Optimal Time following Fluorescein Instillation to Evaluate Rigid Gas Permeable Contact Lens Fit

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ABSTRACT:

Purpose: To examine the optimum time at which fluorescein patterns of gas permeable lenses (GPs) should be evaluated.

Methods: Aligned, 0.2mm steep and 0.2mm flat GPs were fitted to 17 patients (aged 20.6 ± 1.1 years, 10 male). Fluorescein was applied to their upper temporal bulbar conjunctiva with a moistened fluorescein strip. Digital slit lamp images (CSO, Italy) at 10x magnification of the fluorescein pattern viewed with blue light through a yellow filter were captured every 15s. Fluorescein intensity in central, mid peripheral and edge regions of the superior, inferior, temporal and nasal quadrants of the lens were graded subjectively using a +2 to -2 scale and using ImageJ software on the simultaneously captured images.

Results: Subjectively graded and objectively image analysed fluorescein intensity changed with time ($p < 0.001$), lens region (centre, mid-periphery and edge: $p < 0.05$) and there was interaction between lens region with lens fit ($p < 0.001$). For edge band width, there was a significant effect of time ($F = 118.503$, $p < 0.001$) and lens fit ($F = 5.1249$, $p = 0.012$). The expected alignment, flat and steep fitting patterns could be seen from approximately after 30 to180s subjectively and 15 to 105s in captured images.

Conclusion: Although the stability of fluorescein intensity can start to decline in as little as 45 seconds post fluorescein instillation, the diagnostic pattern of alignment, steep or flat fit is

seen in each meridian by subjective observation from about 30s to 3 minutes indicating this is the most appropriate time window to evaluate GP lenses in clinical practice.

Keywords: rigid gas permeable (RGP); gas permeable (GP); fluorescein; fit evaluation

INTRODUCTION

Gas permeable lenses (GPs) were introduced in the late 1970s as an improvement on Polymethylmethacrylate (PMMA) material hard lenses that were impermeable to oxygen. Modern GPs tend to contain silicone and fluorine, resulting in greater flexibility and greater oxygen permeability.[1] Despite this, the International Survey of Rigid Contact Lens Fitting[2] has shown a decline in GP contact lens fits over the past 16 years. Reasons suggested for this decline include the initial lens discomfort, induced corneal pathology (such as 3 and 9 o'clock staining) and lid pathology (ptosis).[3-5] Modern soft contact lenses on the other hand provide excellent comfort[6] even to patients who haven't worn contact lenses before, and daily disposable lenses are very convenient for those who do not have time to clean their lenses. However, GPs still have their place on the market as they generally offer better quality and more stable vision, for example in patients with keratoconus[7] and patients with significant corneal astigmatism, especially if irregular.[8,9] GPs also have a much greater life expectancy than soft contact lenses,[9] are healthier than other forms of contact lens wear[10] and need replacing less often.[2]

The fit of hard contact lenses have been evaluated using fluorescein since their introduction in the 1950s.[11] It allows the practitioner to "assess the complex interactions between the eye and the lens".[12] This is not the case with soft contact lenses because they mould to the front surface of the eye so fit needs to be determined by other metrics[13] and fluorescein can be absorbed by the lens matrix, causing discolouration.[14]

The evaluation of an GP can be split into two sections; the dynamic fit of the lens, using white light and the fluorescein analysis, assessed using blue light and a yellow barrier filter.[11] According to a recent consensus group, fluorescein fit should be assessed in the primary position (the 'Primary Fluorescein Pattern'), rating the intensity of fluorescein in the central zone (which consists of the inner half of the radius, not including the very centre), mid-periphery (which consists of the outer half of the radius) and the edge curve (which is the

final band around the edge of the lens) on a scale from +2 to -2, along both the horizontal and vertical meridians.[11]

There is currently little research on the amount of time fluorescein remains in the eye after instillation and how this impacts on the observation of the lens fit. A study carried out by Peterson and colleagues (2006) investigated the efficacy of fluorescein in a clinical environment, using a 1% minim, 2% minim, a single drop of saline solution on a fluoret and a fluoret moistened with saline, with the excess shaken off.[15] Their results showed that quenching (when fluorescence is decreased by an excessive depth of fluorescein molecules decreases the vibration of surface molecules excited by the blue light) was present in all methods of fluorescein instillation and within 20 seconds a moistened fluoret and a 1% minim reached useful fluorescent levels, which lasted for 160 seconds. This was 2.5 times faster than the saturated fluoret and 2% minim, indicating a 1% minim or a moistened fluoret are the best ways to instil fluorescein for GP fitting. However, the persistence of fluorescein beneath a GP lens to allow evaluation of lens fit has not been investigated and was therefore the aim of this study.

METHODS

Seventeen patients (aged 20.6 ± 1.1 years, 10 males and 7 females) were recruited for this study whose best spherical component of their spectacle prescriptions ranged between +0.50DS and -5.50DS, had ≤0.75D of astigmatism (the steeper axis was orientated at a meridian between 80º and 100º) and whose eyes were healthy as determined by slit-lamp biomicroscopy examination. The validated Medmont E300 (Camberwell, Australia) corneal topographer was used to quantify the corneal curvature (K readings) of the right eye.[16] The K readings obtained were used to calculate the back optic zone radius of the alignment lens based on the formula: $K_{flattest}$ - ($K_{flattest}$ – $K_{steepest}$)/3. From the value calculated for the aligned lens (average 8.02 ± 0.25mm, range 7.65 to 8.40mm), 0.2mm steeper and flatter lenses (Quasar design from No7, Hasting, UK) were also fitted in random order within the hours of 10am to 4pm. The base curve step size was selected to encompass the range of fits that might be seen in clinical practice. Following 5 minutes initial settling time (as the patients were adapted GP wearers), the lens was observed by a masked observer using video slit lamp (CSO SL990 Digital LED Elite, Florence, Italy). The slit lamp was set up at 10x magnification, with its blue light at maximum brightness and slit width, and using the in-build yellow barrier filter in a dark room.

Sodium fluorescein was instilled into the superior temporal conjunctiva with a moistened fluorescein sodium strips (Bioglow, Rose Stone Enterprises, Alta Lorna, CA, USA). A drop of saline was used to moisten the strip and any excess moisture was shaken off.[15] Following the instillation, patients were instructed to blink a couple of times to help distribute the fluorescein.

Based on pilot data on the persistence of fluorescein during subjective and objective imaging and previous findings without GPs in-situ,[15] subjective imaging was graded every 30 seconds over 4 minutes whereas objective image capture was conducted every 15 seconds

over 2 minutes. Fluorescein was subjectively graded on a +2 to -2 scale, in the centre, mid-periphery and edge zones of each lens, along both the horizontal and vertical meridians.[10]

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The intensity of fluorescein was recorded objectively in the same zones as the subjective grading using ImageJ software (NIH.com, USA) on a 256 grayscale 8 bit intensity scale. An acetate template placed in front of the laptop screen was used as a guide to ensure that exactly the same area was analysed in each image. In addition to grading the intensity of fluorescein, the widths of the temporal and nasal fluorescein edge bands were measured using ImageJ following calibration by imaging an object of known size through the same slit-lamp set-up.

DATA ANALYSIS

Horizontal (nasal and temporal) and vertical (superior and inferior) data was averaged.[11] The subjectively rated fluorescein intensity was not normally distributed for any of the lens regions with meridian or fit (Kolmogorov-Smirnov $Z < 0.001$), hence repeated measure analysis of variance was conducted with Greenhouse-Geisser correction to compensate for this and post-hoc testing with Bonferroni to account for multiple comparisons. The objectively rated fluorescein intensity was normally distributed for the central ($Z = 0.542$, $p = 0.931$), mid-peripheral ($Z = 0.598$, $p = 0.867$) and edge ($Z = 0.543$, $p = 0.929$) lens regions as was the edge band width ($Z = 0.765$, $p = 0.752$), hence repeated measure analysis of variance was conducted to assessment effect of lens region, meridian (nasal, temporal, superior and inferior), lens fit (flat, alignment or steep) and time (0-120 seconds in 15 second steps). To detect a difference of 30 seconds with a standard deviation of 45 seconds, 80% power was achieved with a sample size of 17 subjects.

RESULTS

Subjective Rating

Overall, for the subjectively graded fluorescein intensity (Figure 1) there was a significant difference with time ($F = 61.052$, $p < 0.001$) and lens region (centre, mid-periphery and edge: $F = 148.309$, $p < 0.001$), but not lens fit (steep, alignment and flat: $F = 0.088$, $p = 0.916$) or meridian (vertical and horizontal: $F = 1.748$, $p = 0.204$). The only significant interactions were between lens region with time ($F = 6.584$, $p < 0.001$) and with lens fit ($F = 28.638$, $p < 0.001$). The time at which fluorescein intensity significantly ($p < 0.05$ with Bonferonni pot-hoc test) altered for each lens fit, lens meridian and lens region is presented in table 1.

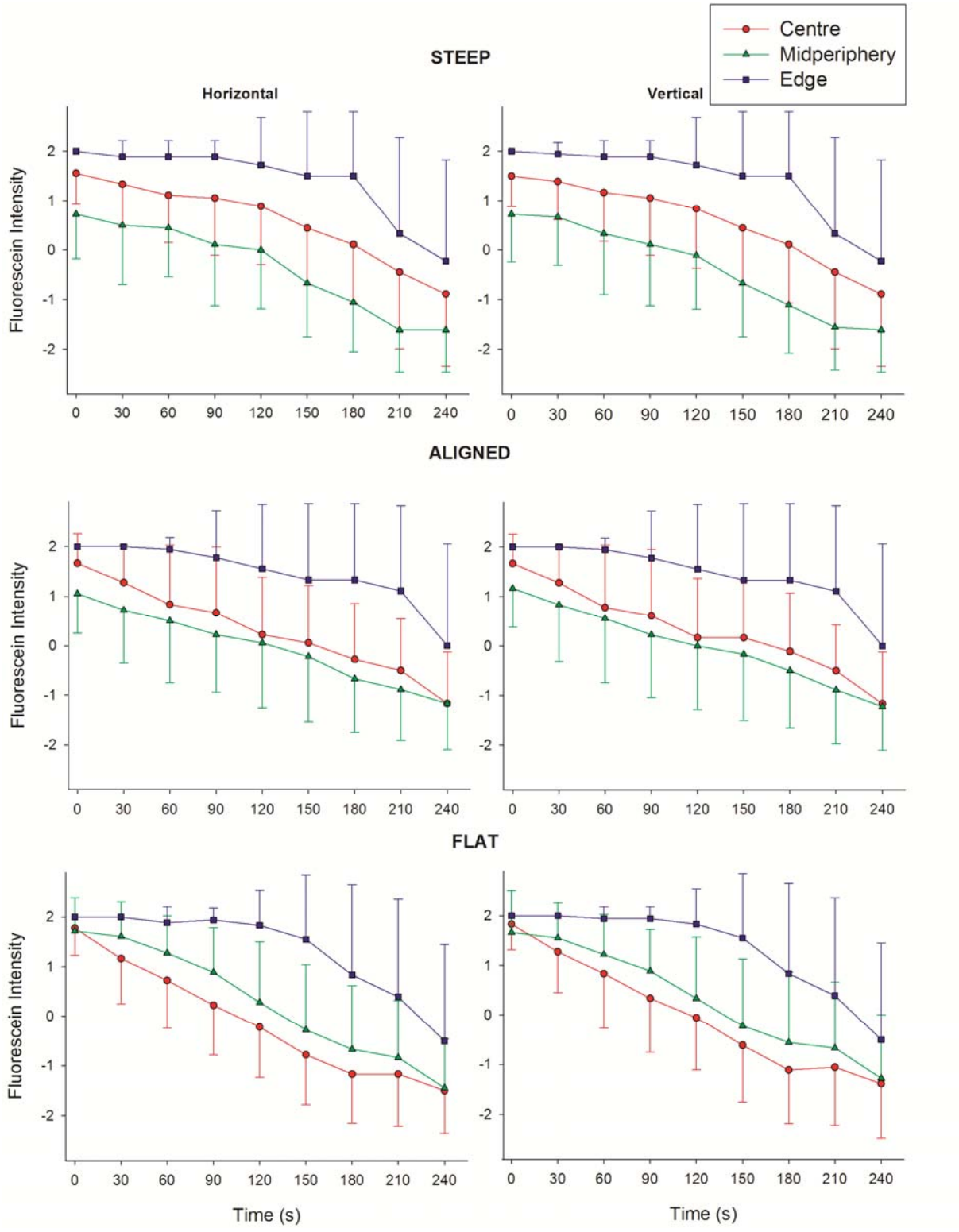

Figure 1: Subjective grading of fluorescein intensity on a +2 to -2 scale in the centre, midperiphery and edge zones of steep, aligned and flat gas permeable contact lenses in the horizontal and vertical meridian. Error bars = 1 S.D. n = 17.

Fit	Meridian	Region	Time when significant change in fluorescein intensity (s)	
			Subjective	Objective
Flat	Vertical	Centre	180	60
		Mid-periphery	150	60
		Edge	210	75
	Horizontal	Centre	180	60
		Mid-periphery	150	45
		Edge	210	120
Aligned	Vertical	Centre	90	120
		Mid-periphery	120	90
		Edge	210	>120
	Horizontal	Centre	90	120
		Mid-periphery	120	105
		Edge	210	120
Steep	Vertical	Centre	120	>120
		Mid-periphery	150	>120
		Edge	240	>120
	Horizontal	Centre	120	>120
		Mid-periphery	150	>120
		Edge	240	>120

Table 1: The time at which fluorescein intensity analysed by subjective grading or by objective image analysis significantly altered for each lens fit, lens meridian and lens region based on subjective grading. N = 17

Objective Image Analysis

Overall, for the objectively image analysed fluorescein intensity (Figure 2) there was a significant difference with time ($F = 114.336$, $p < 0.001$), lens region (centre, mid-periphery and edge: $F = 4.014$, $p = 0.028$) and meridian ($F = 22.163$, $p < 0.001$), but not lens fit (steep, alignment and flat: $F = 0.302$, $p = 0.742$). There were significant interactions between the lens variables (Table 2).

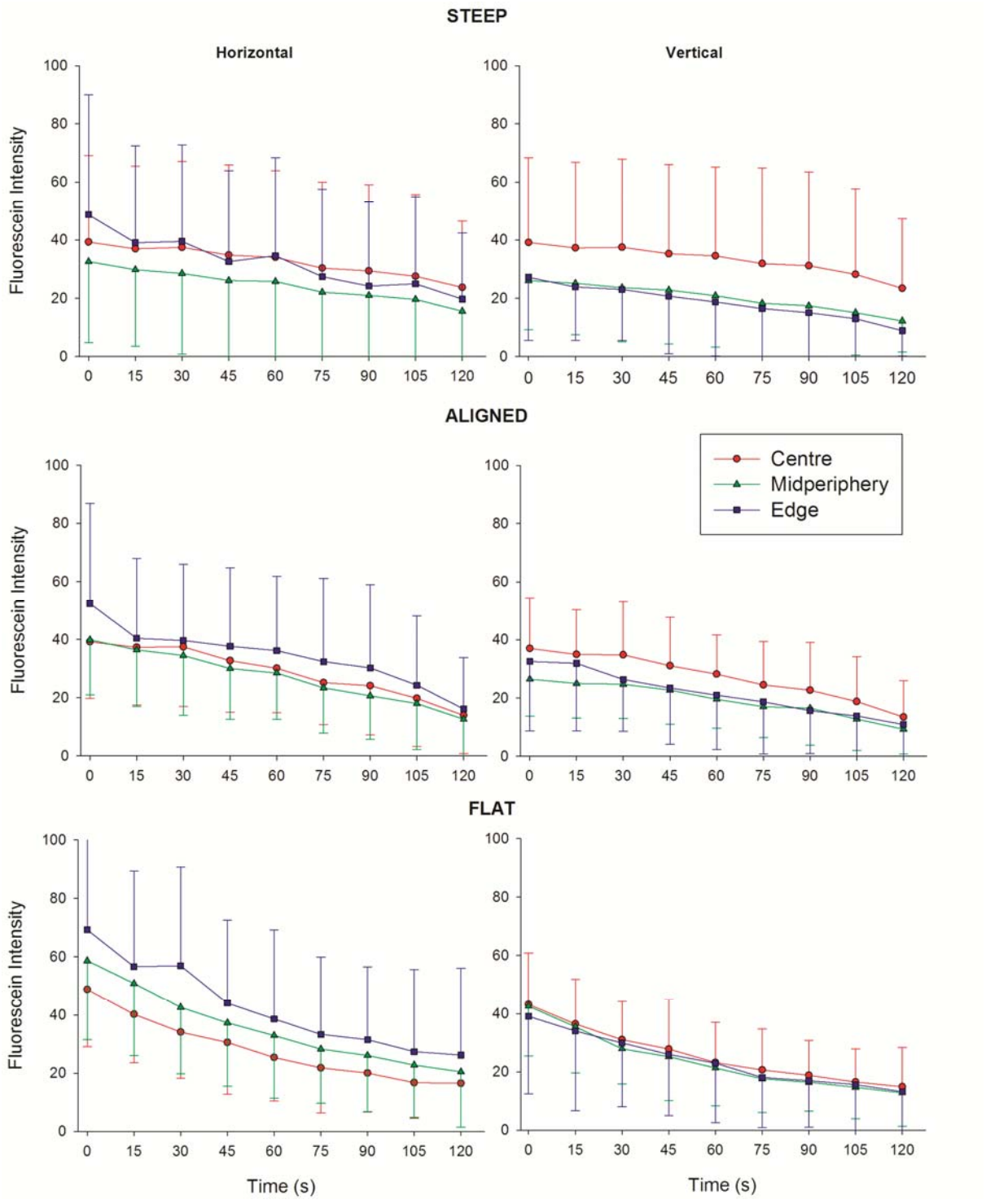

Figure 2: Objective image analysis of fluorescein intensity out of 256 greyscales in the centre, midperiphery and edge zones of steep, aligned and flat gas permeable contact lenses in the horizontal and vertical meridian. Error bars = 1 S.D. n = 17.

	Lens region	Lens meridian	Lens fit	Time
Lens region		F = 9.358 P < 0.001	F = 7.813 P < 0.001	F = 2.371 P = 0.003
Lens meridian			F = 3.554 P = 0.003	F = 4.839 P < 0.001
Lens fit				F = 6.769 P < 0.001

Table 2: Interaction between lens region, lens meridian, lens fit, and time with objective image analysis of fluorescein intensity. N = 17

The time at which objectively analysed fluorescein intensity significantly ($p < 0.05$ with Bonferonni pot-hoc test) altered for each lens fit, lens meridian and lens region is presented in table 1.

For edge band width (Figure 3), there was a significant effect of time ($F = 118.503$, $p < 0.001$), lens fit ($F = 5.1249$, $p = 0.012$), but not meridian ($F = 4.271$, $p = 0.055$), although there was an interaction between lens fit and meridian ($F = 4.266$, $p = 0.023$) as well as between lens fit and time ($F = 3.803$, $p < 0.001$).

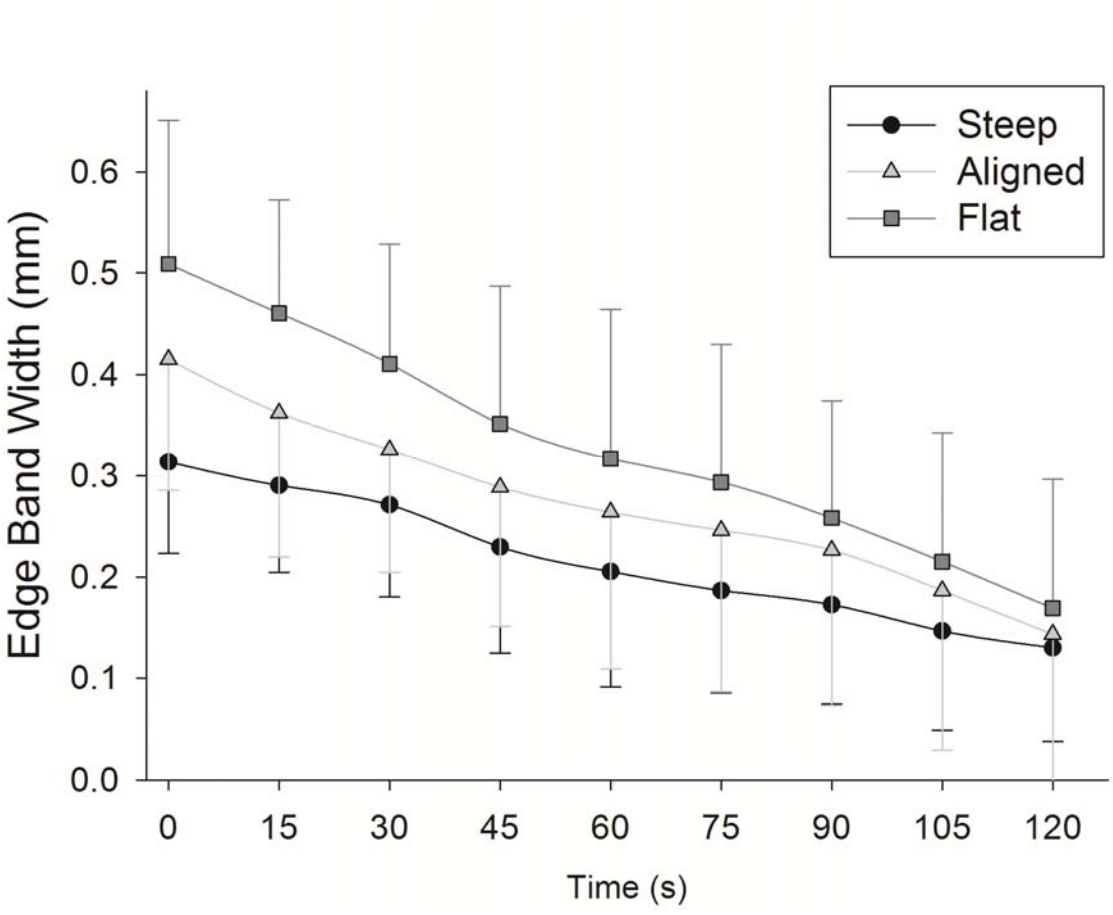

Figure 3: Objective image analysis of horizontal edge band width of steep, aligned and flat gas permeable contact lenses. Error bars = 1 S.D. n = 17.

DISCUSSION

The aim of this study was to measure the persistence of fluorescein beneath a GP lens to indicate the optimum time that this should be assessed. The fluorescein patterns of the lenses designed to be in alignment, 0.2mm flatter and 0.2mm steeper than alignment, demonstrated the typical characteristic features of each lens fit. Along the horizontal meridian, aligned lenses had minimal visible fluorescein in the centre and mid-periphery and an edge band of around 0.25mm after 1 minute post fluorescein instillation. Flat fitting lenses had minimal fluorescein in the centre, a high intensity of fluorescein in the mid periphery and an edge band of on average 0.32mm after 1 minute, merging with the peripheral fluorescein pooling. Steep fitting lenses showed high intensity of fluorescein in the centre, minimal fluorescein in the mid periphery and a narrow edge band of on average 0.20mm after 1 minute. In the objective analysis, but not the subjective, the vertical meridian showed some off-centre pooling, greater with the steep lens due to the gap between the ocular surface and the lens in this meridian, to virtually none with the flat lens where the lens was fitting this meridian. As the subjects had up to 0.75D of with the rule astigmatism, one would expect higher intensity of fluorescein in the vertical meridian and the fact it was only noted in the off-centre position and not mid-periphery might have been due to quenching. This hypothesis is supported by the lower fluorescein edge band intensity in this median compared to the horizontal meridian.

Statistical analysis of the data revealed fluorescein intensity patterns were stable for at least 150s for a flat fitting lens, 90s for an aligned lens and 120 s for a steep fitting lens. Video capture of fluorescein pattern for objective analysis was not as sensitive due to the fill-factor of the CMOS sensor, the light lost through the beam splitter and the superior human retinal sensitivity compared to the slit-lamp camera.[17] However objective image analysis supported the subjective findings on when changes in the fluorescein intensity could first be detected except for the flat fitting lens where fluorescein intensity as measured objectively in some central and mid-peripheral areas were stable for as little as 45s. The reduced stability of

fluorescein intensity would be expected to be poorer in the flat fitting lens due to less peripheral contact of the lens peripheral surface with the ocular surface, impeding the flow of fluorescein behind the lens. The reduction in fluorescein persistence for image capture was similar to that previously found with no lens in place using the same imaging system suggesting lens movement and adaptation had little effect on overall tear flow in this patient cohort.[15]

However, clinically, the relative fluorescein pattern across the centre, mid-peripheral and edge bands is more important than the individual stability of fluorescein intensity within these bands. As can be seen in figures 1 and 2, the expected alignment, flat and steep fitting patterns could be seen from approximately after 30 to180s subjectively and 15 to 105s in captured images. Hence this indicates the window for clinical evaluation of a GP fluorescein fit pattern. Quenching has been shown to affect the observation of fluorescein for the first 20s post instillation,[15] explaining the time for the GP fluorescein pattern to first become clear.

The lenses used in this experiment were spherical and of just one design, so the GP fluorescein evaluation time window might differ slightly with aspheric or different multi-curve designs. Patients were adapted wearers, so the allowed settling time was short, both of which could affect the fluorescein persistence time. Environmental conditions and the time of assessment were controlled within the study, but aspects such as lighting levels could affect the tear film and influence fluorescein persistence. Despite the methodology of moistening the fluoret and flicking off the excess before placing the flat side against the bulbar upper temporal conjunctiva for a period of about 2s, the amount of fluorescein instilled will have differed between applications; however this is the clinical situation and was therefore deemed appropriate for this study. The wavelength of the blue light and yellow filter used to observe the fluorescein along with the form of the fluorescein and the observation skills of the observer will also affect the apparent persistence.[15] It should also be noted that as

camera technology improves, the reduced window of observation of the objective analysis compared to subjective analysis is likely to decrease.

In conclusion, although the stability of fluorescein intensity can start to decline in as little as 45 seconds post fluorescein instillation, the diagnostic pattern of alignment, steep or flat fit is seen by direct observation in each meridian from about 30s to 3 minutes indicating this is the most appropriate time window to evaluate GP lenses in clinical practice.

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