	0	1	0.4
Partially filled	10	9	10	10	9	9.6
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: J. Chalkin

Group: B Data Point: Baseline

SCALE: 20 Div. 13.770 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A 2.220	0.460	0.420	0.465	0.420	0.510	
B 2.920	0.490	0.500	0.555	0.560	0.590	
C 3.130	0.500	0.490	0.515	0.490	0.515	
D 2.630	0.440	0.450	0.445	0.500	0.465	
E 2.250	0.490	0.470	0.500	0.410	0.545	0.4918
						0.0423

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	6.8	6.9	6.8	6.9	6.9	
B	9.4	9.8	9.7	9.9	9.9	
C	10.0	9.8	10.3	10.1	10.3	
D	5.5	5.6	5.7	5.6	5.7	
E	3.7	3.6	3.5	3.6	3.7	7.188
						2.5002

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	6	6	6	5	6	5.8
Partially filled	10	10	10	11	10	10.2
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: J Chalkin

Group: B Data Point: 3/12

SCALE: 20 Div. 13.700 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	0.525	0.520	0.530	0.580	0.585	
B	0.360	0.380	0.410	0.400	0.430	
C	0.335	0.360	0.390	0.420	0.420	
D	0.470	0.440	0.450	0.490	0. 520	
E	0.570	0.550	0.675	0.650	0.670	0.4852
						0.0991

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	7.5	7.4	7.5	7.6	7.6	
B	9.1	9.0	9.1	9.0	9.0	
C	10.2	9.9	9.7	9.9	10.2	
D	5.6	5.5	5.7	5.6	5.7	
E	6.0	6.1	6.3	6.1	6.3	7.664
						1.6946

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	3	3	3	3	2	2.8
Partially filled	12	12	10	10	11	11
Empty	1	1	3	3	3	2.2

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: J. Chalkin

Group: B Data Point: 6/12

SCALE: 20 Div. 13.740 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	0.310	0.335	0.385	0.385	0.400	
B	0.380	0.360	0.380	0.440	0.465	
C	0.380	0.380	0.390	0.460	0.455	
D	0.690	0.710	0.665	0.790	0.700	
E	0.780	0.795	0.825	0.870	0.780	0.5404
						0.1909

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	7.6	7.5	7.3	7.6	7.6	
B	9.9	10.1	9.8	9.9	9.8	
C	10.3	10.1	10.2	10.3	10.3	
D	6.6	6.5	6.6	6.4	6.6	
E	4.2	4.4	4.3	4.3	4.3	7.700
						2.2487

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	1	2	2	1	0	1.2
Partially filled	11	11	11	11	13	11.4
Empty	2	1	1	2	1	1.4

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Dalton

Group: B

Data Point: Baseline

SCALE: 20 Div. 13.730 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A 4.430	0.990	1.090	1.140	0.980	0.985	
B 6.500	0.810	0.700	0.720	0.750	0.710	
C 9.680	0.940	0.920	0.935	0.960	0.930	
D 3.740	0.565	0.595	0.560	0.715	0.700	
E 8.630	0.935	0.950	1.100	1.135	0.990	0.8722
						0.1762

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	16.4	16.2	16.3	16.3	16.4	
B	16.9	16.7	17.0	16.9	16.9	
C	10.8	11.0	11.3	11.1	10.9	
D	12.6	12.8	12.5	12.7	12.6	14.552
E						2.3527

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	5	4	2	4	5	4
Partially filled	10	11	13	11	10	11
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Dalton

Group: B

Data Point: 6/12

SCALE: 20 Div. 13.690 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	1.120	1.245	1.040	1.280	12.00	
B	0.860	0.895	0.945	0.950	0.955	
C	0.840	0.845	0.870	0.835	0.860	
D	0.950	0.925	0.910	0.995	1.010	
E	0.895	0.900	0.880	1.180	0.915	0.972
						0.1319

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	17.6	17.3	17.6	17.7	17.6	
B	14.0	13.9	14.2	13.9	14.0	
C	15.4	15.1	15.4	15.5	15.4	
D	7.0	7.1	7.3	7.0	7.0	
E	13.8	13.6	13 7	13.8	13.8	13.548
						3 5802

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	5	4	4	5	3	4.2
Partially filled	8	9	9	8	10	8.6
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Dawson

Group: B Data Point: Baseline

SCALE: 20 Div. 13.730 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A 4.000	0.890	0.950	1.080	0.825	0.890	
B 3.320	0.715	0.725	0.650	0.665	0.725	
C 5.530	0.590	0.610	0.540	0.570	0.610	
D 6.250	0.920	0.940	0.920	1.030	0.950	
E 12.420	0.610	0.665	0.630	0.650	0.600	0.758
						0.1632

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	21.3	21.0	21.3	21.2	21.3	
B	18.0	18.1	17.9	18.1	18.0	
C	20.8	20.7	20.6	20.8	20.8	
D	22.8	22.9	22.7	22.7	22.8	
E	15.7	15.2	15.3	15.7	15.6	19.5

3) ENGORGEMENT 2.6984

Classification	1	2	3	4	5	
Filled	2	0	0	1	2	1
Partially filled	10	12	12	11	10	11
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Dawson

Group: B Data Point: 3/12

SCALE: 20 Div. 13.740 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A as base	0.840	0.890	1.860	0.830	0.890	
B	0.620	0.590	0.700	0.680	0.630	
C	0.635	0.645	0.620	0.635	0.640	
D	0.945	0.920	0.890	0.885	0.920	
E	0.800	0.765	0.780	0.720	0.720	0.762
						0.1176

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	25.3	25.4	25.2	25.3	25.3	
B	21.5	21.7	21.6	21.5	21.7	
C	18.6	18.7	18.8	18.6	18.5	
D	22.3	22.4	22.5	22.4	22.4	
E	15.4	15.3	15.5	15.6	15.4	20.676

3) ENGORGEMENT 3.4401

Classification	1	2	3	4	5	
Filled	0	1	0	0	0	0.2
Partially filled	16	15	14	14	13	14.4
Empty	1	2	3	3	4	2.6

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Gribbin

Group: B

Data Point: Baseline

SCALE: 20 Div. 13.770 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A 9.330	1.250	1.240	1.220	1.335	1.210	
B 1.540	1.290	1.220	1.290	1.325	1.295	
C 3.500	0.785	0.815	0.815	0.835	0.835	
D 4.530	0.570	0.600	0.585	0.500	0.590	
E 6.700	1.320	1.380	1.300	13.80	1.320	1.0562
						0.3064

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	12.3	12.2	12.6	12.3	12.5	
B	8.1	8.0	7.9	8.1	8.1	
C	5.9	5.8	5.9	6.0	5.9	
D	11.4	11.3	11.4	11.3	11.4	
E	17.7	18.1	18.3	18.0	18.1	11.144
						4.4211

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	3	3	5	5	3	3.6
Partially filled	11	11	9	9	11	10.2
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Gribbin

Group: B

Data Point: 3/12

SCALE: 20 Div. 13.770 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	1.340	1.365	1.465	1.340	1.360	
B	0.875	0.830	0.780	0.810	0.835	
C	1.030	1.060	1.010	1.060	1.035	
D	0.910	0.920	0.965	0.950	0.925	
E	1.470	0.485	1.410	1.490	1.465	1.1274
						0.2561

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	12.7	12.6	12.8	12.7	12.6	
B	8.7	8.6	8.8	8.7	8.7	
C	3.4	3.4	3.3	3.3	3.4	
D	11.1	11.2	11.4	11.4	11.4	
E	15.6	15.3	15.5	15.6	15.6	10.312
						4.2001

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	0	1	0	0	0	0.2
Partially filled	11	10	13	12	12	11.6
Empty	2	2	2	2	2	2

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Herbert

Group: B

Data Point: Baseline

SCALE: 20 Div. 13.700 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A 8.300	0.480	0.510	0.525	0.560	0.510	
B 5.500	0.620	0.650	0.660	0.665	0.655	
C 6.400	0.500	01520	0.470	0.465	0.570	
D 1.750	0.680	0.660	0.775	0.765	0.660	0.592
E						0.0977

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	22.7	22.4	22.7	22.6	22.6	
B	21.4	21.3	21.4	21.5	21.5	
C	11.6	11.5	11.7	11.6	11.7	18.546
D						5.0951
E						

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	0	0	0	2	2	0.8
Partially filled	16	16	16	14	14	15.2
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Herbert

Group: B

Data Point: 3/12

SCALE: 20 Div. 13.680 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A as base	0.520	0.500	0.625	0.575	0.550	
B	0.775	0.750	0.765	0.835	0.780	
C	0.550	0.540	0.560	0.555	0.550	
D	0.920	0.995	0.980	1.000	1.050	0.7187
E						0.1897

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	21.2	21.3	21.1	21.2	21.3	
B	25.8	25.7	25.6	25.9	25.9	
C	22.8	23.2	23.1	23.2	23.1	23.36
D						1.9416
E						

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	1	1	0	0	0	0.4
Partially filled	13	13	14	14	14	13.6
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Hogan

Group: B Data Point: Baseline

SCALE: 20 Div. 13.690 cm.

1) DIAMETERS

REFERENCE		1	2	3	4	5	mean Std. Dev.
A	2.920	0.600	0.570	0.665	0.620	0.615	
B	5.830	0.610	0.650	0.655	0.600	0.590	
C	3.900	0.440	0.430	0.500	0.485	0.450	
D	4.350	0.415	0.420	0.400	0.385	0.420	
E	6.550	0.495	0.540	0.530	0.520	0.550	0.5238
							0.0883

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	6.1	6.2	5.9	6.0	6.1	
B	8.9	8.7	8.6	8.8	8.9	
C	10.3	10.4	10.1	10.3	10.4	
D	8.9	8.7	9.1	8.9	8.9	
E	12.2	11.8	11.7	12.1	12.0	9.2

3) ENGORGEMENT 1.9916

Classification	1	2	3	4	5	
Filled	3	4	4	3	3	3.4
Partially filled	11	10	10	11	11	10.6
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Hogan

Group: B Data Point: 3/12

SCALE: 20 Div. 13.670 cm.

1) DIAMETERS

REFERENCE		1	2	3	4	5	mean Std. Dev.
A	as base.	0.890	0.890	0.910	0.840	0.910	
B		0.620	0.665	0.670	0.655	0.620	
C		0.630	0.600	0.615	0.630	0.625	
D		0.625	0.680	0.695	0.670	0.685	
E		0.830	0.885	0.930	0.835	0.830	0.7374
							0.1192

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	6.6	6.8	6.7	6.6	6.8	
B	9.7	9.6	9.8	9.7	9.6	
C	10.7	10.5	10.8	10.8	10.8	
D	9.2	9.1	9.3	9.3	9.2	
E	13.8	13.8	13.6	13.8	13.7	10.012

3) ENGORGEMENT 2.3338

Classification	1	2	3	4	5	
Filled	3	2	1	2	3	2.2
Partially filled	10	11	12	11	10	10.8
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Howells

Group: B

Data Point: Baseline

SCALE: 20 Div. 13.710 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A 1.650	0.775	0.765	0.840	0.710	0.730	
B 2.300	0.475	0.540	0.550	0.470	0.550	
C 2.000	0.570	0.680	0.665	0.680	0.685	
D 8.580	0.945	0.960	0.950	0.670	0.960	
E						0.7085
						0.1591

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	17.4	17.3	17.4	17.3	17.5	
B	10.4	10.3	10.5	10.3	10.5	
C	11.0	11.2	11.1	11.0	11.2	
D	9.7	10.1	10.3	10.0	9.8	
E						12.215
						3.0898

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	6	5	1	1	5	3.6
Partially filled	6	7	11	11	7	8.4
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Howells

Group: B

Data Point: 3/12

SCALE: 20. Div. 13.715 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	0.685	0.730	0.790	0.765	0.740	
B	1.065	0.900	1.020	0.900	1.000	
C	0.840	0.785	0.820	0.935	0.840	
D	0.775	0.690	0.710	0.775	0.700	
E						0.8233
						0.1134

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	16.7	16.4	16.6	16.7	16.7	
B	10.3	10.5	10.2	10.4	10.4	
C	6.6	6.5	6.4	6.6	6.6	
D	6.8	6.7	6.9	6.8	6.8	
E						10.08
						4.1730

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	5	3	3	2	3	3.2
Partially filled	8	9	10	11	10	9.6
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Howells

Group: B Data Point: 6/12

SCALE: 20 Div. 13.735 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean, Std. Dev.
A as base	0.675	0.700	0.730	0.880	0.715	
B	0.635	0.535	0.590	0.530	0.535	
C	1.185	1.150	1.080	1.085	1.140	
D	0.935	0.890	0.940	0.940	0.880	
E						0.8375
						0.2199

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	19.8	19.2	19.4	19.4	19.5	
B	13.3	13.2	13.0	13.4	13.5	
C	8.6	8.6	8.9	8.9	8.8	
D	10.1	10.3	10.2	10.1	10.0	
E						12.92
						4.2207

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	5	4	3	8	4	4.8
Partially filled	9	10	11	6	10	9.2
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Hunn

Group: B Data Point: Baseline

SCALE: 20 Div. 13.620 cm.

1) DIAMETERS

REFERENCE		1	2	3	4	5	mean Std. Dev.
A	3.580	0.620	0.635	0.620	0.630	0.615	
B	1.540	0.490	0.470	0.525	0.530	0.525	
C	13.000	0.550	0.575	0.625	0.590	0.610	
D	9.800	0.680	0.650	0.620	0.660	0.640	
E	4.050	0.585	0.590	0.580	0.595	0.600	0.593
							0.5883

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	12.6	12.8	12.2	12.6	12.5	
B	13.3	13.6	13.2	13.5	13.3	
C	22.4	22.3	22.5	22.5	22.3	
D	22.3	22.6	22.2	22.2	22.3	
E	21.2	20.9	21.1	21.0	20.9	18.332
						4.5150

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	3	3	1	1	1	1.8
Partially filled	11	11	13	13	13	12.2
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Humm

Group: B

Data Point: 3/12

SCALE: 20 Div. 13.640 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	0.835	0.820	0.700	0.715	0.810	
B	0.590	0.700	0.720	0.715	0.720	
C	0.595	0.650	0.680	0.665	0.670	
D	0.670	0.620	0.680	0.575	0.660	
E	1.120	1.185	1.175	1.160	1.125	0.7822
						0.1999

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	14.7	14.5	14.8	14.8	14.7	
B	10.7	10.3	10.4	10.3	10.4	
C	18.2	18.0	18.3	18.3	18.2	
D	19.1	19.1	19.1	19.1	19.1	
E	19.0	19.1	19.5	19.2	19.0	16.316
						3.4412

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	1	1	2	4	2	2
Partially filled	14	14	13	11	13	13
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Lawrance

Group: B

Data Point: Baseline

SCALE: 20 Div. 13.800 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A 4.300	0.425	0.590	0.575	0.560	0.550	
B 3.920	0.710	0.770	0.795	0.765	0.740	
C 2.850	0.900	0.985	1.000	1.010	0.980	
D 2.305	0.525	0.595	0.530	0.580	0.545	
E 14.850	0.550	0.600	0.585	0.540	0.605	0.6804
						0.1745

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	17.8	18.1	17.9	18.0	18.0	
B	16.9	16.8	16.9	17.0	16.9	
C	1.8	1.8	1.7	1.9	1.8	
D	11.7	11.6	11.8	11.8	11.6	
E	25.4	25.3	25.6	25.3	25.3	14.748
						7.9709

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	3	2	2	3	3	2.6
Partially filled	9	8	8	7	8	8
Empty	0	2	2	2	2	1.8

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Lawrance

Group: B Data Point: 3/12

SCALE: 20 Div. 13.850 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A as base	1.130	1.185	1.180	1.175	1.165	
B	1.220	1.240	1.340	1.270	1.275	
C	1.215	1.195	1.200	1.235	1.230	
D	1.080	1.040	1.085	1.060	1.045	
E	0.600	0.615	0.680	0.620	0.600	1.0672
						0.2386

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	23.2	23.1	23.2	23.3	23.3	
B	16.0	16.2	16.1	15.9	15.9	
C	7.8	7.6	7.7	7.8	7.8	
D	20.4	20.5	20.3	20.2	20.5	
E	25.3	25.1	25.4	25.4	25.3	18.532
						6.3579

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	5	5	4	4	5	4.6
Partially filled	8	8	9	9	8	8.4
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Lawrance

Group: B Data Point: 6/12

SCALE: 20 Div. 13.820 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A as base	0.800	0.835	0.825	0.860	0.845	
B	1.075	1.100	1.070	1.170	1.100	
C	1.100	1.120	1.095	1.140	1.140	
D	0.630	0.595	0.660	0.590	0.580	
E	0.650	0.660	0.635	0.630	0.650	0.8622
						0.2227

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	18.3	18.2	18.1	18.3	18.1	
B	8.4	8.4	8.3	8.5	8.4	
C	2.2	2.3	2.2	2.2	2.3	
D	15.0	14.9	14.9	15.1	15.1	
E	28.1	27.7	27.8	27.9	27.9	14.34
						8.9020

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	2	1	0	1	1	1
Partially filled	14	15	16	15	15	15
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Lee

Group: B

Data Point: Baseline

SCALE: 20 Div. 13.680 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A 5.800	0.930	1.000	0.910	0.920	1.010	
B 3.800	0.785	0.720	0.770	0.765	0.750	
C 2.450	0.430	0.515	0.500	0.495	0.530	
D 3.750	0.560	0.565	0.530	0.535	0.560	
E 5.550	0.670	0.660	0.685	0.690	0.680	0.6866
						0.1685

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	21.4	21.3	21.5	21.5	21.4	
B	28.7	28.6	28.8	28.7	28.7	
C	11.7	11.6	11.7	11.7	11.6	
D	16.9	17.0	17.0	16.8	16.9	
E	23.6	23.7	23.5	23.5	23.7	20.46
						5.9280

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	2	3	5	5	6	4.2
Partially filled	14	13	11	11	10	11.8
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Lee

Group: B

Data Point: 3/12

SCALE: 20 Div. 13.670 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A as base	1.000	1.060	0.980	0.985	0.990	
B	0.790	0.865	0.800	0.835	0.820	
C	0.615	0.630	0.675	0.650	0.660	
D	0.950	0.940	0.875	0.890	0.900	
E	1.270	1.250	1.250	1.265	1.230	0.927
						0.2068

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	28.8	28.7	28.6	28.9	28.9	
B	34.2	34.3	34.0	34.4	34.4	
C	18.0	18.2	18.4	18.2	18.3	
D	25.2	25.5	25.1	25.1	25.3	
E	29.5	29.6	29.3	29.6	29.7	27.208
						5.4466

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	3	2	3	6	2	3.2
Partially filled	11	12	11	8	12	10.8
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Lee

Group: B

Data Point: 6/12

SCALE: 20 Div. 13.690 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A as base	1.030	1.055	1.000	0.985	0.975	
B	1.095	1.100	1.050	1.090	1.095	
C	0.870	0.835	0.810	0.830	0.810	
D	0.825	0.800	0.855	0.860	0.850	
E	0.770	0.720	0.700	0.765	0.760	0.9014
						0.1313

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	20.7	20.6	20.5	20.8	20.8	
B	31.3	31.6	31.0	31.0	31.4	
C	16.9	17.2	16.8	16.8	17.0	
D	21.4	21.3	21.6	21.6	21.2	
E	19.7	20.2	20.0	19.8	19.6	22.024
						4.9656

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	5	5	3	3	5	4.2
Partially filled	12	12	14	12	10	12
Empty	0	0	0	2	2	0.8

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Mackie

Group: B

Data Point: Baseline

SCALE: 20 Div. 13.700 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A 2.100	0.530	0.565	0.510	0.490	0.540	
B 1.350	0.790	0.780	0.810	0.835	0.815	
C 7.200	0.750	0.830	0.775	0.815	0.830	
D 2.600	0.675	0.710	0.725	0.675	0.640	
E 1.050	0.610	0.635	0.635	0.640	0.645	0.6902
						0.1104

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	14.1	14.2	14.2	14.0	14.0	
B	12.3	12.4	12.4	12.1	12.4	
C	13.4	13.5	13.5	13.2	13.4	
D	9.1	9.3	9.3	9.1	9.0	
E	13.0	13.2	13.3	13.5	13.5	12.456
						1.7837

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	5	5	3	2	5	4
Partially filled	11	11	13	14	11	12
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Mackie

Group: B Data Point: 3/12

SCALE: 20 Div. 13.700 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	0.480	0.535	0.540	0.475	0.490	
B	0.630	0.590	0.610	0.615	0.595	
C	0.540	0.515	0.630	0.535	0.540	
D	0.520	0.595	0.520	0.545	0.525	
E	0.550	0.660	0.640	0.615	0.620	0.5644
						0.0536

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	11.2	11.3	11.1	11.1	11.3	
B	14.6	14.8	14.5	14.5	14.6	
C	15.5	15.7	15.4	15.3	15.6	
D	9.4	9.1	9.5	9.5	9.5	
E	13.6	13.9	13.5	13.5	13.6	12.864
						2.2998

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	5	1	1	5	2	2.8
Partially filled	9	13	13	9	12	11.2
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Mackie

Group: B Data Point: 6/12

SCALE: 20 Div. 13.730 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	0.450	0.485	0.560	0.515	0.490	
B	0.830	0.835	0.795	0.845	0.850	
C	0.785	0.780	0.845	0.830	0.820	
D	0.840	0.785	0.810	0.865	0.830	
E	0.780	0.780	0.730	0.735	0.795	0.7466
						0.1312

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	15.9	16.1	15.8	15.8	15.9	
B	15.6	15.7	15.7	15.6	15.7	
C	16.1	16.3	16.2	16.0	16.0	
D	10.6	10.6	10.9	10.4	10.4	
E	10.7	10.8	10.6	10.6	10.7	13.788
						2.6387

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	2	0	0	0	2	0.8
Partially filled	10	12	12	12	10	11.2
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Martin

Group: B Data Point: Baseline

SCALE: 20 Div. 13.620 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A 5.080	0.750	0.730	0.720	0.725	0.720	
B 7.540	9.730	0.730	0.700	0.670	0.670	
C 8.220	0.690	0.730	0.740	0.685	0.725	
D 6.250	0.860	0.815	0.780	0.770	0.785	
E 7.785	0.880	0.885	0.890	0.875	0.885	0.7656
						0.0734

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	12.7	12.6	12.8	12.8	12.8	
B	18.0	18.3	17.9	17.9	17.8	
C	15.8	15.6	15.9	15.9	15.8	
D	13.1	12.7	12.9	12.9	13.1	
E	10.2	10.4	10.5	10.3	10.3	13.96
						2.7103

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	3	4	3	2	4	3.2
Partially filled	11	10	11	12	10	10.8
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Martin

Group: B Data Point: 3/12

SCALE: 20 Div. 13.660 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	0.640	0.640	0.665	0.630	0.665	
B	0.855	0.825	0.830	0.810	0.830	
C	0.695	0.720	0.780	0.785	0.770	
D	1.090	1030	1.070	0.970	1.090	
E	0.820	0.865	0.825	0.865	0.860	0.825
						0.1386

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	23.5	23.7	23.4	23.5	23.4	
B	13.7	13.8	13.7	13.7	13.8	
C	14.9	14.8	14.7	14.91	15.0	
D	14.7	14.4	14.6	14.4	14.4	
E	12.8	13.0	13.1	13.1	13.0	15.92
						3.9244

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	2	3	2	2	3	2.4
Partially filled	10	9	10	10	9	9.6
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Mattheson

Group: B

Data Point: Baseline

SCALE: 20 Div. 13.700 cm.

1) DIAMETERS

REFERENCE		1	2	3	4	5	mean Std. Dev.
A	5.100	0.375	0.410	0.430	0.415	0.385	
B	3.300	0.690	0.710	0.725	0.770	0.700	
C	3.050	0.620	0.675	0.680	0.600	0.610	
D	4.100	0.475	0.480	0.575	0.460	0.510	
E	8.000	0.620	0.625	0.650.	0.660	0.645	0.5774
							0.1198

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	21.4	21.2	21.0	21.2	21.3	
B	22.8	22.7	22.9	22.9	22.6	
C	10.8	10.6	10.9	10.8	10.9	
D	17.0	17.0	16.9	16.8	17.1	
E	23.4	23.3	23.1	23.2	23.2	19.0
						4.758

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	3	2	2	3	2	2.4
Partially filled	11	12	12	11	12	1.6
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Mattheson

Group: B

Data Point: 3/12

SCALE: 20 Div. 13.700 cm.

1) DIAMETERS

REFERENCE		1	2	3	4	5	mean Std. Dev.
A	as base	0.500	0.520	0.535	0.510	0.525	
B		0.615	0.625	0.595	0.580	0.610	
C		0.840	0.775	0.785	0.775	0.760	
D		0.500	0.520	0.525	0.510	0.500	
E		0.730	0.690	0.735	0.710	0.700	0.6268
							0.1122

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	22.6	22.4	22.2	22.3	22.4	
B	24.7	24.4	24.3	24.5	24.4	
C	13.6	13.8	13.7	13.4	13.6	
D	19.6	19.4	19.4	19.5	19.5	
E	22.7	22.9	22.6	22.6	22.7	20.528
						3.886

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	2	2	2	0	0	1.2
Partially filled	11	11	10	12	12	11.2
Empty	0	0	1	1	1	0.6

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Mattheson

Group: B Data Point: 6/12

SCALE: 20 Div. 13.720 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	0.480	0.575	0.580	0.525	0.520	
B	0.630	0.645	0.630	0.650	0.650	
C	0.570	0.590	0.590	0.620	0.595	
D	0.740	0.720	0.745	0.730	0.650	
E	0.930	0.980	0.950	0.995	0.990	0.6888
						0.1588

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	19.1	18.8	19.2	19.2	19.0	
B	17.3	17.2	17.3	17.4	17.2	
C	13.6	13.5	13.4	13.7	13.7	
D	23.4	23.5	23.5	23.2	23.5	
E	24.1	23.9	23.9	24.2	24.2	19.48

3) ENGORGEMENT 8/989

Classification	1	2	3	4	5	
Filled	3	2	0	0	0	1.2
Partially filled	10	11	13	11	11	11.2
Empty	0	0	0	2	2	0.8

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: McAdam

Group: B Data Point: Baseline

SCALE: 20 Div. 13.730 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A 7.950	0.540	0.485	0.550	0.570	0.565	
B 2.600	0.670	0.710	0.770	0.725	0.700	
C 5.100	0.720	0.710	0.760	0.685	0.710	
D 2.510	0.645	0.630	0.665	0.645	0.610	
E 4.680	0.430	0.490	0.475	0.440	0.445	0.6238
						0.0170

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	8.4	8.1	8.0	8.3	8.1	
B	6.3	6.1	6.2	6.0	6.3	
C	19.8	19.8	20.0	19.8	19.8	
D	8.3	8.6	8.6	8.4	8.3	
E	13.7	13.4	13.8	13.8	13.7	11.264

3) ENGORGEMENT 5.0579

Classification	1	2	3	4	5	
Filled	1	2	0	0	1	0.8
Partially filled	7	6	8	8	7	7.2
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Mc Adam

Group: B Data Point: 3/12

SCALE: 20 Div. 13.730 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	0.525	0.780	0.530	0.795	0.780	
B	0.815	0.830	0.825	0.830	0.800	
C	0.990	1.030	1.050	1.035	1.025	
D	0.780	0.790	0.765	0.770	0.760	
E	0.820	0.880	0.840	0.835	0.850	0.8292
						0.1298

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	12.5	12.3	12.6	12.3	12.6	
B	11.9	12.3	12.0	12.0	11.9	
C	24.2	24.3	24.1	24.1	24.2	
D	10.2	1 .5	10.4	10.2	10.2	
E	13.7	13.4	13.8	13.7	13.7	14.524

3) ENGORGEMENT 5.0505

Classification	1	2	3	4	5	
Filled	3	3	3	0	3	2.4
Partially filled	10	10	11	13	10	10.8
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Munks

Group: B Data Point: baseline

SCALE: 20 Div. 13.780 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A 4.650	0.540	0.570	0.575	0.580	0.550	
B 1.000	0.780	0.775	0.750	0.735	0.795	
C 5.500	0.920	0.980	0.915	0.840	0.935	
D 1.150	0.480	0.470	0.485	0.480	0.470	
E 0.900	0.765	0.820	0.780	0.760	0.735	0.697
						0.1665

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	12.8	13.1	13.0	12.7	12.7	
B	15.7	15.5	15.8	15.8	15.6	
C	25.7	25.6	25.8	25.7	25.8	
D	12.1	12.1	12.0	11.9	12.1	
E	14.2	14.3	14.2	14.1	14.2	16.1

3) ENGORGEMENT 5.0697

Classification	1	2	3	4	5	
Filled	3	2	2	2	3	2.4
Partially filled	8	9	9	9	8	8.6
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Siniak

Group: B

Data Point: Baseline

SCALE: 20 Div. 13.630 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A 4.710	0.790	0.720	0.800	0.810	0.800	
B 4.540	0.685	0.690	0.700	0.715	0.690	
C 2.950	0.985	0.990	1.000	1.030	0.985	
D 6.140	0.670	0.680	0.655	0.530	0.635	
E 7/780	0.720	0.760	0.780	0.735	0.750	0.7762
						0.1238

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	9.3	9.3	9.2	9.3	9.3	
B	10.2	10.5	10.4	10.2	10.1	
C	12.5	12.3	12.5	12.5	12.5	
D	17.1	17.0	17.2	17.2	17.1	
E	10.9	10.9	10.8	10.9	11.0	12.008
						2.8148

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	1	1	2	2	4	2
Partially filled	15	14	13	13	11	13.2
Empty	0	1	1	1	1	0.8

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Siniak

Group: B

Data Point: 3/12

SCALE: 20 Div. 13.660 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	0.850	0.850	0.885	0.910	0.875	
B	0.730	0.720	0.695	0.680	0.730	
C	1.000	1.075	1.025	1.035	1.000	
D	0.650	0.680	0.635	0.620	0.615	
E	0.765	0.800	0.810	0.795	0.780	0.8084
						0.1390

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	14.0	14.1	14.0	14.0	13.9	
B	11.3	11.5	11.8	11.7	11.5	
C	11.1	11.4	11.3	11.2	11.3	
D	16.6	1 .4	16.7	16.7	16.6	
E	17.3	17.5	17.5	17.3	17.2	14.156
						2.5601

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	5	4	7	6	5	4.8
Partially filled	14	15	12	15	14	15.6
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Timlin

Group: B Data Point: Baseline

SCALE: 20 Div. 13.755 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A 6.930	0.670	0.670	0.670	0.665	0.650	
B 8.000	0.760	0.775	0.795	0.810	0.800	
C 4.700	0.725	0.750	0.785	0.790	0.795	
D 2.400	0.480	0.525	0.535	0.510	0.490	
E 1.680	0.390	0.390	0.340	0.395	0.400	0.6242
						0.1608

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	20.2	20.1	20.3	20.3	20.1	
B	32.4	32.3	32.5	32.4	32.5	
C	11.8	12.0	11.7	11.7	11.8	
D	4.2	4.1	4.3	4.1	4.3	
E	13.7	13.5	13.8	13.8	13.8	16.468
						9.6640

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	2	2	1	0	0	1
Partially filled	10	10	11	11	11	10.6
Empty	0	0	0	1	1	0.4

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Timlin

Group: B Data Point: 3/12

SCALE: 20 Div. 13.730 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A as base	0.610	0.685	0.690	0.680	0.695	
B	1.170	1.120	1.090	1.120	1.135	
C	0.795	0.735	0.785	0.780	0.800	
D	0.920	0.910	0.980	1.000	0.965	
E	0.910	0.965	0.910	0.915	0.935	0.892
						0.1616

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	15.4	15.3	15.5	15.4	15.3	
B	32.4	32.3	32.5	32.5	32.3	
C	17.4	17.4	17.5	17.3	17.3	
D	8.6	8.7	8.6	8.6	8.6	
E	18.1	18.0	18.1	18.0	18.0	18.364
						7.9314

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	2	1	3	2	1	1.8
Partially filled	10	10	9	10	10	9.8
Empty	0	1	0	0	1	0.4

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Ti mlin

Group: B Data Point: 6/12

SCALE: 20 Div. 13.655 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	1.075	1.020	1.010	1.000	1.025	
B	0.820	0.885	0.865	0.925	0.865	
C	0.930	0.930	0.925	0.975	0.930	
D	0.720	0.710	0.725	0.710	0.710	
E	0.920	0.940	0.965	0.980	0.980	0.9016
						0.1102

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	17.8	17.6	17.9	17.9	17.8	
B	32.2	32.3	32.3	32.2	32.2	
C	16.7	16.8	16.7	16.7	16.8	
D	8.7	8.5	8.8	8.8	8.8	
E	14.3	14.1	14.2	14.3	14.4	17.948
						7.9578

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	0	1	2	2	1	1.2
Partially filled	13	9	8	7	8	9
Empty	0	3	3	4	4	2.8

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Travers

Group: B Data Point: Baseline

SCALE: 20 Div. 13.780 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A 13.280	0.800	0.780	0.760	0.780	0.765	
B 6.120	0.750	0.780	0.710	0.700	0.700	
C 6.800	0.520	0.570	0.580	0.580	0.550	
D 3.440	0.580	0.575	0.530	0.525	0.540	
E 11.650	0.565	0.540	0.510	0.515	01520	0.629
						0.1072

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	24.8	24.9	24.7	24.7	24.8	
B	17.4	17.4	17.3	17.4	17.4	
C	7.4	7.5	7.4	7.5	7.4	
D	6.7	6.9	6.9	6.8	6.7	
E	13.7	13.6	13.6	13.8	13.7	14.016
						0.6104

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	1	4	4	3	3	3
Partially filled	23	20	20	17	17	19.4
Empty	0	0	0	0	0	

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Travers

Group: B Data Point: 3/12

SCALE: 20 Div. 13.800 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	0.970	0.960	0.975	1.010	0.980	
B	0.740	0.700	0.765	0.720	0.740	
C	0.670	0.600	0.615	0.630	0.615	
D	0.440	0.490	0.490	0.480	0.480	
E	0.620	0.650	0.665	0.615	0.635	6.902
						0.1708

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	8.3	8.6	8.5	8.4	8.4	
B	16.8	16.5	16.6	16.7	16.8	
C	9.2	8.9	9.0	9.1	8.9	
D	7.7	7.5	7.6	7.6	7.6	
E	14.5	14.7	14.7	14.6	14.6	11.272
						3.7383

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	6	5	6	2	2	4.2
Partially filled	22	23	22	26	26	23.8
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Warren

Group: B Data Point: Baseline

SCALE: 20 Div. 13.795 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A 2.120	0.780	0.785	0.800	0.835	0.820	
B 1.110	0.980	0.975	1.000	0.970	0.980	
C 3.200	0.665	0.700	0.675	0.680	0.665	
D 2.810	1.225	1.225	1.210	1.220	1.225	
E 1.350	0.960	0.970	0.965	0.975	0.960	

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	14.8	15.1	15.3	15.1	15.0	
B	17.8	17.7	17.9	17.9	17.8	
C	13.1	13.0	13.2	13.0	13.1	
D	17.9	17.7	18.0	18.0	17.9	
E	13.2	13.6	13.6	13.3	13.2	15.448
						2.1290

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	2	1	2	1	2	1.6
Partially filled	11	13	12	12	12	12
Empty	1	0	0	1	0	0.4

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Warren

Group: B Data Point: 3/12

SCALE: 20 Div. 13.790 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A as base	0.880	0.830	0.920	0.835	0.840	
B	0.625	0.665	0.690	0.710	0.630	
C	0.750	0.725	0.710	0.765	0.750	
D	0.820	0.800	0.815	0.800	0.835	
E	0.685	0.730	0.715	0.700	0.690	0.7566
						0.0776

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	23.2	23.3	23.1	23.2	23.1	
B	18.8	18.6	18.9	18.9	18.8	
C	12.5	12.4	12.6	12.6	12.5	
D	17.4	17.4	17.5	17.4	17.4	
E	14.4	14.4	14.3	14.5	14.4	17.264
						3.7672

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	0	0	0	0	0	0
Partially filled	13	15	15	16	18	15.4
Empty	5	3	3	2	0	2.6

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Warren

Group: B Data Point: 6/12

SCALE: 20 Div. 13.795 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A as base	0.630	0.610	0.665	0.650	0.610	
B	0.670	0.730	0.690	0.765	0.710	
C	0.710	0.740	0.695	0.680	0.715	
D	0.525	0.575	0.615	0.590	0.595	
E	0.830	0.840	0.885	0.925	0.870	7.008
						0.1041

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	13.9	14.1	14.0	14.0	13.8	
B	18.8	18.9	18.7	18.9	18.9	
C	14.4	13.9	14.0	14.2	14.4	
D	18.1	18.2	18.2	18.1	18.2	
E	13.4	12.9	13.4	13.3	13.3	15.684
						2.3822

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	0	2	3	3	3	2.2
Partially filled	11	12	11	11	10	11.0
Empty	0	1	1	1	2	1

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Wightman

Group: B

Data Point: Baseline

SCALE: 20 Div. 13.780 cm.

1) DIAMETERS

REFERENCE		1	2	3	4	5	mean / Std. Dev.
A	4.350	0.490	0.490	0.540	0.515	0.530	
B	3.850	0.560	0.490	0.565	0.560	0.570	
C	2.700	0.765	0.720	0.740	0.700	0.690	
D	2.840	0.890	0.820	0.835	0.840	0.830	
E	1.1700	0.720	0.735	0.720	0.740	0.720	0.671
							0.1274

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	14.8	14.9	14.7	14.7	14.9	
B	18.8	18.4	18.6	18.6	18.7	
C	17.5	17.5	17.5	17.4	17.5	
D	13.5	13.4	13.5	13.6	13.5	
E	14.6	14.4	14.6	14.4	14.5	15.78
						1.9786

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	2	3	2	4	3	2.8
Partially filled	9	8	10	8	8	8
Empty	3	3	2	4	3	8

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Wightman

Group: B

Data Point: 3/12

SCALE: 20 Div. 13.775 cm.

1) DIAMETERS

REFERENCE		1	2	3	4	5	mean / Std. Dev.
A	as base	0.765	0.725	0.730	0.765	0.760	
B		0.920	0.880	0.895	0.880	0.930	
C		0.760	0.770	0.790	0.790	0.795	
D		1.020	1.010	1.030	1.045	1.015	
E		1.120	1.170	1.140	1.145	1.135	0.9194
							0.1516

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	12.5	12.4	12.3	12.4	12.4	
B	18.9	19.1	19.1	18.9	18.9	
C	23.5	23.5	23.4	23.4	23.5	
D	17.4	17.8	17.8	17.6	17.6	
E	17.7	17.6	17.8	17.6	17.6	17.988
						3.5992

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	1	0	1	0	0	0.4
Partially filled	10	11	10	9	9	9.8
Empty	0	0	0	2	2	0.8

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OPTICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Yates

Group: B

Data Point: Baseline

SCALE: 20 Div. 13.770 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A 1.300	1.000	1.050	1.065	1.065	1.000	
B 1.450	1.525	1.520	1.580	1.595	1.520	
C 10.275	0.920	0.930	0.965	0.965	0.925	
D 1.675	0.640	0.680	0.680	0.665	0.670	
E 5.330	1.160	1.140	1.100	1.100	1.125	1.0634
						0.2938

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	8.2	8.1	8.3	8.4	8.2	
B	14.5	14.4	14.5	14.5	14.5	
C	12.7	12.7	12.5	12.8	12.8	
D	6.4	6.3	6.5	6.4	6.4	10.455
E						3.3489

3) ENCORGEMENT

Classification	1	2	3	4	5	
Filled	0	0	0	0	0	0
Partially filled	9	9	7	7	9	8.2
Empty	0	0	2	2	0	0.8

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OPTICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Yates

Group: B

Data Point: 3/12

SCALE: 20 Div. 13.780 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A as base	1.220	1.240	1.185	1.180	1.195	
B	1.030	1.040	1.065	1.010	1.030	
C	1.030	1.055	0.980	0.985	1.030	
D	0.820	0.890	0.825	0.820	0.820	
E	1.270	1.285	1.210	1.215	1.185	1.0646
						0.1497

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	15.0	15.1	14.9	14.9	15.1	
B	28.4	28.8	28.6	28.6	28.7	
C	23.8	24.2	24.0	23.9	24.0	
D	17.8	17.4	17.7	17.5	17.6	
E						21.3

3) ENCORGEMENT

5.8422

Classification	1	2	3	4	5	
Filled	0	0	0	0	1	0.2
Partially filled	13	12	12	13	12	12.4
Empty	0	1	1	0	0	0.4

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OPTICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Yates

Group: B

Data Point: 6/12

SCALE: 20 . Div. 13.765 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	1.140	1.150	1.180	1.115	1.140	
B	1.110	1.135	1.100	1.165	1.150	
C	0.885	0.830	0.825	0.815	0.800	
D	0.815	0.810	0.800	0.810	0.815	
E	1.135	1.095	1.090	1.130	1.110	1.006
						0.1565

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	14.8	14.6	14.9	14.8	14.9	
B	14.4	13.9	13.9	14.3	14.2	
C	14.3	14.4	14.4	14.3	14.3	
D	8.8	8.6	8.8	8.8	8.9	
E						13.015
						2.5240

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	2	1	2	2	2	1.8
Partially filled	8	10	8	6	6	7.6
Empty	1	0	1	3	3	1.6

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OPTICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Arnold

Group: A

Data Point: Baseline

SCALE: 20 Div. 13.720 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A 9.360	0.720	0.680	0.645	0.850	0.790	
B 9.270	0.715	0.710	0.720	0.980	0.895	
C 9.930	0.730	0.710	0.740	0.900	0.920	
D 12.000	0.450	0.455	0.460	0.590	0.620	
E 5.050	0.545	0.520	0.470	0.580	0.610	0.6802
						0.1523

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	22.9	23.0	22.8	23.1	23.1	
B	17.3	17.3	17.4	17.4	17.3	
C	13.8	13.6	13.7	13.8	13.9	
D	18.5	18.4	18.7	18.6	18.7	
E	15.0	15.1	15.1	15.2	15.2	17.556
						3.256

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	5	4	6	7	5	5.4
Partially filled	8	9	8	7	8	8
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Arnold

Group: A

Data Point: 3/12

SCALE: 20 Div. 13.735 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A 9.360	0.595	0.600	0.590	0.640	0.685	
B 9.270	0.730	0.690	0.720	0.760	0.790	
C 9.930	0.600	0.625	0.685	0.690	0.745	
D 12.000	0.520	0.545	0.580	0.590	0.630	
E 5.050	0.345	0.375	0.390	0.560	0.510	0.6116
						0.1230

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	20.4	20.7	20.6	20.6	20.7	
B	17.3	17.5	17.5	17.4	17.4	
C	13.4	13.4	13.5	13.4	13.6	
D	16.9	17.0	16.8	16.9	16.8	
E	12.2	12.4	12.5	12.6	12.6	16.164
						2.9879

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	3	4	2	2	2	2.6
Partially filled	12	11	14	13	14	12.8
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Arnold

Group: A

Data Point: 6/12

SCALE: 20 Div. 13.715 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A As Base	0.590	0.580	0.670	0.680	0.700	
B	0.890	0.830	0.890	0.890	0.910	
C	0.520	0.540	0.550	0.600	0.650	
D	0.590	0.550	0.600	0.620	0.640	
E	0.590	0.600	0.700	0.720	0.730	0.6732
						0.1208

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	16.7	16.8	16.8	17.0	16.9	
B	12.8	13.0	13.1	12.9	13.0	
C	12.8	12.9	12.8	12.7	12.6	
D	17.1	17.2	17.4	17.3	17.4	
E	10.9	10.8	10.9	10.7	10.9	14.136
						2.5572

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	1	1	2	2	0	1.2
Partially filled	13	13	12	12	14	12.8
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Besley

Group: A

Data Point: Baseline

SCALE: 20 Div. 13.800 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A 8.995	0.280	0.290	0.345	0.350	0.400	
B 11.000	0.590	0.550	0.570	0.590	0.680	
C 4.000	0.655	0.680	0.675	0.850	0.680	
D 11.090	0.340	0.340	0.550	0.525	0.550	
E 3.000	0.610	0.800	0.600	0.850	0.800	0.566
						0.1731

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	16.5	16.4	16.6	16.8	16.8	
B	17.4	17.5	17.6	17.4	17.6	
C	7.5	7.3	7.5	7.7	7.5	
D	14.8	14.4	14.5	14.4	14.5	
E	14.4	14.6	14.3	14.4	14.3	14.108
						3.5888

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	6	5	5	4	6	5.2
Partially filled	13	14	14	15	13	13.8
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Besley

Group: A

Data Point: 3/12

SCALE: 20 Div. 13.795 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A as base	0.450	0.460	0.535	0.580	0.540	
B	0.665	0.640	0.650	0.720	0.735	
C	0.890	0.860	0.875	0.820	0.870	
D	0.930	0.865	0.900	1.020	0.960	
E	0.600	0.640	0.720	0.725	0.720	0.7348
						0.1590

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	19.3	19.1	19.4	19.3	19.4	
B	23.2	23.2	23.1	22.9	22.9	
C	11.5	11.5	11.3	11.1	11.6	
D	26.3	26.1	26.2	26.3	26.1	
E	16.5	16.3	16.4	16.5	16.4	19.276
						5.2545

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	1	3	2	1	3	2
Partially filled	15	13	14	15	13	14
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Besley

Group: A

Data Point: 6/12

SCALE: 20 Div. 13.790 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	0.600	0.665	0.650	0.740	0.720	
B	0.530	0.560	0.580	0.560	0.595	
C	1.010	0.965	0.980	0.990	1.020	
D	0.910	0.965	0.930	0.950	0.960	
E	0.660	0.690	0.620	0.750	0.780	0.7752
						0.1724

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	20.4	20.1	20.2	20.2	20.1	
B	23.1	23.4	22.9	23.2	23.2	
C	17.6	17.8	17.9	17.2	17.2	
D	26.6	26.6	26.7	26.7	26.7	
E	17.8	17.6	17.6	17.9	17.9	21.072
						3.5388

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	2	1	2	0	1	1.2
Partially filled	10	10	9	12	11	10.4
Empty	0	1	1	0	0	0.4

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Clayphan

Group: A

Data Point: Baseline

SCALE: 20 Div. 13.780 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A 6.000	0.730	0.515	0.710	0.750	0.730	
B 8.000	0.440	0.525	0.440	0.465	0.430	
C 5.200	0.610	0.600	0.610	0.680	0.630	
D 6.700	0.450	0.465	0.470	0.520	0.540	
E 10.000	0.460	0.495	0.535	0.590	0.540	

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	14.7	15.0	14.6	14.9	15.0	
B	12.9	13.2	13.1	13.0	13.0	
C	12.5	12.4	12.5	12.7	12.3	
D	7.1	7.0	7.3	7.2	7.2	
E	12.6	12.4	12.9	12.7	12.8	12.04
						2.6360

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	6	2	2	6	6	4.4
Partially filled	16	20	20	16	16	17.6
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Clayphon

Group: A

Data Point: 3/12

SCALE: 20 Div. 13.780 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	0.610	0.650	0.655	0.720	0.740	
B	0.484	0.550	0.560	0.600	0.570	
C	0.600	0.660	0.625	0.700	0.650	
D	0.520	0.484	0.510	0.600	0.530	
E	0.625	0.640	0.645	0.685	0.685	0.6120
						0.0714

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	11.2	11.3	11.2	11.1	11.2	
B	14.2	14.3	14.2	14.0	14.2	
C	12.5	12.3	12.9	12.5	12.6	
D	9.1	8.9	9.3	9.1	9.1	
E	11.7	11.8	11.8	11.7	11.8	11.760
						1.7051

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	7	3	3	9	9	6.2
Partially filled	21	25	25	19	19	21.8
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Clayphon

Group: A

Data Point: 6/12

SCALE: 20 Div. 13.780 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	0.500	0.530	0.535	0.590	0.530	
B	0.360	0.340	0.400	0.380	0.370	
C	0.465	0.485	0.610	0.620	0.510	
D	0.880	0.900	0.905	0.935	0.895	
E	0.740	0.775	0.800	0.865	0.830	0.6296
						0.2026

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	13.8	13.7	13.4	13.8	13.7	
B	11.5	11.2	11.3	11.4	11.2	
C	12.0	12.2	11.9	12.1	12.1	
D	10.3	10.2	10.4	10.0	10.3	
E	19.7	20.0	20.1	19.7	19.9	13.46
						3.4612

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	6	7	6	8	5	6.4
Partially filled	22	21	21	18	22	20.8
Empty	0	0	1	0	1	0.4

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Cotton T

Group: A

Data Point: Baseline

SCALE: 20 Div. 13.675 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A 1.740	0.400	0.425	0.490	0.500	0.500	
B 1.400	0.575	0.600	0.620	0.595	0.600	
C 3.550	0.565	0.500	0.580	0.560	0.576	
D 12.700	0.565	0.590	0.585	0.615	0.600	
E 1.730	0.755	0.790	0.800	0.865	0.800	0.602
						0.1171

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	8.1	7.9	7.9	8.0	8.0	
B	8.3	8.1	8.2	8.1	8.3	
C	12.7	13.1	13.3	12.9	12.9	
D	6.4	6.6	6.3	6.5	6.6	
E	6.3	6.1	6.2	6.3	6.1	8.368
						2.4912

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	3	2	1	2	2	2
Partially filled	8	9	10	9	9	9
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Cotton T

Group: A

Data Point: 3/12

SCALE: 20 Div. 13.660 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A as base	0.770	0.790	0.890	0.810	0.800	
B	0.450	0.465	0.500	0.525	0.560	
C	0.790	0.810	0.585	0.830	0.835	
D	0.495	0.510	0.545	0.560	0.550	
E	0.685	0.625	0.680	0.740	0.690	0.6596
						0.1385

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	12.0	12.1	12.1	12.2	12.0	
B	9.8	9.7	9.8	9.7	9.8	
C	14.9	15.1	15.1	15.0	14.9	
D	7.4	7.3	7.4	7.1	7.4	
E	6.5	6.6	6.6	6.5	6.7	10.148
						3.1684

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	3	3	2	1	3	2.4
Partially filled	11	11	12	13	11	11.6
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Cotton T

Group: A Data Point: 6/12

SCALE: 20 Div. 13.690 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	0.685	0.675	0.730	0.680	0.675	
B	0.745	0.825	0.850	0.885	0.850	
C	0.665	0.690	0.740	0.700	0.710	
D	0.480	0.430	0.445	0.385	0.460	
E	0.765	0.715	0.775	0.750	0.745	0.6822
						0.1373

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	11.2	11.1	11.2	11.0	11.2	
B	8.8	8.6	8.7	8.6	8.7	
C	13.2	13.1	13.2	13.3	13.2	
D	6.9	6.8	6.8	6.9	6.9	
E	10.8	10.7	11.2	10.7	10.8	10.144

3) ENGORGEMENT 2.2265

Classification	1	2	3	4	5	
Filled	6	5	5	4	5	5
Partially filled	6	7	7	8	7	7
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Duncan

Group: A Data Point: Baseline

SCALE: 20 Div. 13.710 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A 6.500	0.700	0.790	0.810	0.840	0.795	
B 7.770	0.985	0.990	1.060	1.090	0.900	
C 8.800	0.680	0.620	0.630	0.600	0.590	
D 9.780	0.400	0.440	0.500	0.510	0.490	
E 11.000	0.485	0.520	0.530	0.475	0.480	0.6764
						0.2081

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	19.2	19.1	19.3	19.2	19.1	
B	13.4	13.5	13.3	13.4	13.4	
C	20.6	20.7	20.8	20.4	20.6	
D	18.5	18.7	18.4	18.4	18.5	
E	21.9	22.0	21.8	21.8	21.9	18.716

3) ENGORGEMENT 2.9651

Classification	1	2	3	4	5	
Filled	3	5	2	3	3	3.2
Partially filled	18	16	19	18	18	17.8
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Duncan

Group: A

Data Point: 3/12

SCALE: 20 Div. 13.720 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A as base	0.600	0.625	0.675	0.640	0.645	
B	0.980	0.975	1.000	1.020	1.080	
C	0.860	0.900	0.820	0.875	0.850	
D	0.600	0.520	0.500	0.515	0.465	
E	0.570	0.610	0.600	0.625	0.590	0.7256
						0.1894

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	19.2	19.1	19.3	19.1	19.3	
B	26.4	26.6	26.3	26.3	26.4	
C	22.2	22.3	22.0	22.3	22.2	
D	18.4	18.3	18.1	18.2	18.4	
E	16.2	16.0	16.1	16.1	16.2	0.2044
						3.6382

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	4	3	3	5	4	3.8
Partially filled	15	16	16	14	15	15.2
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Duncan

Group: A

Data Point: 6/12

SCALE: 20 Div. 13.700 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A as base	0.480	0.550	0.510	0.550	0.490	
B	0.950	1.030	1.090	0.990	1.010	
C	0.865	0.910	0.950	0.980	0.930	
D	0.575	0.550	0.520	0.500	0.530	
E	0.475	0.465	0.420	0.500	0.460	0.6912
						0.2382

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	19.7	19.6	19.8	19.9	19.9	
B	24.3	24.1	24.1	24 4	24.3	
C	22.0	21.8	21.9	22.1	22.1	
D	14.0	14.2	14.1	13.8	13.9	
E	21.6	21.1	21.1	21.2	21.3	20.256
						3.5162

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	7	7	5	4	5	5.6
Partially filled	11	11	13	14	12	12.2
Empty	1	1	2	2	2	1.6

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Gatward

Group: A

Data Point: Baseline

SCALE: 20 Div. 13.730 cm.

1) DIAMETERS

REFERENCE		1	2	3	4	5	mean / Std. Dev.
A	2.000	0.310	0.320	0.365	0.400	0.365	
B	2.080	0.480	0.495	0.535	0.500	0.485	
C	1.260	0.710	0.750	0.665	0.660	0.700	
D	5.420	0.825	0.790	0.810	0.855	0.860	
E	5.370	0.480	0.545	0.550	0.560	0.565	0.5832
							0.1704

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	6.9	7.3	7.4	7.5	7.3	
B	5.1	4.9	5.0	5.1	5.2	
C	6.6	6.4	6.7	6.6	6.7	
D	11.2	11.3	11.1	11.3	11.2	
E	9.4	9.7	9.7	9.8	9.7	7.964
						2.2512

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	6	5	5	6	6	5.6
Partially filled	9	10	10	9	9	9.4
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Gatward

Group: A

Data Point: 3/12

SCALE: 20 Div. 13.715 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A as base	0.660	0.675	0.595	0.695	0.675	
B	0.575	0.515	0.615	0.580	0.575	
C	0.810	0.810	0.795	0.800	0.775	
D	0.690	0.740	0.735	0.760	0.760	
E	0.495	0.600	0.585	0.610	0.595	0.6688
						0.09574

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	12.1	12.3	12.1	12.3	12.1	
B	11.9	12.1	12.3	12.0	12.1	
C	9.3	9.0	9.2	9.3	9.0	
D	11.3	11.3	11.4	11.3	11.4	
E	10.6	10.7	10.2	10.1	10.1	11.02
						1.17331

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	8	8	9	10	9	8.8
Partially filled	6	6	5	4	5	5.2
Empty	1	1	1	1	1	1

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Gatward

Group: A Data Point: 6/12

SCALE: 20 Div. 13.740 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	0.560	0.535	0.620	0.565	0.560	
B	0.770	0.820	0.810	0.840	0.800	
C	0.850	0.785	0.760	0.800	0.850	
D	0.910	0.925	0.920	0.910	0.925	
E	0.385	0.425	0.490	0.500	0.485	0.712
						0.1776

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	12.1	12.2	12.3	12.2	12.3	
B	13.7	13.6	13.7	13.7	13.8	
C	8.4	8.3	8.5	8.5	8.3	
D	11.3	11.0	11.0	11.1	11.0	
E	9.8	9.7	9.9	9.8	9.8	11.04
						1.8826

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	5	4	5	7	5	5.2
Partially filled	20	21	20	18	20	19.8
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Gregory

Group: A Data Point: Baseline

SCALE: 20 Div. 13.690 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A 4.300	0.875	0.830	0.880	0.825	0.840	
B 3.700	1.345	1.240	1.320	1.375	1.350	
C 3.900	0.860	0.825	0.810	0.800	0.860	
D 3.950	0.770	0.700	0.780	0.760	0.750	
E 3.920	0.075	0.935	0.980	1.020	1.000	0.9522
						0.2109

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	10.2	1.01	10.0	10.2	10.2	
B	13.2	13.0	13.1	13.3	13.2	
C	19.8	20.1	20.2	19.9	20.2	
D	16.9	17.3	17.1	17.2	17.0	
E	17.5	17.4	17.4	17.5	17.4	15.576
						3.5700

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	2	1	1	1	1	1.2
Partially filled	10	11	11	10	10	10.4
Empty	0	0	0	1	1	0.4

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Gregory

Group: A Data Point: 3/12

SCALE: 20 Div. 13.700 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	0.870	0.945	0.830	0.865	0.870	
B	1.200	1.290	1.310	1.295	1.290	
C	0.535	0.630	0.600	0.595	0.580	
D	0.600	0.625	0.635	0.610	0.630	
E	0.715	0.690	0.710	0.695	0.700	0.8125
						0.2596

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	12.0	12.1	11.9	11.9	12.1	
B	12.4	12.5	12.5	12.3	12.3	
C	21.2	20.9	21.1	20.9	21.0	
D	19.9	20.0	20.1	19.9	19.8	
E	19.1	19.3	19.0	19.0	19.1	16.892
						3.9625

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	4	4	2	2	2	2.8
Partially filled	12	12	14	12	12	12.4
Empty	0	0	0	2	2	0.8

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Gregory

Group: A Data Point: 6/12

SCALE: 20 Div. 13.680 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	1.165	1.185	1.220	1.180	1.165	
B	1.180	1.200	1.335	1.310	1.210	
C	0.765	0.760	0.780	0.765	0.750	
D	0.720	0.780	0.785	0.765	0.760	
E	0.935	0.915	0.990	0.985	1.000	0.9842
						0.2106

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	21.7	21.5	21.7	21.8	21.8	
B	21.5	21.4	21.5	21.5	21.4	
C	22.7	22.6	22.8	22.7	22.7	
D	19.4	19.3	19.5	19.4	19.3	
E	16.8	16.7	16.6	16.6	16.6	20.372
						2.2112

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	2	2	0	2	2	1.6
Partially filled	15	15	15	13	13	14.2
Empty	0	0	2	2	2	1.2

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Groom

Group: A

Data Point: Baseline

SCALE: 20 Div. 13.685 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A 3.560	0.595	0.610	0.640	0.635	0.630	
B 3.140	0.665	0.650	0.565	0.620	0.650	
C 2.150	0.635	0.710	0.750	0.700	0.715	
D 2.630	0.490	0.560	0.490	0.510	0.495	
E 3.440	0.620	0.595	0.660	0.615	0.600	0.6162
						0.0696

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	22.2	21.7	21.9	22.2	22 1	
B	14.2	14.3	14.1	14.1	14.3	
C	11.0	11.1	10.9	10.9	11.1	
D	8.4	8.3	8.4	8.5	8.4	
E	4.7	4.6	4.7	4.7	4.6	12.056
						6.0055

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	4	4	4	4	4	4
Partially filled	11	11	11	11	11	11
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Groom

Group: A

Data Point: 3/12

SCALE: 20 Div. 13.670 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	0.520	0.425	0.465	0.470	0.475	
B	0.620	0.625	0.600	0.615	0.630	
C	0.685	0.515	0.650	0.665	0.615	
D	0.475	0.415	0.460	0.470	0.530	
E	0.765	0.710	0.695	0.710	0.680	0.5834
						0.1031

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	21.1	21.2	21.0	21.1	21.0	
B	16.9	16.8	16.9	16.9	16.7	
C	11.2	11.1	11.2	11.3	11.1	
D	14.7	14.6	14.8	14.6	14.8	
E	11.6	11.5	11.6	11.5	11.5	15.068
						5.7363

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	5	6	3	4	5	4.6
Partially filled	11	10	13	12	11	11.4
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Groom

Group: A

Data Point: 6/12

SCALE: 20 Div. 13.675 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A as base	0.660	0.690	0.660	0.650	0.670	
B	0.830	0.765	0.795	0.970	0.790	
C	0.935	0.930	0.875	0.870	0.935	
D	0.600	0.625	0.690	0.630	0.690	
E	0.630	0.655	0.660	0.720	0.655	0.7392
						0.1099

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	15.7	15.6	15.8	15.8	15.7	
B	19.4	19.3	19.5	19.3	19.4	
C	18.2	18.1	18.3	18.1	18.1	
D	15.2	15.3	15.3	15.3	15.3	
E	11.6	11.5	11.3	11.6	11.7	16.012
						2.7630

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	4	4	3	5	5	4.2
Partially filled	11	11	11	10	9	10.4
Empty	1	1	1	1	2	1.2

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Higgerson

Group: A

Data Point: Baseline

SCALE: 20 Div. 13.670 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A 1.800	0.685	0.700	0.745	0.760	0.710	
B 2.850	0.420	0.550	0.510	0.490	0.500	
C						
D						
E						0.607
						0.1249

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	7.9	7.8	8.1	8.0	7.9	
B						
C						
D						
E						7.94
						0.1140

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	0	0	1	1	1	0.6
Partially filled	8	8	7	7	7	7.4
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Higgerson

Group: A

Data Point: 3/12

SCALE: 20 Div. 13.680 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A as base	0.630	0.600	0.635	0.610	0.620	
B	0.640	0.640	0.620	0.620	0.695	
C						
D						
E						0.631
						0.2590

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	10.4	10.3	9.8	9.9	10.1	
B						
C						
D						10.1
E						0.2549

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	0	0	0	0	0	0
Partially filled	11	11	11	11	11	11
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Higgerson

Group: A

Data Point: 6/12

SCALE: 20 Div. 13.650 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A as base			EMPTY			
B	0.620	0.635	0.610	0.595	0.615	
C						
D						
E						0.3075
						0.3242

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	7.8	7.7	8.0	7.9	7.9	
B						
C						
D						
E						7.86

3) ENGORGEMENT 0.

Classification	1	2	3	4	5	
Filled	0	0	0	0	0	0
Partially filled	10	10	10	10	10	10
Empty	1	1	1	1	1	

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Hinton

Group: A

Data Point: Baseline

SCALE: 20 Div. 13.760 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A 7.840	0.570	0.630	0.625	0.630	0.620	
B 4.300	0.550	0.530	0.570	0.565	0.530	
C 8.350	0.765	0.720	0.760	0.780	0.760	
D 7.430	0.480	0.565	0.495	0.510	0.495	
E 8.650	0.660	0.595	0.680	0.600	0.660	0.6144
						0.0928

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	15.5	15.7	15.6	15.4	15.5	
B	8.3	8.2	8.4	8.3	8.3	
C	12.5	12.4	12.8	12.7	12.6	
D	11.3	11.4	11.5	11.3	11.2	
E	14.2	14.1	14.2	14.1	14.2	12.388
						2.5404

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	4	2	3	2	2	2.6
Partially filled	13	15	14	15	13	1.4
Empty	1	1	1	2	3	1.6

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Hinton

Group: A

Data Point: 3/12

SCALE: 20 Div. 13.775 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	0.560	0.525	0.580	0.565	0.560	
B	0.440	0.420	0.570	0.515	0.560	
C	0.645	0.635	0.680	0.615	0.630	
D	0.570	0.585	0.525	0.510	0.540	
E	0.745	0.735	0.650	0.660	0.665	0.5874
						0.0798

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	16.1	15.9	15.7	15.9	16.0	
B	8.1	8.2	8.0	8.1	8.1	
C	12.7	12.6	12.4	12.5	12.6	
D	11.8	11.4	11.6	11.8	11.8	
E	14.3	14.2	14.3	14.3	14.2	12.504
						2.6960

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	5	4	4	4	4	4.2
Partially filled	10	11	11	9	9	1.0
Empty	1	1	1	3	3	1.8

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Hudman

Group: A

Data Point: baseline

SCALE: 20 Div. 13.770 cm.

1) DIAMETERS

REFERENCE		1	2	3	4	5	mean Std. Dev.
A	4.900	0.920	0.875	0.930	0.895	0.910	
B	2.760	0.575	0.445	0.545	0.530	0.510	
C	3.860	1.220	1.340	1.270	1.200	1.205	
D	3.550	1.290	1.390	1.340	1.320	1.315	
E	3.000	0.415	0.420	0.480	0.440	0.430	0.8862
							0.3761

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	8.8	8.6	8.9	8.9	8.8	
B	12.1	12.3	11.9	11.9	12.0	
C	27.5	27.3	27.6	27.5	27.5	
D	25.1	25.0	25.2	25.2	25.0	
E	13.7	13.6	13.8	13.7	13.7	17.424

3) ENGORGEMENT 7.6011

Classification	1	2	3	4	5	
Filled	2	2	1	1	2	1.6
Partially filled	8	9	9	10	9	9
Empty	3	2	3	2	2	2.4

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Hudman

Group: A

Data Point: 3/12

SCALE: 20 Div. 13.720 cm.

1) DIAMETERS

REFERENCE		1	2	3	4	5	mean Std. Dev.
A	as base	0.910	0.830	0.940	0.900	0.915	
B		0.700	0.720	0.810	0.765	0.700	
C		1.195	1.115	1.120	1.105	1.105	
D		1.020	0.980	0.995	1.035	1.040	
E		0.680	0.725	0.760	0.695	0.725	0.8994
							0.1645

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	21.7	21.6	21.8	21.7	21.7	
B	15.9	15.8	15.9	16.1	15.9	
C	24.5	24.3	24.6	24.6	24.5	
D	16.5	16.7	16.6	16.5	16.6	
E	15.4	15.6	15.3	15.4	15.4	18.812

3) ENGORGEMENT 3.7067

Classification	1	2	3	4	5	
Filled	3	3	1	3	1	2.2
Partially filled	10	10	12	10	12	10.8
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Hudmon

Group: A

Data Point: 6/12

SCALE: 20 Div. 13.745 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	1.080	1.150	1.170	1.100	1.100	
B	0.430	0.485	0.485	0.460	0.430	
C	1.245	1.370	1.310	1.265	1.295	
D	1.385	1.390	1.465	1.460	1.450	
E	0.780	0.790	0.865	0.870	0.810	1.0256
						0.3581

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	14.1	13.9	14.2	14.0	14.1	
B	17.5	17.2	17.9	17.9	17.9	
C	21.5	21.3	21.6	21.6	21.4	
D	24.3	24.1	24.2	24.1	24.4	
E	18.6	18.4	18.7	18.7	18.5	19.204

3) ENGORGEMENT 3.5250

Classification	1	2	3	4	5	
Filled	4	3	1	1	1	2
Partially filled	9	10	7	7	7	8
Empty	0	0	2	2	2	1.2

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Joyce

Group: A

Data Point: Baseline

SCALE: 20 Div. 13.740 cm.

1) DIAMETERS

REFERENCE		1	2	3	4	5	mean Std. Dev.
A	3.150	0.510	0.620	0.510	0.535	0.540	
B	10.950	0.715	0.730	0.780	0.765	0.755	
C	5.530	0.910	0.930	9.000	0.915	0.935	
D	3.600	0.880	0.900	0.830	0.845	0.830	
E	6.150	0.480	0.540	0.550	0.520	0.540	0.7186
							0.1655

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	20.7	20.4	20.7	20.8	20.7	
B	19.4	19.1	19.4	19.5	19.4	
C	10.0	10.1	10.0	9.9	10.0	
D	14.3	14.2	14.4	14.4	14.3	
E	13.6	13.5	13.5	13.8	13.6	15.588

3) ENGORGEMENT 3.9999

Classification	1	2	3	4	5	
Filled	2	1	1	1	1	1.2
Partially filled	10	11	11	11	11	10.8
Empty	0	0	0	0	0	

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Joyce

Group: A

Data Point: 3/12

SCALE: 20 Div. 13.730 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	0.980	0.910	1.000	0.975	0.960	
B	0.400	0.390	0.525	0.570	0.415	
C	0.870	0.810	0.835	0.830	0.815	
D	0.910	0.925	0.930	0.975	0.935	
E	0.700	0.610	0.635	0.620	0.625	0.7632
						0.2024

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	16.1	16.7	16.6	16.2	16.1	
B	22.2	21.9	22.5	22.3	22.2	
C	16.3	16.1	16.4	16.3	16.2	
D	20.6	20.5	20.4	20.7	20.6	
E	18.0	18.1	18.2	18.1	18.2	18.7
						2.4083

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	0	1	1	1	1	0.8
Partially filled	11	8	9	9	8	9
Empty	0	2	1	1	2	1.2

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Joyce

Group: A

Data Point: 6/12

SCALE: 20 Div. 13.755 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	0.630	0.620	0.640	0.635	0.625	
B	0.610	0.635	0.665	0.600	0.675	
C	0.760	0.720	0.715	0.740	0.735	
D	1.000	1.050	1.100	1.075	0.050	
E	0.550	0.595	0.625	0.595	0.570	0.7286
						0.1758

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	18.4	18.3	18.1	18.4	18.4	
B	23.7	23.6	23.8	23.7	23.7	
C	15.8	15.7	15.8	15.9	15.7	
D	16.4	16.3	16.5	16.4	16.5	
E	14.9	15.0	15.5	15.2	15.3	17.88
						3.1613

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	2	1	2	2	2	1.8
Partially filled	11	10	11	11	11	10.8
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Longstreth

Group: A Data Point: baseline

SCALE: 20 Div. 13.775 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A 5.230	0.920	0.980	0.970	0.920	0.925	
B 1.780	0.725	0.700	0.740	0.725	0.715	
C 4.660	0.895	0.940	0.945	0.870	0.895	
D 2.450	0.575	0.540	0.570	0.535	0.535	
E 5.920	0.815	0.850	0.840	0.855	0.835	0.7926
						0.1472

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	9.3	9.2	9.4	9.4	9.3	
B	3.8	3.6	3.9	3.6	3.6	
C	12.6	12.8	12.7	12.5	12.6	
D	11.6	11.8	11.5	11.5	11.8	
E	7.3	7.4	7.4	7.6	7.3	8.94
						3.260

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	1	0	2	3	3	0.45
Partially filled	10	11	9	7	7	8.8
Empty	0	0	0	1	1	0.2

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Longstreth

Group: A Data Point: 3/12

SCALE: 20 Div. 13.745 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	0.780	0.790	0.715	0.785	0.775	
B	0.625	0.630	0.640	0.635	0.630	
C	0.715	0.730	0.770	0.685	0.715	
D	1.000	0.980	0.975	0.980	1.000	
E	0.610	0.590	0.580	0.605	0.595	0.7414
						0.1416

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	10.8	10.7	10.9	11.0	10.7	
B	11.0	11.3	10.9	10.9	11.0	
C	15.8	16.0	15.7	15.7	15.8	
D	13.4	13.5	13.3	13.3	13.4	
E	15.3	15.5	15.1	15.1	15.5	13.256
						2.1350

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	2	3	2	2	2	2.2
Partially filled	13	12	13	10	11	11.8
Empty	0	0	0	2	2	0.8

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Lynam

Group: A

Data Point: Baseline

SCALE: 20 Div. 13.825 cm.

1) DIAMETERS

REFERENCE		1	2	3	4	5	mean Std. Dev.
A	3.000	0.660	0.675	0.650	0.656	0.685	
B	3.150	0.640	0.610	0.675	0.660	0.645	
C	2.050	0.970	0.985	1.000	0.950	0.950	
D	0.900	0.900	0.915	0.870	0.920	0.915	
E	7.430	0.800	0.800	0.815	0.830	0.785	0.7984
							0.1319

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	7.4	7.3	7.1	7.6	7.4	
B	11.8	11.7	11.8	11.9	11.8	
C	7.9	8.0	8.0	7.8	7.9	
D	11.7	11.6	11.8	11.6	11.7	
E	11.3	11.2	11.4	11.4	11.3	10.016
						1.9972

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	1	1	2	2	1	1.4
Partially filled	16	16	15	15	16	15.6
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Lynam

Group: A

Data Point: 3/12

SCALE: 20 Div. 13.850 cm.

1) DIAMETERS

REFERENCE		1	2	3	4	5	mean Std. Dev.
A	3.00	0.610	0.595	0.600	0.630	0.590	
B	3.150	0.305	0.305	0.315	0.310	0.300	
C	2.050	1.460	1.465	1.420	1.480	1.475	
D	0.900	0.880	0.885	0.865	0.860	0.895	
E	7.430	0.710	0.710	0.700	0.730	0.690	0.7914
							0.3904

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	7.6	7.7	7.7	7.8	7.7	
B	8.3	8.3	8.6	8.3	8.4	
C	7.0	7.3	7.5	7.5	7.3	
D	11.8	11.9	11.9	11.6	11.8	
E	9.0	9.1	9.1	8.9	9.0	8.844
						1.6255

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	7	6	6	7	7	6.6
Partially filled	13	14	14	13	13	13.4
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Lynam

Group: A

Data Point: 6/12

SCALE: 20 Div. 13.830 cm.

1) DIAMETERS

REFERENCE		1	2	3	4	5	mean / Std. Dev.
A	3.000	0.600	0.620	0.615	0.585	0.610	
B	3.150	0.540	0.545	0.495	0.560	0.560	
C	2.050	0.530	0.535	0.560	0.515	0.520	
D	0.900	0.460	0.485	0.435	0.440	0.455	
E	7.430	0.740	0.743	0.740	0.745	0.730	0.5745
							0.0987

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	7.7	7.6	7.5	7.8	7.7	
B	12.0	12.1	12.1	11.9	12.0	
C	7.7	7.6	7.8	7.8	7.7	
D	10.2	9.8	9.9	10.3	10.2	
E	15.3	15.2	15.4	15.4	15.3	10.56
						2.9425

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	1	1	2	1	1	1.2
Partially filled	15	15	14	15	15	14.8
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Mc Comick

Group: A

Data Point: Baseline

SCALE: 20 Div. 13.760 cm.

1) DIAMETERS

REFERENCE		1	2	3	4	5	mean / Std. Dev.
A	4.620	0.670	0.720	0.745	0.670	0.750	
B	4.640	0.790	0.860	0.865	0.815	0.830	
C	5.330	0.860	0.900	0.915	0.885	0.890	
D	1.290	0.700	0.745	0.715	0.730	0.710	
E	2.840	1.130	1.120	1.085	1.095	1.090	0.8514
							0.1483

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	11.8	11.6	11.4	11.7	11.6	
B	5.7	5.6	5.4	5.7	5.7	
C	3.7	3.6	3.7	3.7	3.8	
D	12.0	12.1	12.0	12.0	11.9	
E	15.6	15.8	15.5	15.5	15.5	9.704
						4.4779

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	4	3	3	2	3	3
Partially filled	4	5	5	6	4	5
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Mc Comick

Group: A. Data Point: 3/12

SCALE: 20 Div. 13.790 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	0.660	0.580	0.620	0.640	0.660	
B	0.675	0.675	0.700	0.660	0.650	
C	0.885	0.920	0.850	0.860	0.855	
D	0.610	0.715	0.680	0.735	0.710	
E	0.900	0.930	0.915	0.890	0.910	0.7554
						0.1190

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	10.6	10.5	10.7	10.6	10.7	
B	6.0	6.1	6.0	6.1	6.1	
C	5.1	4.9	4.9	5.3	5.3	
D	13.7	13.5	13.5	13.7	13.8	
E	14.9	15.0	15.0	14.7	14.8	10.06
						4.0060

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	9	8	6	6	7	7.2
Partially filled	3	4	6	6	5	4.8
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Newell

Group: A Data Point: baseline

SCALE: 20 Div. 13.730 cm.

1) DIAMETERS

REFERENCE		1	2	3	4	5	mean Std. Dev.
A	2.080	0.765	0.760	0.800	0.765	0.760	
B	7.170	0.680	0.700	0.670	0.610	0.685	
C	6.100	0.490	0.490	0.480	0.450	0.490	
D	2.550	0.865	0.820	0.875	0.880	0.865	
E	5.060	0.620	0.630	0.620	0.640	0.635	0.6820
							0.1344

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	5.2	5.1	5.3	5.2	5.2	
B	5.0	5.4	5.4	5.1	5.0	
C	6.2	6.2	6.3	6.1	6.2	
D	6.1	6.0	6.3	6.0	6.2	
E	5.1	5.2	4.9	5.2	5.1	5.56
						0.5155

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	6	6	4	4	6	5.2
Partially filled	8	8	10	10	8	8.8
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Newell

Group: A Data Point: 3/12

SCALE: 20 Div. 13.720 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	0.875	0.885	0.940	0.945	0.965	
B	0.915	0.940	0.950	0.930	0.35	
C	0.620	0.640	0.665	0.610	0.650	
D	0.940	0.995	1.060	1.090	1.000	
E	0.890	0.935	0.915	0.885	0.920	0.8838
						0.1355

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	9.0	9.1	9.0	8.9	8.9	
B	5.6	5.5	5.7	5.6	5.6	
C	6.4	6.4	6.6	6.8	6.6	
D	6.2	6.3	6.1	6.3	6.1	
E	8.7	8.6	8.7	8.9	8.9	7.22
						1.4159

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	7	7	5	7	5	6.2
Partially filled	7	7	9	7	9	7.8
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Newell

Group: A Data Point: 6/12

SCALE: 20 Div. 13.700 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	0.760	0.745	0.810	0.830	0.810	
B	0.765	0.735	0.840	0.820	0.795	
C	0.625	0.600	0.615	0.590	0.590	
D	1.060	1.000	1.035	1.040	1.025	
E	1.540	1.420	1.530	1.525	1.520	0.945
						0.3202

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	12.2	12.1	12.0	12.1	12.2	
B	5.7	5.6	5.7	5.8	5.8	
C	12.4	12.4	12.2	12.4	12.3	
D	7.4	7.3	7.3	7.4	7.5	
E	8.3	8.1	8.4	8.4	8.3	9.172
						2.6867

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	8	9	8	6	8	7.8
Partially filled	9	8	9	11	9	9.2
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Peters

Group: A

Data Point: Baseline

SCALE: 20 Div. 13.730 cm.

1) DIAMETERS

REFERENCE		1	2	3	4	5	mean Std. Dev.
A	5.510	0.565	0.560	0.580	0.580	0.575	
B	2.840	0.595	0.630	0.645	0.620	0.615	
C	11.150	0.515	0.525	0.540	0.550	0.550	
D	14.880	0.520	0.600	0.625	0.615	0.610	
E	5.180	0.490	0.500	0.540	0.510	0.495	0.566
							0.0467

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	13.1	13.6	13.8	13.6	13.5	
B	16.0	16.1	16.1	16.0	15.9	
C	24.5	24.3	24.6	24.6	2.45	
D	21.6	21.7	21.5	21.5	21.5	
E	7.4	7.2	7.3	7.4	7.3	16.584
						6.1751

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	2	2	2	0	0	1.2
Partially filled	21	20	20	20	20	20.2
Empty	1	0	0	2	2	1

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Peters

Group: A

Data Point: 3/12

SCALE: 20 Div. 13.710 cm.

1) DIAMETERS

REFERENCE		1	2	3	4	5	mean Std. Dev.
A	as base	0.600	0.625	0.670	0.645	0.670	
B		0.725	0.740	0.850	0.860	0.745	
C		0.820	0.845	0.860	0.825	0.830	
D		0.685	0.690	0.710	0.730	0.685	
E		0.700	0.680	0.725	0.660	0.715	0.7318
							0.0778

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	14.4	14.2	14.3	14.4	14.5	
B	15.9	15.8	15.8	16.0	16.0	
C	24.5	24.1	24.3	24.2	24.4	
D	27.3	27.5	27.4	27.3	27.4	
E	14.6	14.7	14.5	14.6	14.5	19.304
						5.5636

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	3	3	3	5	5	
Partially filled	19	15	15	14	14	
Empty	0	4	4	3	3	

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Peters

Group: A

Data Point: 6/12

SCALE: 20 Div. 13.730 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A as base	0.745	0.780	0.730	0.715	0.795	
B	0.750	0.765	0.710	0.725	0.760	
C	0.480	0.485	0.550	0.565	0.550	
D	0.780	0.800	0.800	0.775	0.760	
E	0.470	0.420	0.420	0.445	0.450	0.6493
						0.1439

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	15.1	15.7	15.9	15.6	15.5	
B	11.4	11.1	11.5	11.4	11.5	
C	18.7	19.1	19.0	18.8	18.9	
D	27.9	27.8	27.4	27.7	27.7	
E	7.7	7.8	7.9	7.7	7.7	16.25
						6.9902

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	0	2	1	0	1	
Partially filled	19	17	17	18	17	
Empty	0	0	1	1	1	

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Plum

Group: A

Data Point: Baseline

SCALE: 20 Div. 13.720 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A 6.550	1.190	1.275	1.225	1.235	1.230	
B 2.360	0.420	0.415	0.450	0.445	0.440	
C 2.390	0.660	0.595	0.660	0.630	0.615	
D 9.100	0.985	0.980	1.010	1.020	0.975	
E 2.670	0.710	0.740	0.740	0.710	0.700	0.8022
						0.2865

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	6.4	6.6	6.4	6.5	6.4	
B	4.5	4.7	4.6	4.7	4.5	
C	5.2	4.9	4.9	5.0	5.0	
D	5.7	5.6	5.7	5.7	5.6	
E	4.0	4.4	4.1	4.1	4.0	5.168
						0.8429

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled						
Partially filled						
Empty						

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Plum

Group: A

Data Point: 3/12

SCALE: 20 Div. 13.720 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A as base	0.950	1.025	1.000	1.030	0.995	
B	0.590	0.595	0.620	0.625	0.680	
C	0.760	0.720	0.685	0.695	0.690	
D	0.840	0.820	0.865	0.815	0.850	
E	0.450	0.500	0.535	0.495	0.500	0.7332
						0.1797

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	6.10	6.9	6.5	6.6	6.5	
B	4.4	4.5	4.4	4.5	4.5	
C	5.8	5.5	5.6	5.6	5.7	
D	5.2	5.2	5.1	5.2	5.2	
E	10.6	10.7	10.6	10.7	10.7	6.492
						2.2575

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	1	2	3	1	1	1.6
Partially filled	9	8	7	9	9	8.4
Empty	3	3	3	3	3	3

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Plum

Group: A

Data Point: 6/12

SCALE: 20 Div. 13.700 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean / Std. Dev.
A as base	1.130	1.145	1.130	1.140	1.145	
B	0.720	0.750	0.695	0.690	0.710	
C	0.670	0.730	0.760	0.735	0.725	
D	1.000	1.080	1.065	1.010	1.025	
E	0.770	0.750	0.760	0.765	0.760	

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	7.3	6.8	6.9	7.1	7.1	
B	9.4	9.3	9.3	9.6	9.3	
C	10.8	10.8	10.7	10.8	10.8	
D	9.1	9.0	9.2	9.1	9.1	
E	9.6	9.8	9.5	9.5	9.6	9.18
						1.2436

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	9	12	10	12	10	10.4
Partially filled	16	13	15	13	15	14.4
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Shackleton

Group: A

Data Point: Baseline

SCALE: 20 Div. 13.785 cm.

1) DIAMETERS

REFERENCE		1	2	3	4	5	mean / Std. Dev.
A	4.180	0. 790	0.800	0.785	0.865	0.850	
B	1.530	0.740	0.785	0.830	0.830	0.780	
C	2.850	0.790	0.810	0.835	0.800	0.790	
D	5.790	1.230	1.265	1.280	1.285	1.360	
E	7.130	0.840	0.830	0.840	0.835	0.835	0.9072
							0.1951

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	18.4	18.3	18.3	18.5	18.4	
B	15.0	14.8	15.1	15.1	15.0	
C	21.5	20.9	21.1	21.2	21.2	
D	17.5	17.5	17.6	17.6	17.4	
E	9.7	9.5	9.8	9.8	9.8	16.36
						3.9442

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	0	2	1	0	0	0.6
Partially filled	13	12	13	14	14	13.2
Empty	1	0	0	0	0	0.2

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Shackleton

Group: A

Data Point: 3/12

SCALE: 20 Div. 13.780 cm.

1) DIAMETERS

REFERENCE		1	2	3	4	5	mean / Std. Dev.
A	as base	1.085	1.120	1.120	1.135	1.140	
B		0.980	0.980	0.965	0.960	0.965	
C		0.995	0.995	0.950	1.035	0.990	
D		2.120	2.130	2.165	2.115	2.120	
E		1.190	1.220	1.285	1.200	1.285	1.2898
							0.4404

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	22.5	21.9	21.9	22.0	22.2	
B	26.7	27.0	26.8	26.8	26.7	
C	29.0	28.9	29.1	29.1	29.1	
D	21.8	21.7	21.9	21.7	21.8	
E	16.4	16.3	16.5	16.5	16.4	23.228
						4.4800

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	6	6	3	5	8	5.6
Partially filled	12	12	15	13	10	12.4
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Shackleton

Group: A

Data Point: 6/12

SCALE: 20 Div. 13.770 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	1.220	1.210	1.280	1.285	1.275	
B	1.060	0.950	0.965	0.935	0.930	
C	1.120	1.120	1.165	1.175	1.170	
D	1.920	1.945	2.000	1.985	1.965	
E	1.265	1.250	1.255	1.285	1.235	1.3186
						0.3474

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	19.2	19.1	19.4	19.1	19.2	
B	14.0	13.7	13.8	13.8	14.0	
C	24.9	25.0	25.0	24.8	24.9	
D	22.7	22.6	22.8	22.8	22.9	
E	18.0	18.1	18.2	18.3	18.0	19.772
						3.9129

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	5	2	5	4	4	4
Partially filled	14	17	14	15	15	15
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Silverwood

Group: A

Data Point: Baseline

SCALE: 20 Div. 13.780 cm.

1) DIAMETERS

REFERENCE		1	2	3	4	5	mean Std. Dev.
A	13.680	0.785	0.755	0.760	0.715	0.710	
B	4.530	0.840	0.855	0.870	0.835	0.830	
C	7.780	1.145	1.145	1.150	1.125	1.170	
D	7.760	0.580	0.610	0.635	0.680	0.620	
E	5.200	0.730	0.765	0.750	0.800	0.750	0.8244
							0.1812

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	20.7	20.9	20.6	20.7	20.9	
B	12.3	12.1	12.4	12.4	12.3	
C	19.7	19.9	19.8	19.7	19.8	
D	16.7	16.6	16.6	16.5	16.6	
E	12.2	12.1	12.2	12.0	12.2	16.316
						3.6922

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	2	1	1	2	2	1.6
Partially filled	10	9	9	10	10	9.6
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Silverwood

Group: A

Data Point: 3/12

SCALE: 20 Div. 13.800 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	0.845	0.800	0.815	0.895	0.900	
B	0.955	0.875	0.910	0.945	0.950	
C	1.220	1.215	1.240	1.285	1.265	
D	0.485	0.440	0.435	0.450	0.445	
E	0.730	0.750	0.715	0.730	0.735	0.8412
						0.2655

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	21.2	21.1	21.3	21.0	21.0	
B	13.8	13.7	13.6	13.7	13.7	
C	19.0	19.1	19.3	19.0	19.0	
D	16.4	16.1	16.5	16.5	16.4	
E	11.9	12.0	12.0	11.8	11.9	16.44
						3.442

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	3	5	3	4	4	3.8
Partially filled	9	7	9	8	8	8.2
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Silverwood

Group: A

Data Point: 6/12

SCALE: 20 Div. 13.780 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	0.985	0.970	1.000	1.070	0.995	
B	0.890	0.850	0.865	0.870	0.850	
C	1.285	1.285	1.220	1.215	1.220	
D	0.640	0.650	0.675	0.670	0.655	
E	1.080	1.080	1.050	1.045	1.035	0.966
						0.2019

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	21.4	21.1	21.1	21.0	21.0	
B	11.5	11.4	11.5	11.5	11.4	
C	20.7	21.3	21.2	20.9	21.1	
D	18.2	17.7	17.9	18.1	18.0	
E	12.9	12.9	12.8	12.9	12.9	16.896
						4.1324

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	4	4	7	6	4	5
Partially filled	9	9	6	7	9	8
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Whitehouse

Group: A

Data Point: Baseline

SCALE: 20 Div. 13.745 cm.

1) DIAMETERS

REFERENCE		1	2	3	4	5	mean / Std. Dev.
A	3.000	0.550	0.575	0.580	0.525	0.580	
B	6.230	0.785	0.835	0.810	0.815	0.800	
C	1.650	0.440	0.430	0.465	0.415	0.430	
D	5.120	0.730	0.670	0.700	0.695	0.680	
E	3.130	0.530	0.565	0.490	0.565	0.560	0.6088
							0.1340

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	17.9	17.8	17.9	18.0	18.0	
B	7.7	7.7	7.6	7.7	7.7	
C	10.2	10.1	10.1	10.3	10.3	
D	10.6	10.6	10.7	10.8	10.7	
E	11.7	11.8	11.7	11.8	11.7	11.644
						3.4805

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	3	3	1	1	2	1.8
Partially filled	16	13	17	17	17	16
Empty	0	3	1	1	0	1

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Whitehouse

Group: A

Data Point: 3/12

SCALE: 20 Div. 13.745 cm.

1) DIAMETERS

REFERENCE		1	2	3	4	5	mean / Std. Dev.
A	as base	0.710	0.735	0.750	0.765	0.710	
B		1.000	0.935	0.995	1.000	0.990	
C		0.500	0.565	0.570	0.510	0.570	
D		0.610	0.625	0.635	0.595	0.630	
E		0.660	0.665	0.580	0.585	0.660	0.702
							0.1592

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	10.4	10.2	10.3	10.4	10.3	
B	16.6	16.4	16.6	16.4	16.5	
C	10.4	10.2	10.5	10.6	10.4	
D	10.3	10.1	10.4	10.4	10.4	
E	10.1	9.8	9.9	9.9	10.1	11.504
						2.5569

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	3	4	3	4	3	3.4
Partially filled	16	15	16	15	16	15.6
Empty	1	1	1	1	1	1

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Whitehouse

Group: A

Data Point: 6/12

SCALE: 20 Div. 13.760 cm.

1) DIAMETERS

REFERENCE		1	2	3	4	5	mean Std. Dev.
A	as base	0.700	0.730	0.780	0.765	0.750	
B		0.850	0.830	0.810	0.815	0.800	
C		0.650	0.680	0.600	0.615	0.600	
D		0.735	0.740	0.710	0.760	0.710	
E		0.660	0.680	0.635	0.635	0.670	0.7164
							0.0736

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	12.5	12.4	12.8	12.4	12.8	
B	18.7	18.6	18.7	18.7	18.7	
C	10.6	10.5	10.7	10.5	10.7	
D	10.4	10.2	10.5	10.5	10.5	
E	9.7	9.5	9.8	9.7	9.8	12.396
						3.3537

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	4	4	3	3	1	3
Partially filled	17	17	18	18	20	18
Empty	1	1	1	1	1	1

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Young

Group: A

Data Point: Baseline

SCALE: 20 Div. 131730 cm.

1) DIAMETERS

REFERENCE		1	2	3	4	5	mean Std. Dev.
A	9.650	0.620	0.620	0.590	0.615	0.630	
B	3.050	0.600	0.620	0.635	0.640	0.640	
C	4.600	1.235	1.240	1.300	1.245	1.250	
D	5.460	0.460	0.420	0.420	0.460	0.450	
E	6.150	0.445	0.420	0.380	0.460	0.420	0.6726
							0.3095

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	23.5	23.6	23.3	23.5	23.6	
B	24.7	24.5	24.8	24.8	24.8	
C	20.6	20.4	20.6	20.4	20.t	
D	14.4	14.5	14.4	14.6	14.4	
E	12.2	12.1	12.1	12.3	12.3	19.072
						5.0421

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	6	6	2	2	6	4.4
Partially filled	16	16	20	20	16	17.6
Empty	0	0	0	0	0	0

THE UNIVERSITY OF ASTON IN BIRMINGHAM
SOFT LENS RESEARCH (OPHTHALMIC OTPICS DEPARTMENT)

LIMBAL BLOOD VESSEL DATA

Name: Young

Group: A

Data Point: 3/12

SCALE: 20 Div. 13.700 cm.

1) DIAMETERS

REFERENCE	1	2	3	4	5	mean Std. Dev.
A as base	0.515	0.500	0.560	0.530	0.525	
B	0.765	0.780	0.730	0.785	0.720	
C	0.780	0.785	0.735	0.735	0.780	
D	0.490	0.480	0.495	0.510	0.495	
E	0.600	0.595	0.630	0.570	0.515	0.6238
						0.1196

2) APPARENT LIMBAL DEPTH

REFERENCE	1	2	3	4	5	
A	23.8	23.7	23.8	23.9	23.8	
B	23.9	24.0	24.1	23.9	23.8	
C	14.2	14.4	14.7	14.6	14.7	
D	14.4	14.4	14.7	14.6	14.7	
E	15.7	15.7	15.7	15.8	15.7	18.484
						4.5140

3) ENGORGEMENT

Classification	1	2	3	4	5	
Filled	5	5	5	5	5	5
Partially filled	29	29	29	30	30	29.4
Empty	1	1	1	0	0	0.6

APPENDIX 4.11 (iii)

Repeated readings of Apparent Limbal Depth, using the slit lamp method, to obtain an error estimate.

Day on which readings taken	Position at which measurements of limbal depth were taken			
	0°	90°	180°	270°
1	15	30	20	20
	15	35	20	25
2	10	30	20	20
	15	30	15	20
3	15	30	20	20
	10	35	25	25
4	10	35	20	25
	10	30	20	20
5	15	35	25	20
	10	35	20	15

From these paired values the mean of the variances was found to be 8.1248.

Therefore, Error estimate = 8.1248

APPENDIX 6.1

THE UNIVERSITY OF ASTON IN BIRMINGHAM

OPHTHALMIC OPTICS DEPARTMENT

SOFT LENS RESEARCH

CLASSIFICATION OF SEVERITY OF CORNEAL MICRO-EPITHELIAL CYSTS.

a. NO MICRO-EPITHELIAL CYSTS PRESENT.	R.	L.
b. PRESENCE OF MICRO-EPITHELIAL CYSTS.	R.	L.

CLASSIFICATION:

A. DISTRIBUTION

The area containing micro-epithelial cysts is expressed as a percentage of the total corneal surface area.

B. DENSITY

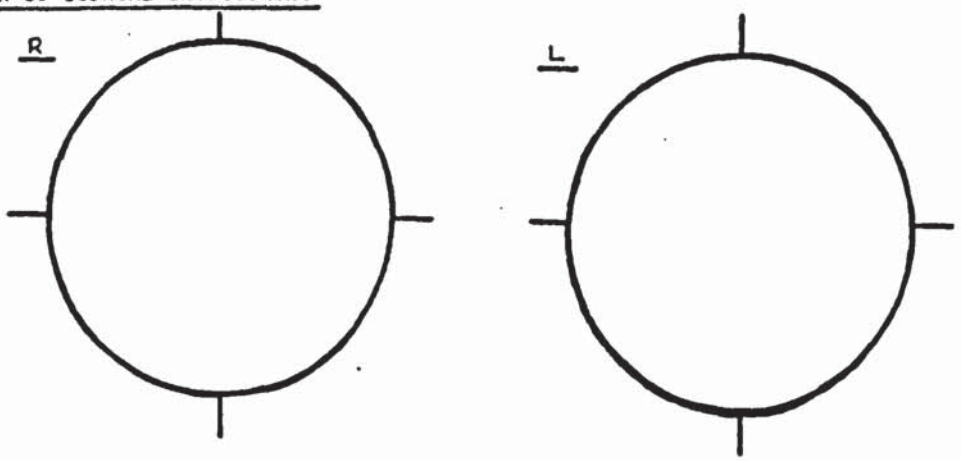
The ratio of the surface area of micro-epithelial cysts to the surface area of the affected cornea, expressed as a percent..

	R	L		R	L
1. DISTRIBUTION 20%			1. DENSITY 20%		
2. 20% DISTRIBUTION 40%			2. 20% DENSITY 40%		
3. 40% DISTRIBUTION 60%			3. 40% DENSITY 60%		
4. 60% DISTRIBUTION 80%			4. 60% DENSITY 80%		
5. DISTRIBUTION 80%			5. DENSITY 80%		

c. Degree of corneal involvement

	R	L
1. epithelial		
2. stromal		
3. endothelial		

d. area of corneal involvement



APPENDIX 6.3 (a)

TABULATED RESULTS OF THE RATE OF RECOVERY OF MICRO-EPITHELIAL CYSTS DISTRIBUTION WITH AN INITIAL SEVERITY OF GRADE I

Patient Name and Group		TIME (Weeks)																						
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
ARNOLD A	R																							
	L	1		1	2			1			1		1	1		1	1	1	1		1			
BETHEL B	R	1	1																					
	L	1	1																					
BOOTH B	R	1		1		1		1				1			1									
	L	1		1		1		1				1			1									
CHALKLIN J. B	R	1				2					1	1	1	1	1	1	1	1						
	L	1				2					1	1	1	1	1	1	1	1						
DUNCAN A	R	1					1									1								
	L	1					1									1								
GREGORY A	R	1	1		1			1						1	1									
	L	1	1		1			1						1	1									
GRIBBIN B	R	1		1				1	1															
	L	1		1				1	1															
GROOM A	R	1	1		1	1			1	1	1	1		1	1	1	1							
	L	1	1		1	1			1	1	1	1		1	1	1	1							

TABULATED RESULTS OF THE RATE OF RECOVERY OF MICRO-EPITHELIAL CYSTS DISTRIBUTION WITH AN INITIAL SEVERITY OF GRADE I

Patient Name and Group		TIME (Weeks)																						
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
HERBERT B	R	1	1			1		1		1		1				1	1	1	1	1	1	1	1	1
	L	1	1			1		1		1		1				1	1	1	1	1	1	1	1	1
HINTON A	R	1		1		2		1		1		1	2	1			1							
	L																							
HOGAN B	R	1		1			2	1							1		1	1			1			
	L																							
HOWELLS B	R	1	2	2	1			1	1		1		1	1	1			1						
	L	1	2	2	2			2	2		1		1	1	1			1						
HUDMAN A	R	1		2	1	1						1	1	1	1				1					
	L	1		2	1	2						1	1	1	1				1					
HUMM B	R	1		1																				
	L	1		2																				
JOYCE A	R	1	1		1		1	1	1	1	1	1	1		1									
	L	1	1		1		1	1	1	1	1	1	1		1									
LEE B	R	1		1				1									1							
	L	1		1				1									1							

TABULATED RESULTS OF THE RATE OF RECOVERY OF MICRO-EPITHELIAL CYSTS

DISTRIBUTION WITH AN INITIAL SEVERITY OF GRADE I

Patient Name and Group		TIME (Weeks)																						
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
LONGSTRETH A	R	1	2			1		1	1		1		1		1					1				
	L	1	2			1		1	1		1		1		1					1				
LYNAM A	R	1			1								1	1	1									
	L	1			1								1	1	1									
MACKIE B	R	1	1	1	1	1	1	0	0	1	0	1		1	1	1	1	0	0	0	0			
	L	1	1	1	0	1	1	1	1	1	1	0		1	0	1	0	1	1	1	1			
MARTIN B	R	1				1		1		1		1			1									
	L	1				1		1		1		1			1									
MATHESON B	R	1	1	1	1					1		1		1							1			
	L	1	1	1	1					1		1		1							1			
McADAM B	R	1	1	1	1			1	1															
	L	1	1	1	1			1	1															
McCORMICK A	R	1			1	1				1	1													
	L	1			1	1				1	1													
MUNKS B	R	1		1			1				1	1	1	1										
	L	1		1			1				1	1	1	1										

TABULATED RESULTS OF THE RATE OF RECOVERY OF MICRO-EPITHELIAL CYSTS DISTRIBUTION WITH AN INITIAL SEVERITY OF GRADE I

Patient Name and Group		TIME (Weeks)																						
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
PETERS A	R	1			1						1	1		1	1									
	L	1			1						1	1		1	1									
PLUM A	R	1			2					1		1	1	1	1	1	1	1	1	1				
	L																							
SHACKLETON A	R	1			1					1		1	1	1										
	L	1			1					1		1	1	1										
SILVERWOOD A	R	1	1	2				1		1	1		1		1		1							
	L	1	1	2				1		1	1		1		1		1							
SINIAK A	R	1	1	1	1																			
	L	1	1	1	1																			
TIMLIN B	R	1		1		1							1			1								
	L																							
TRAVERS B	R	1	1				1	1	1		1	1		1										
	L	1	1				1	1	1		1	1		1										
WARREN B	R	1		2		1				1		1									1			
	L	1		2		2				1		1									1			

TABULATED RESULTS OF THE RATE OF RECOVERY OF MICRO-EPITHELIAL CYSTS

DISTRIBUTION WITH AN INITIAL SEVERITY OF GRADE I

Patient Name and Group		TIME (Weeks)																					
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
WHITEHOUSE	R	1	2	1		1		1		1		1		1		1		1						
B	L	1	2	1		1		1		1		1		1		1		1						
WIGHTMAN	R	1	1	1						0	1		1				1							
B	L	1	1	1						1	1		1				1							
YATES	R	1	1	1	1	1	1		1		1		1		1		1		1					
B	L	1	1	1	1	1	1		1		1		1		1		1		1					
YOUNG	R	1	2				2	1	1		1													
A	L	1	2				1	1	1		1													
	R																							
	L																							
	R																							
	L																							
	R																							
	L																							
	R																							
	L																							

TABULATED RESULTS OF THE RATE OF RECOVERY OF MICRO-EPITHELIAL CYSTS DENSITY WITH AN INITIAL SEVERITY OF GRADE I

Patient Name and Group		TIME (Weeks)																						
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
ARNOLD	R	1		1	1			1			1		1	1		1	1	1	1		1			
A	L	1		1	1			1			1		1	1		1	1	1	1		1			
BETHEL	R	1	1																					
B	L	1	1																					
BOOTH	R	1		1		1		1				1			1									
B	L	1		1		1		1				1			1									
CHALKLIN J	R	1				2					1	1	1	1	1	1	1	1						
B	L	1				1					1	1	1	1	1	1	1	1						
COTTON T	R	1	2		1	1																		
A	L	1	2		1	1																		
DALTON	R	1			1			1					1											
B	L	1			1			2					1											
DAWSON	R	1	2		2	2	1					1				1				1				
B	L	1	2		2	2	1					1				1				1				
DUNCAN	R	1					1									1								
A	L	1					1									1								

TABULATED RESULTS OF THE RATE OF RECOVERY OF MICRO-EPITHELIAL CYSTS DENSITY WITH AN INITIAL SEVERITY OF GRADE I

Patient Name and Group		TIME (Weeks)																						
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
GATWARD	R	1	2		2			1		1			1	1	1	1	1	1	1					
A	L	1	2		2			1		1			1	1	1	1	1	1	1					
GREGORY	R	1	1		1			1						1	1									
A	L	1	1		1			1						1	1									
GRIBBIN	R	1		1				1	2															
B	L	1		1				1	1															
GROOM	R	1	1		1	1			1	1	1	1		1	1	1	1							
A	L	1	1		1	1			1	1	1	1		1	1	1	1							
HERBERT	R	1	1			1		1		1		1				1	1	1	1	1	1	1	1	
B	L	1	1			1		1		1		1				1	1	1	1	1	1	1	1	
HINTON	R	1		1		1		1		1		1	1	1			1							
A	L	1		1		1		1		1		1	1	1			1							
HOGAN	R	1		1			1	1							1		1	1			1			
B	L																							
HOWELLS	R	1	1	1	1			1	1		1		1	1	1			1						
B	L	1	1	1	1			1	1		1		1	1	1			1						

TABULATED RESULTS OF THE RATE OF RECOVERY OF MICRO-EPITHELIAL CYSTS

DENSITY WITH AN INITIAL SEVERITY OF GRADE I

Patient Name and Group		TIME (Weeks)																						
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
HUDMAN A	R	1	—	1	1	1						1	1	1	1				1					
	L	1	—	1	1	1						1	1	1	1				1					
HUMM B	R	1	—	1																				
	L	1	—	1																				
JOYCE A	R	1	1	—	1	—	1	1	1	1	1	1	1	—	1									
	L	1	1	—	1	—	1	1	1	1	1	1	1	—	1									
LEE B	R	1	—	1				1									1							
	L	1	—	1				1									1							
LONGSTRETH A	R	1	1	—	—	1	—	1	1	—	1	—	1	—	1					1				
	L	1	1	—	—	1	—	1	1	—	1	—	1	—	1					1				
LYNAM A	R	1	—	—	1								1	1	1									
	L	1	—	—	1								1	1	1									
MACKIE B	R	1	1	1	—	2	1	1	1	1	1	—	—	1	—	1	—	1	1	1	1	—		
	L																							
MARTIN B	R	1	—	—	—	1	—	1	—	1	—	1	—	—	1	—	—	—	—	—	—	—	—	—
	L	1	—	—	—	1	—	1	—	1	—	1	—	—	1	—	—	—	—	—	—	—	—	—

TABULATED RESULTS OF THE RATE OF RECOVERY OF MICRO-EPITHELIAL CYSTS

DENSITY WITH AN INITIAL SEVERITY OF GRADE I

Patient Name and Group		TIME (Weeks)																						
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
MATHESON	R	1	1	1	1					1		1		1							1			
B	L	1	1	1	1					1		1		1							1			
McADAM	R	1	1	1	1			1	1															
B	L	1	1	1	1			1	1															
McCORMICK	R	1			1	1				1	1													1
A	L	1			1	1				1	1													
MUNKS	R	1		1			1				1	1	1	1										
B	L	1		1			1				1	1	1	1										
PETERS	R	1			1						1	1		1	1									
A	L	1			1						1	1		1	1									
PLUM	R	1			1	1				1		1	1	1	1	1	1	1	1	1				1
A	L	1			1	1				1		1	1	1	1	1	1	1	1	1				1
SHACKLETON	R	1	1					1		1	1	1												
A	L	1	1					1		1	1	1												
SILVERWOOD	R	1	1	1				1		1	1		1		1		1							
A	L	1	1	1				1		1	1		1		1		1							

TABULATED RESULTS OF THE RATE OF RECOVERY OF MICRO-EPITHELIAL CYSTS

DENSITY WITH AN INITIAL SEVERITY OF GRADE I

Patient Name and Group		TIME (Weeks)																						
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
SINIAK	R	1	1	1	1																			
A	L	1	1	1	1																			
TIMLIN	R	1		1		1							1	1		1	1							
B	L	1		2		2							1	1		1	1							
TRAVERS	R	1	1				1	1	1		1	1		1										
B	L	1	1				1	1	1		1	1		1										
WARREN	R	1		2		2				1		1									1			
B	L	1		2		2				1		1									1			
WIGHTMAN	R	1	1	1						0	1		1				1							
B	L	1	1	1						1	1		1				1							
YATES	R	1	1	1	1	1	1		1		1		1		1		1		1				1	
B	L	1	1	1	1	1	1		1		1		1		1		1		1				1	
YOUNG	R	1	2				1	1	1		1													
A	L	1	2				1	1	1		1													
	R																							
	L																							

TABULATED RESULTS OF THE RATE OF RECOVERY OF MICRO-EPITHELIAL CYSTS

DISTRIBUTION WITH AN INITIAL SEVERITY OF GRADE 2

Patient Name and Group		TIME (Weeks)																					
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
ARNOLD	R	2		2	2			1			1		1	1		1	1	1	1		1			
A	L																							
BESLEY	R	2			1		1		1		1		1		1							1		
A	L	2			2		2		1		1		1		1							1		
COTTON T.	R	2	2		1	2																		
A	L	2	2		1	2																		
DALTON	R	2			2			1					1											
B	L	2			2			1					1											
GATWARD	R	2	2		1			2		2			1	1	1	1	1	1	1					
A	L	2	2		1			1		1			1	1	1	1	1	1	1					
HINTON	R																							
A	L	2		2		2		1		1		1	1											
HOGAN	R																							
B	L	2		2			2	1							1		1	1			1			
LAWRENCE	R	2			2		1		1		1	1	1	1	1	1	1							
B	L	2			2		1		1		1	1	1	1	1	1	1							

TABULATED RESULTS OF THE RATE OF RECOVERY OF MICRO-EPITHELIAL CYSTS

DISTRIBUTION WITH AN INITIAL SEVERITY OF GRADE 2

Patient Name and Group		TIME (Weeks) 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
NEWELL	R	2	1		1	1			1		1		1											
A	L																							
PLUM	R																							
A	L	2			1	1				1		1	1	1	1	1	1	1	1	1				1
TIMLIN	R																							
B	L	2		2		1							1	1		1	1							
	R																							
	L																							
	R																							
	L																							
	R																							
	L																							
	R																							
	L																							
	R																							
	L																							

TABULATED RESULTS OF THE RATE OF RECOVERY OF MICRO-EPITHELIAL CYSTS DENSITY WITH AN INITIAL SEVERITY OF GRADE 2

Patient Name and Group		TIME (Weeks)																						
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
BESLEY	R	2			1		1		1		1		1		1									
A	L	2			2		1		1		1		1		1									
HOGAN	R																							
B	L	2		2			2	1							1		1	1			1			
LAWRENCE	R	2			2		1		1		1	1	1	1	1	1	1							
B	L	2			1		1		1		1	1	1	1	1	1	1							
MACKIE	R																							
B	L	2	1	1	1	1	1			1		1		1	1	1	1							
NEWELL	R	2	2		1	1			1		1		1											
A	L	2	1		1	1			1		1		1											
WHITEHOUSE	R	2	2	2		1		1		1		1		1		1		1						
A	L	2	2	2		1		1		1		1		1		1		1						
	R																							
	L																							
	R																							
	L																							

TABULATED RESULTS OF THE RATE OF RECOVERY OF MICRO-EPITHELIAL CYSTS

DISTRIBUTION WITH AN INITIAL SEVERITY OF GRADE 3

Patient Name and Group		TIME (Weeks)																						
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
CARR	R	3	2				1							1		1			1		1			
B	L	3	2				2							1		1			1		1			
DAWSON	R	3	2		1	1	1					1				1				1				
B	L																							
NEWELL	R																							
A	L	3	2		2	2			1		1		1											
	R																							
	L																							
	R																							
	L																							
	R																							
	L																							
	R																							
	L																							
	R																							
	L																							

TABULATED RESULTS OF THE RATE OF RECOVERY OF MICRO-EPITHELIAL CYSTS

DENSITY WITH AN INITIAL SEVERITY OF GRADE 3

Patient Name and Group		TIME (Weeks)																						
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
CARR	R	3	2				1							1		1			1		1			
B	L	3	2				2							1		1			1		1			
	R																							
	L																							
	R																							
	L																							
	R																							
	L																							
	R																							
	L																							
	R																							
	L																							
	R																							
	L																							
	R																							
	L																							

TABULATED RESULTS OF THE RATE OF RECOVERY OF MICRO-EPITHELIAL CYSTS

DISTRIBUTION WITH AN INITIAL SEVERITY OF GRADE 4

Patient Name and Group		TIME (Weeks)																						
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
DAWSON	R																							
B	L	4	2		1	1	1					1				1				1				
	R																							
	L																							
	R																							
	L																							
	R																							
	L																							
	R																							
	L																							
	R																							
	L																							
	R																							
	L																							
	R																							
	L																							

APPENDIX 6.3 (b)

Tabulated results of the Rate of Recovery of N Plum (Patient with suspected Fuch's Endothelial Dystrophy).

Tabulated recovery of corneal sensitivity of patient Plum.

Number of days (weeks) after termination of contact lens wear.	Aesthesiometry	
	R	L
0	3.25	2.40
5	2.40	2.40
31	4.60	4.60
40	6.64	2.40
49 (7)	4.60	6.64
52	6.64	8.84
64	8.84	6.64
71 (10)	8.84	8.84
78	12.84	8.84
86	6.64	6.64
97 (14)	4.60	4.60
111	4.60	6.64
125 (18)	4.60	4.60
139	2.40	2.40
147 (21)	1.84	1.84
155	1.16	1.16
162	1.08	1.16
169 (24)	1.08	1.08

After 24 weeks (6 months) corneal sensitivity in both eyes had returned to the baseline values.

APPENDIX 6.6 ii) (a)

The University of Aston in Birmingham

Department of Ophthalmic Optics

Soft Lens Research

Name: _____ Date: _____

Micro-epithelial cyst qualilative data sheet

		R	L
1.	Fine cysts observed centrally	☐	☐
2.	Cysts, varying in size, viewed peripherally	☐	☐
3.	Numerous cysts viewed in the mid periphery of the nasal and/or temporal cornea	☐	☐
4.	Numerous cysts viewed in the mid periphery of the superior and/or inferior cornea.	☐	☐
5.	25% or less of cysts observed to stain with 2% fluorescein sodium	☐	☐
6.	25% to 50% of cysts staining with 2% fluorescein sodium	☐	☐
7.	50% or more of cysts staining with 2% fluorescein sodium	☐	☐
8.	Presence of oedema	☐	☐
9.	Presence of sub-epithelal infiltrates within the cystic region	☐	☐
10.	Presence of limbal bloodvessel congestion which could have been associated with cystic areas.	☐	☐
11.	Prescence of limbal blood vessel encroachment which could have been associated with the cystic areas.	☐	☐

APPENDIX 6.6 ii) (b)

THE UNIVERSITY OF ASTON IN BIRMINGHAM

OPHTHALMIC OPTICS DEPARTMENT

SOFT LENS RESEARCH

NAME:..... DATE:.....

A.Presence of micro-epithelial cysts.....R; L:

B.

i.Male / Female.

ii.Caucasian.....yes / no.

C.i.Type of contact lens worn.....

Contact lens trade name.....

ii.Length of regular contact lens wear.....

Average length of wear per day.....

iii.Type of cleaning procedure.....a.Sterilizing technique.

b.Cleaning solutions.

D.Any other relevent details.....

.....

.....

Key to Survey File

Each patient occupies two lines on the file.

Line	Column	Variables recorded
1	1 - 2	Patient number
	4	Card number
	6	Presence of cysts, right
	8	Distribution of cysts, right
	10	Density of cysts, right
	12	Degree of corneal cystic involvement, right
	14	Patient sex
	16 - 17	Years of contact lens wear
	19	Cleaning regime
	20 - 25	Lens power right
	27	Fine cysts observed centrally, right
	29	Cysts, various size, peripherally, right
	31	Numerous cysts, mid-peripherym nasal or temporal cornea, right
	33	Numerous cysts, mid-periphery, superior or inferior cornea, right
	35	Proportion of cyts staining with 2% fluorescein, right
	37	Presence of oedema, right
	39	Presence of sub-epithelial infiltrates in cystic area, right

Line	Column	Variables recorded
1 continued	41	Presence of limbal blood vessel congestion which could have been associated with cystic areas, right
	43	Presence of limbal blood vessel encroachment which could have been associated with cystic areas, right
2	1 - 2	Patient number
	4	Card number
	6	Presence of cysts, left
	8	Distribution of cysts, left
	10	Density of cysts, left
	12	Degree of corneal involvement, left
	14	Lens type
	16 - 17	Daily hours of wear
	20 - 25	Lens power, left
	27	Fine cysts observed centrally, left
	29	Cysts, various sizes, peripherally, left
	31	Numerous cysts, mid-periphery, nasal or temporal cornea, left
	33	Numerous cysts, mid-periphery, superior or inferior cornea, left
	35	Proportion of cysts staining with 2% fluorescein, left
	37	Presence of oedema, left
	39	Presence of sub-epithelial infiltrates in cystic area, left

41 Presence of limbal blood vessel congestion which could have been associated with cystic areas, left

43 Presence of limbal blood vessel which could have been associated with cystic areas, left.

The variable "Proportion of cysts staining with 2% fluorescein" takes values of 1, 2 and 3. These equate to less than 25%, 25% to 50%, and 50% or more respectively.

```
01 1 1 1 1 1 F 02 2 -3.25 0 1 1 0 3 0 0 1 0
01 2 1 1 1 1 H 16   -3.25 0 1 1 0 3 0 0 1 0
02 1 1 1 1 1 M 02 2 -2.25 0 1 1 0 3 0 0 1 0
02 2 1 1 1 1 H 10   -2.25 0 1 0 0 2 0 0 0 0
03 1 1 1 1 1 F 01 2 -3.75 0 1 0 0 1 0 0 0 0
03 2 1 1 1 1 H 14   -3.75 1 1 0 0 1 0 0 0 0
04 1 1 1 1 1 F 02 2 -4.50 1 1 0 0 2 0 0 0 0
04 2 1 1 1 1 H 10   -4.50 0 1 1 0 3 0 0 1 0
05 1 1 1 1 1 F 01 2 -2.50 1 1 0 0 1 0 0 0 0
05 2 1 1 1 1 H 16   -2.50 1 1 0 0 1 0 0 0 0
06 1 1 1 1 1 F 02 2 -1.75 1 1 1 0 3 0 0 1 0
06 2 1 1 1 1 H 16   -1.75 1 1 1 0 3 0 0 1 0
07 1 1 1 1 1 F 02 2 -3.50 0 1 1 0 3 0 0 1 0
07 2 1 1 1 1 H 14   -3.50 0 1 1 0 3 0 0 1 0
08 1 1 1 2 1 F 01 2 -2.00 0 1 1 0 3 0 0 1 0
08 2 1 1 1 1 H 12   -2.00 0 1 1 0 3 0 0 0 0
09 1 1 1 1 1 F 02 2 -4.00 1 1 0 0 1 0 0 0 0
09 2 0 0 0 0 H 08   -4.00 0 0 0 0 0 0 0 0 0
10 1 1 1 1 1 F 01 2 -3.00 1 1 0 0 1 0 0 0 0
10 2 1 1 1 1 H 10   -3.00 1 0 0 0 1 0 0 0 0
11 1 1 1 1 1 M 02 2 -1.50 1 0 0 0 1 0 0 0 0
11 2 1 1 1 1 H 10   -1.50 1 0 0 0 1 0 0 0 0
12 1 1 1 1 1 F 02 2 -3.25 1 1 0 0 2 0 0 1 0
12 2 1 2 2 1 H 12   -3.25 1 1 0 0 2 0 0 1 0
13 1 1 1 1 1 F 02 2 -4.25 1 1 0 0 1 0 0 0 0
13 2 1 1 1 1 H 10   -4.25 1 1 0 0 1 0 0 0 0
14 1 1 1 1 1 F 03 2 -4.50 1 1 1 0 3 0 0 1 0
14 2 1 1 1 1 H 12   -4.50 1 1 1 0 3 0 0 1 0
15 1 1 1 1 1 F 01 2 -4.00 1 0 0 0 1 0 0 0 0
15 2 1 1 1 1 H 14   -4.00 1 0 0 0 1 0 0 0 0
16 1 1 1 1 1 M 05 2 -2.25 1 1 0 1 1 0 0 1 0
16 2 1 1 1 1 H 10   -2.25 1 1 0 0 1 0 0 0 0
17 1 1 1 1 1 M 01 2 -3.25 0 1 0 0 2 0 0 0 0
17 2 1 1 1 1 H 16   -3.25 0 1 0 0 2 0 0 0 0
18 1 1 1 1 1 F 02 2 -3.50 1 1 0 0 2 0 0 0 0
18 2 1 1 1 1 H 14   -3.50 1 1 0 0 2 0 0 0 1
19 1 1 2 2 1 M 02 2 -3.75 0 1 1 0 3 0 0 1 0
19 2 1 1 1 1 H 14   -3.75 0 1 1 0 3 0 0 1 0
20 1 1 2 1 1 M 02 2 -2.25 0 1 0 0 2 0 0 1 0
20 2 1 1 1 1 H 16   -2.25 0 1 0 0 2 0 0 1 0
21 1 1 1 1 1 M 02 2 -3.50 1 1 0 0 1 0 0 0 0
21 2 1 1 1 1 H 14   -3.50 1 1 0 0 1 0 0 0 0
22 1 1 1 1 1 F 02 2 -3.00 1 0 0 0 1 0 0 0 0
22 1 1 1 1 1 H 12   -3.00 1 0 0 0 1 0 0 0 0
23 1 1 1 1 1 F 01 2 -2.00 1 1 0 0 2 0 0 0 0
23 2 1 1 1 1 H 14   -2.00 1 1 0 0 2 0 0 0 0
24 1 1 2 2 1 F 03 2 -3.50 0 1 1 0 3 0 0 1 0
24 2 1 2 2 1 H 12   -3.50 0 1 1 0 3 0 0 1 0
25 1 1 1 1 1 F 01 2 -4.00 0 1 0 0 2 0 0 1 0
25 2 1 2 1 1 H 12   -4.00 1 1 0 0 2 0 0 1 0
26 1 1 2 2 1 M 02 2 -5.00 0 1 1 0 3 0 0 1 0
26 2 1 3 2 1 H 12   -5.00 1 1 1 0 3 0 0 1 0
27 1 1 1 1 1 M 02 2 -3.00 1 1 0 0 2 0 0 1 0
27 2 1 1 1 1 H 14   -3.00 1 1 0 0 2 0 0 1 0
28 1 1 1 1 1 F 02 2 -2.75 0 1 1 0 2 0 0 1 0
28 2 1 2 1 1 H 14   -2.75 0 1 1 0 2 0 0 1 0
29 1 1 2 2 1 M 03 2 -2.00 1 1 1 0 2 0 0 1 0
29 2 1 1 1 1 H 12   -2.00 1 1 1 0 2 0 0 1 0
30 1 1 2 1 1 M 01 1 13.00 1 1 0 1 2 0 0 0 1
30 2 1 2 1 1 E 24   13.00 1 1 0 1 2 0 0 0 1
```

31	1	1	1	1	1	M	02	1	13.00	1	0	0	0	2	0	0	0	0
31	2	1	1	1	1	E	24		13.00	1	0	0	0	2	0	0	0	0
32	1	0	0	0	0	M	02	1	15.50	0	0	0	0	0	0	0	0	0
32	2	1	1	1	1	E	24		15.50	1	1	0	0	1	0	0	0	1
33	1	1	1	1	1	M	02	2	-2.25	1	1	0	0	1	0	0	1	0
33	2	1	1	1	1	S	18		-2.25	1	1	0	0	1	0	0	1	0
34	1	1	1	1	1	F	02	2	-2.00	1	1	0	0	1	0	0	1	0
34	2	1	1	1	1	S	18		-2.00	1	1	0	0	1	0	0	1	0
35	1	1	1	1	1	M	02	2	-2.00	1	1	0	1	1	0	1	0	1
35	2	1	1	1	1	S	18		-2.00	1	1	0	1	1	0	1	0	1
36	1	1	1	1	1	F	02	2	-2.50	0	1	0	0	1	0	0	1	0
36	2	1	1	1	1	S	14		-2.50	0	1	0	0	1	0	0	1	0
37	1	1	1	1	1	M	02	2	-4.00	1	1	0	0	1	0	0	1	0
37	2	1	1	1	1	S	08		-4.00	1	1	0	1	1	0	0	1	0
38	1	1	1	1	1	M	01	2	-2.00	0	1	0	0	1	0	0	0	0
38	2	1	1	1	1	S	12		-2.00	1	0	0	0	1	0	0	0	0
39	1	1	1	1	1	F	02	2	-1.75	1	1	0	0	1	0	0	1	0
39	2	1	1	1	1	S	10		-1.75	1	1	0	0	1	0	0	1	0
40	1	1	1	1	1	M	03	2	-2.50	1	1	0	0	1	0	0	0	0
40	2	1	1	1	1	S	16		-2.50	0	1	0	0	1	0	0	0	0
41	1	1	1	1	1	F	01	2	-3.00	1	1	0	0	1	0	0	0	0
41	2	1	1	1	1	S	14		-3.00	1	0	0	0	1	0	0	0	0
42	1	1	1	1	1	M	01	2	-4.00	1	1	0	0	1	0	0	0	0
42	2	1	1	1	1	S	14		-4.00	1	1	0	0	1	0	0	0	0
43	1	1	1	1	1	M	01	2	-3.00	1	1	0	0	1	0	0	0	0
43	2	1	1	1	1	S	14		-3.00	1	1	0	0	1	0	0	0	0
44	1	1	1	1	1	F	02	2	-3.00	1	1	0	0	1	0	0	0	0
44	2	1	1	1	1	S	16		-3.00	1	1	0	0	1	0	0	0	0
45	1	1	1	1	1	M	01	2	-1.75	0	1	0	0	1	0	0	1	0
45	2	1	1	1	1	S	16		-1.75	0	1	0	0	1	0	0	1	0
46	1	1	1	1	1	M	03	2	-4.50	1	1	0	0	1	0	0	1	0
46	2	1	1	1	1	S	16		-7.00	1	1	0	0	1	0	0	1	0
47	1	1	4	4	1	F	01	2	4.00	1	0	1	0	1	0	0	1	0
47	2	1	2	2	1	S	16		4.00	1	0	1	0	1	0	0	1	0
48	1	1	1	1	1	F	02	2	-1.00	1	0	0	0	1	0	0	0	0
48	2	1	1	1	1	S	18		-1.00	1	0	0	0	1	0	0	0	0
49	1	1	1	1	1	F	02	2	-2.50	1	1	0	0	1	0	0	1	0
49	2	1	1	1	1	S	12		-2.50	1	1	0	0	1	0	0	1	0
50	1	1	1	1	1	F	01	2	-3.00	1	0	0	0	1	0	0	0	0
50	2	1	1	1	1	S	08		-3.00	1	0	0	0	1	0	0	0	0
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54	2	1	1	1	1	S	16		-2.50	1	1	0	0	1	0	0	0	0
55	1	1	1	1	1	M	02	2	-3.50	1	0	0	0	1	0	0	0	0
55	2	1	1	2	1	S	18		-3.50	1	0	0	1	1	0	0	1	0
56	1	1	1	1	1	M	02	2	-2.00	0	1	0	0	1	0	0	0	0
56	2	1	1	1	1	S	16		-2.00	0	1	0	0	1	0	0	0	0
57	1	1	1	1	1	F	03	2	-3.75	1	1	0	0	1	0	0	1	0
57	2	1	1	1	1	S	16		-3.75	1	1	0	0	1	0	0	1	0
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58	2	1	2	1	1	S	14		-2.00	1	1	0	1	2	0	0	1	0
59	1	1	2	1	1	F	02	2	-6.25	1	0	0	1	1	0	0	0	0
59	2	1	2	1	1	S	12		-5.75	1	0	0	1	1	0	0	0	0
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62	1	1	1	1	1	M	01	2	-3.00	0	1	0	0	1	0	0	1	0
62	2	1	1	1	1	S	18		-3.00	0	1	0	0	1	0	0	1	0
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68	1	1	1	1	1	F	01	2		1	0	0	0	1	0	0	0	0
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69	2	1	1	1	1	S	18			1	0	0	0	1	0	0	0	0
70	1	1	1	1	1	M	01	2	-9.00	1	1	1	0	1	0	1	0	1
70	2	1	1	1	1	S	18		-10.00	1	1	1	0	1	0	1	0	1
71	1	1	1	1	1	F	02	2	-8.50	1	1	0	0	1	0	0	0	0
71	2	1	1	1	1	S	18		-8.50	1	1	0	0	1	0	0	0	0
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72	2	1	2	1	1	S	18		-5.00	1	0	0	1	1	0	0	1	0
73	1	1	1	1	1	M	04	2	-2.00	1	0	0	0	1	0	0	0	0
73	2	1	1	1	1	S	12		-2.00	1	0	0	0	1	0	0	0	0
74	1	1	1	1	1	F	03	2		1	1	0	1	1	0	0	0	1
74	2	1	1	1	1	S	08			1	1	0	1	1	0	0	0	1
75	1	1	1	1	1	F	02	2	-4.00	1	1	0	1	1	0	0	0	1
75	2	1	1	1	1	S	16		-4.00	1	1	0	1	1	0	0	0	1
76	1	1	1	1	1	F	01	2	-3.25	1	1	0	1	1	0	0	1	0
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77	2	1	1	1	1	S	18		-3.50	1	1	0	0	1	0	0	0	1
78	1	1	2	1	1	F	04	2	-5.00	1	1	0	1	2	0	0	0	1
78	2	1	1	1	1	S	18		-5.00	1	1	0	1	2	0	0	0	1
79	1	1	1	1	1	F	04	2	-5.00	1	1	0	0	1	0	0	0	0
79	2	1	1	1	1	S	12		-5.00	1	1	0	0	1	0	0	0	0
80	1	1	1	1	1	M	01	2	-1.50	1	0	1	0	1	0	0	0	0
80	2	1	1	1	1	S	18		-1.50	1	0	0	0	1	0	0	0	0
81	1	1	1	1	1	F	02	2	-3.50	1	1	0	1	1	0	0	1	0
81	2	1	1	1	1	S	12		-3.50	1	1	0	1	1	0	0	1	0
82	1	1	1	1	1	F	02	2	0.75	1	0	0	0	1	0	0	0	0
82	2	1	1	1	1	S	12		0.50	1	0	0	0	1	0	0	0	0
83	1	1	1	1	1	F	02	2	7.00	1	1	0	0	1	0	0	0	0
83	2	1	1	1	1	S	12		6.50	0	1	1	0	1	0	0	0	0
84	1	1	1	1	1	F	02	2		1	1	0	0	1	0	0	0	1
84	2	1	1	1	1	S	12			1	1	0	0	1	0	0	0	1
85	1	1	1	1	1	F	02	2	-11.00	1	1	0	0	1	0	0	1	0
85	2	1	1	1	1	S	12		-7.25	1	1	0	0	1	0	0	1	1
86	1	1	2	1	1	F	03	2	-5.00	1	1	0	0	1	0	0	0	1
86	2	1	2	1	1	S	12		-5.00	1	1	0	0	1	0	0	0	1
87	1	1	1	1	1	M	01	2	-5.00	1	1	0	0	2	0	1	1	0
87	2	1	1	1	1	S	12		-5.00	1	1	0	0	2	0	1	1	0
88	1	1	1	1	1	F	05	2	-3.50	0	1	0	1	1	0	0	0	1
88	2	1	1	1	1	S	12		-3.50	1	1	0	1	1	0	0	0	1
89	1	1	1	1	1	F	01	2	-2.00	1	0	0	0	1	0	0	0	0
89	2	1	1	1	1	S	12		-1.00	1	0	0	0	1	0	0	0	0
90	1	1	1	1	1	F	03	2	-6.00	1	1	0	1	1	0	0	1	0
90	2	1	1	1	1	S	12		-6.00	1	1	0	1	1	0	0	1	0

91	1	1	1	1	1	F		2	-3.00	0	1	0	1	1	0	0	0	0
91	2	1	1	1	1	S			-3.00	0	1	0	1	1	0	0	0	0
92	1	1	1	1	1	F	03	2	-4.50	1	0	0	0	1	0	0	0	0
92	2	1	1	1	1	S	12		-4.75	1	0	0	0	1	0	0	0	0
93	1	1	1	1	1	F	02	2	-1.25	0	1	0	1	1	0	0	1	0
93	2	1	1	1	1	S	12		-1.25	0	1	0	1	1	0	0	1	0
94	1	1	1	1	1	M	01	2	-2.25	1	0	0	0	1	0	0	1	0
94	2	1	1	1	1	S	12		-2.25	1	0	0	0	1	0	0	1	0
95	1	1	2	3	1	F	01	2	4.25	1	1	0	1	1	0	0	1	0
95	2	1	2	2	1	S	08		5.00	1	1	0	1	1	0	0	1	0
96	1	1	2	1	1	M	03	2	-3.00	1	1	0	0	1	0	0	0	1
96	2	1	2	1	1	S	08		-3.00	1	1	0	0	1	0	0	0	1
97	1	1	1	1	1	M	11	2	-5.00	1	1	0	0	1	0	0	0	1
97	2	1	1	1	1	S	18		-5.00	1	1	0	0	1	0	0	0	1
98	1	1	1	1	1	F	03	2	3.75	0	1	0	0	1	0	1	1	0
98	2	1	1	1	1	S	13		3.75	1	1	0	0	1	0	0	1	0
99	1	1	1	1	1	F	01	2	-4.75	1	1	0	0	1	0	0	0	0
99	2	1	1	1	1	S	18		-4.75	1	1	0	0	1	0	0	0	0
1001	1	1	1	1	M	03	2	-3.00	1	1	0	0	2	0	0	0	1	
1002	1	2	2	1	S	18		-3.00	1	1	0	0	2	0	0	0	1	
1011	1	1	1	1	F	01	1		1	1	0	0	1	0	0	0	1	
1012	1	1	1	1	S	06			1	1	0	0	1	0	0	0	1	
1021	1	1	1	1	F	02	2		1	1	0	0	1	0	0	1	0	
1022	1	1	1	1	S	18			1	1	0	0	1	0	0	1	0	
1031	1	1	1	1	F	02	2	2.25	1	0	0	0	1	0	0	0	0	
1032	1	1	1	1	S	06		2.25	1	0	0	0	1	0	0	0	0	
1041	1	2	1	1	F	03	2	-0.75	1	1	0	0	1	0	0	0	1	
1042	1	2	1	1	S	06		-0.75	1	1	0	0	1	0	0	0	1	
1051	1	1	1	1					1	1	0	0	1	0	0	0	0	
1052	0	0	0	0					0	0	0	0	1	0	0	0	0	
1061	1	1	1	1					1	1	0	0	1	0	0	0	0	
1062	1	1	1	1					1	1	0	0	1	0	0	0	0	
1071	1	1	1	1					1	0	0	0	1	0	0	0	0	
1072	1	1	1	1					1	0	0	0	1	0	0	0	0	
1081	1	1	1	1					1	0	0	0	1	0	0	0	0	
1082	0	0	0	0					0	0	0	0	0	0	0	0	0	
1091	1	1	1	1					1	0	0	0	1	0	0	0	0	
1092	1	1	1	1					1	0	0	0	1	0	0	0	0	
1101	1	1	1	1					1	0	0	0	1	0	0	0	0	
1102	1	1	1	1					1	0	0	0	1	0	0	0	0	
1111	1	1	1	1					0	1	0	0	1	0	0	0	0	
1112	1	1	1	1					0	1	0	0	1	0	0	0	0	
1121	1	1	1	1					1	0	0	0	1	0	0	0	0	
1122	1	1	1	1					1	0	0	0	1	0	0	0	0	
1131	1	1	1	1					1	0	0	0	1	0	0	0	0	
1132	1	1	1	1					1	0	0	0	1	0	0	0	0	
1141	1	1	1	1					1	0	0	0	1	0	0	0	0	
1142	1	1	1	1					1	0	0	0	1	0	0	0	0	
1151	1	1	1	1					1	1	0	0	1	0	0	0	0	
1152	1	1	1	1					1	1	0	0	1	0	0	0	0	
1161	1	1	1	1					1	1	0	0	1	0	0	0	0	
1162	1	1	1	1					1	1	0	0	1	0	0	0	0	
1171	1	1	1	1					1	1	0	0	1	0	0	0	0	
1172	1	1	1	1					1	1	0	0	1	0	0	0	0	
1181	1	1	1	1					1	0	0	0	1	0	0	0	0	
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1312	1	1	1	1	1	1	0	0	1	0
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1322	1	1	1	1	1	1	1	0	1	0
1331	1	1	1	1	1	1	0	0	1	0
1332	1	1	1	1	1	1	0	0	1	0
1341	1	1	1	1	1	1	1	0	1	0
1342	1	1	1	1	1	1	1	0	1	0

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