Investigating the utility of clinical assessments to predict success with presbyopic contact lens correction

Sivardeen Ahmed DOptom,[1,2] Laughton Deborah PhD,[1] Wolffsohn James S PhD.[1]

1) Ophthalmic Research Group, School of Life and Health Sciences, Aston University, Birmingham, United Kingdom
2) Specsavers, New Malden, London, United Kingdom

Corresponding Author

J.S. Wolffsohn, Ophthalmic Research Group, School of Life and Health Sciences, Aston University, Birmingham, United Kingdom

Email: j.s.w.wolffsohn@aston.ac.uk

Tel: +44 (0) 121 204 4140
Fax: +44 (0) 121 204 4048

Abstract

Purpose: To determine the utility of a range of clinical and non-clinical indicators to aid the initial selection of the optimum presbyopic contact lens. In addition, to assess whether lens preference was influenced by the visual performance compared to the other designs trialled (intra-subject) or compared to participants who preferred other designs (inter-subject).

Methods: A double-masked randomised crossover trial of Air Optix Aqua multifocal, PureVision 2 for Presbyopia, Acuvue OASYS for Presbyopia, Biofinity multifocal and monovision was conducted on 35 presbyopes (54.3±6.2 years). Participant lifestyle, personality, pupil characteristics and aberrometry were assessed prior to lens fitting. After 4 weeks of wear, high and low contrast visual acuity (VA) under photopic and mesopic conditions, reading speed, Near Activity Visual Questionnaire (NAVQ) rating, subjective quality-of-vision scoring, defocus curves, stereopsis, halometry, aberrometry and ocular physiology were quantified.

Results: After trialling all the lenses, preference was mixed (n=12 Biofinity, n=10 monovision, n=7 Purevision, n=4 Air Optix Aqua, n=2 Oasys). Lens preference was not dependent on personality ($F=1.182$, $p=0.323$) or the hours spent working at near ($p=0.535$) or intermediate ($p=0.759$) daily. No intersubject or strong intrasubject relationships emerged between lens preference and reading speed, NAVQ rating, halo size, aberrometry or ocular physiology ($p>0.05$).

Conclusions: Participant lifestyle and personality, ocular optics, contact lens visual performance and ocular physiology provided poor indicators of the preferred lens type after 4 weeks of wear. This is confounded by the wide range of task visual demands of presbyopes and the limited optical differences between current multifocal contact lens designs.

Key words: Contact lenses; multifocal; simultaneous images; monovision; presbyopia

Introduction

Presbyopic contact lenses offer a versatile vision correction option for presbyopic individuals, who are reportedly becoming increasingly more active than their predecessors [1]. However, an international survey reporting data from 2005-9 revealed the majority of presbyopic contact lens patients were fitted with non-presbyopic corrections [2], perhaps suggesting eye care practitioner awareness, fitting skills or confidence in presbyopic contact lens performance may be deficient. Indeed, data suggest it is unwise to rely on initial consulting room tests to predict the success of presbyopic contact lens options [3, 4], at least for older designs. Therefore, the utility of additional indicators, clinical and/or non-clinical, to aid the initial selection of the optimum presbyopic lens would be beneficial, reducing the presbyopic contact lens drop-out rate and minimising chair time.

In addition to routine contact lens fit data (including pupil size), ocular aberrations may also influence presbyopic contact lens performance and acceptance [5-7]. Simultaneous image design multifocal contact lenses induce concentric zones of varying power or transition in power within the pupil, altering aberrations [8]. Centre-near multifocal contact lenses typically induce negative spherical aberration, whereas centre -distance multifocal contact lenses induce positive spherical aberration [7]. However, the retinal image is created from the combination of ocular aberrations in combination with the lens design, so the patient's pre-existing ocular aberration may influence the preference and performance of multifocal contact lens designs.

Potentially important non-clinical indicators may include patient lifestyle and personality. For example, an individual who plays tennis regularly is likely to prefer multifocal contact lenses when compared to monovision contact lenses due to the superior stereoacuity afforded by multifocal contact lens designs [9, 10]. Assessment of patient personality may also help to determine patient motivation and the likelihood of accepting a compromise in distance vision to gain intermediate or near clarity [11-13]. Individuals who are easy going and optimistic are the most likely candidates for presbyopic contact lens success [13].

The main aim of this study was to determine the utility of a range of clinical and non-clinical indicators to aid the initial selection of the optimum presbyopic lens. In addition, secondary investigations were conducted to determine whether lens preference was influenced by the visual performance of the preferred lens compared to participants who preferred other designs (inter-subject) or compared to participants who preferred other designs (inter-subject).

Method

The study design was a double-masked randomised controlled crossover trial, which was approved by the Aston University Ethics Committee and was conducted in accordance with the tenets of the Declaration of Helsinki. Thirty-five presbyopic patients (77% female) with a mean age of 54.3 ± 6.2 years (range 42 to 65 years) and a spectacle refraction of between -8.00 and +3.25D with +1.25 to +2.50D near addition were recruited from a community optometric practice in the South West of London to participate in the study. Participants were screened to exclude those with a positive history of systemic disease, ocular disease or abnormalities (including corneal endothelial dystrophy, guttata, recurrent corneal erosion), corneal surgery, lenticular opacities, intraocular surgery, astigmatism >0.75D, amblyopia (>0.1 logMAR difference in visual acuity between eyes), heterotropia or anisometropia (> 1.00 D mean spherical equivalent difference between eyes)). Informed written consent was obtained from all the participants after an explanation of the nature and possible consequences of the study. Ocular examination revealed all participants attained ≤0.00 logMAR distance visual acuity in each eye and had no binocular vision abnormalities. Seven of the cohort were neophytes and of the 28 (80%) currently wearing contact lenses, two had previously worn presbyopic contact lenses; however no one had previously worn the contact lenses trialled in the present investigation.

Assessment of lifestyle and personality

Prior to contact lens fitting, each participant completed a questionnaire designed to determine the lifestyle of each participant and included questions from previous multifocal contact lens and refractive error studies [9, 14, 15]. The questions examined whether the participant worn glasses (no, only for some tasks at these distances, sometimes, all of the time), the time participants spent conducting near and intermediate tasks on average each day and the relative importance of performing tasks as these distances without glasses (very important, important or not important), the distance they held a book (close to their face, chest level or in their lap), roughly how far away did they do intermediate tasks such as reading (position indicated measured in centimetres), whether they drove at night (no, occasionally, nightly, as a profession) and visual activities conducted on a regular basis (and whether they desired to perform these without glasses, Figure 1). A personality assessment was also incorporated into the questionnaire by asking the participant to self-report their personality traits on a linear 0 to 10 scale, where 0 represented easy going and 10 represented a perfectionist. This question was taken from the one item previously found to influence monovision choice from Cattell's 16 Personality Factor (16 PF) test.[16]

Assignment of contact lenses

After a full eye examination, participants were randomly assigned to be initially fitted with either Air Optix Aqua multifocal (Alcon, Texas, USA), PureVision 2 for Presbyopia multifocal (Bausch & Lomb, New York, USA), Acuvue OASYS for Presbyopia (Vistakon, Division of Johnson & Johnson Vision Care, Florida, USA), Biofinity multifocal (CooperVision, New York, USA) or monovision with Biofinity single vision (CooperVision, New York, USA) contact lenses. Each lens was strictly fitted according to each respective lens manufacturer’s guidelines. Biofinity was the only design where for the higher adds of +2.00D and +2.50D, a different design is recommended (centre distance in the dominant eye and centre near in the non-dominant eye) in each eye. Eye dominance (sensory) was established by three successive consistent trials of the eye that resulting in greatest uncomfortably blurred visual percept when blurred with a +1.50D lens being the dominant eye.[17] Participants trialling monovision were fitted with a contact lens to correct their distance refractive error in their dominant eye, and the near prescription in the contralateral eye. The participant remained masked as to which lens design they had been prescribed, and were provided with the contact lenses in an unmarked case by an unmasked practitioner. All the participants were provided with a supply of preservative-free multi-purpose solution and case (Synergi, Sauflon, Twickenham, UK) and talked through the cleaning regimen including rubbing and rinsing. Participants were asked to wear the contact lenses each day for as long as possible, up to a maximum of 12 hours per day, for 4 weeks. After 4 weeks of contact lens wear, each participant returned for an assessment of visual function and ocular physiology before being randomly assigned the next lens type (no wash-out period as lenses assessed after a month's wear when there are unlikely to be any residual effects of previous lens wear) . All participants wore all lenses and the fitting was conducted at the beginning of the months wear.

Assessment of visual function and ocular physiology

A second researcher, who was masked to the lens design and brand worn, conducted the 4 week assessment after the participant had worn the lenses for at least 3 hours that day. The assessments of each lens type were scheduled at the same time of day ± 1 hour for each participant.

Binocular high (95%) and low (12.5%) contrast distance visual acuity was measured using a 6 m computerized logMAR chart (David Thomson Chart 2000, IOO Marketing, London, UK) under both photopic (85 cd/m^2) and mesopic (5 cd/m^2) lighting conditions. Reading speed and critical print size were evaluated with a mobile app reading speed test [8]. Subjective evaluation of near visual ability was assessed with the Near Activity Visual Questionnaire (NAVQ) [9] and participants rated their quality of vision on a 10-point scale (10 being excellent) when viewing an iPhone 4S apps navigation screen for 30s (Apple, Cupertino, CA, USA) held at their habitual working distance under 85 cd/m^2 lighting conditions.

Defocus curves were measured binocularly over the range of +1.50DS to -5.00DS in 0.50DS steps, with randomised logMAR high contrast letter sequences and lens presentation.[20] Stereoacuity was assessed binocularly using the TNO random dot stereogram test held at 40cm (Lameris Ootech B.V., Nieuwegein, Holland). Halometry was used to quantify the radial glare in 8 meridians around a light source [21]. Aberrometry was measured using a KR-1W Wavefront Analyzer (Topcon, Tokyo, Japan) with and without a contact lens *in situ*. The aberrometer also measured the pupil size with the in-build camera and calculated the decentration of the pupil (direction and magnitude) relative to the visual axis.

Slit lamp biomicroscopy was performed at each 4 week visit after lens removal to evaluate bulbar, limbal and the palpebral hyperaemia (with lid eversion) and the corneal staining (with fluorescein), graded using the Efron grading scale in 0.5 steps.

After trialling all 5 contact lenses, participants were asked to choose their preferred presbyopic correction (i.e. “no preference” was not an option).

Statistical analysis

Data from the right eye only was included in analysis of all parameters except for aberrations and pupil size, where the analysed eyes were grouped as ocular dominant or non-dominant. Mean ± a standard deviation are reported in the text and tables. Failure to correctly recognize plate IV on the TNO stereopsis test was allocated a score of 540 minutes of arc, one step between plates below plate IV. The repeated measures design allowed sufficient degrees of freedom for the analyses to be powered even with only a few participants preferring some lens designs [22]. However, when comparing individual visual performance measures only Biofinity, Purevision 2 and monovision had sufficient numbers preferring each of these presbyopic lens options to allow comparison.

Lifestyle characteristics were found to be not normally distributed (Kolmogorov-Smirnov test $p<0.05$), therefore non-parametric rank analysis of variance (Independent samples Kruskal-Wallis distribution comparison Test) was conducted. Baseline pupil parameters, aberrations, age, computer working distance and near addition power were found to be normally distributed (Kolmogorov-Smirnov test p>0.05), therefore parametric repeated measures analysis of variance was conducted.

Pupil measurements, defocus acuities and aberrations after 4 weeks were found to be normally distributed (Kolmogorov-Smirnov test $p > 0.05$), therefore parametric t-tests or repeated measures analysis of variance was conducted. For the other metrics, Friedman non-parametric testing was employed. SPSS Version 20 (IBM Corporation, New York, USA) was used.

The cohort was divided according to overall lens preference to compare whether lens preference was influenced by the visual performance compared to the other designs trialled (intra-subject) or compared to participants who preferred other designs (inter-subject).

Results

All participants completed the student and reported achieving at least 8 hours wearing time each day.

Contact lens preference

At the end of the study, 10 participants (29%) preferred monovision, 12 (34%) preferred Biofinity, 7 (20%) preferred Purevision, 4 (11%) preferred Air Optix Aqua and 2 (6%) preferred Oasys multifocal contact lenses. As the least preferred options, Air Optix Aqua and Oasys lenses were excluded from subsequent analysis.

Baseline Data Predictive Ability

- ***Demographics***

No difference in contact lens preference emerged based on gender (*p*=0.756), age (F = 1.761; p = 0.192), refractive error (F = 2.117; p = 0.141) or magnitude of the near addition power (F=0.137, *p*=0.967)

- ***Lifestyle***

All participants reported using glasses at least some of the time before the study with the median usage reported to be 'all of the time'. Participants self-reported conducting near tasks for 4.1 ± 2.1 hours and intermediate tasks for 5.6 ± 2.3 hours per day and graded both tasks as "important" (median rating). Books were most commonly held at chest level (median rating) and computer screens were estimated to be set a distance of 55 ± 15 cm from the participant. Night driving was reported to be undertaken 'occasionally' (median rating). Contact lens preference was not related to reported glasses usage (*p*=0.117), the importance of near (*p*=0.287) or intermediate (*p*=0.346) work or the hours spent working at near (*p*=0.535) or intermediate (*p*=0.759) per day , the distance of book reading (*p*=0.350), their intermediate working distance (1.927, *p*=0.132) or their night driving status (*p=0.793*).

Considering the activities performed by over 80% of participants (Figure 1), contact lens preference was not dependent on whether participants read newspapers/books (*p*=0.629), drove during the day (*p*=0.285) or night (*p*=0.858), dined in restaurants (*p=0.611*), used a computer (*p*=0.702), cooked (*p*=0.382), shopped (*p*=0.899), used a mobile phone (*p*=0.983), did paperwork (*p*=0.194 or watched movies (*p*=0.415).

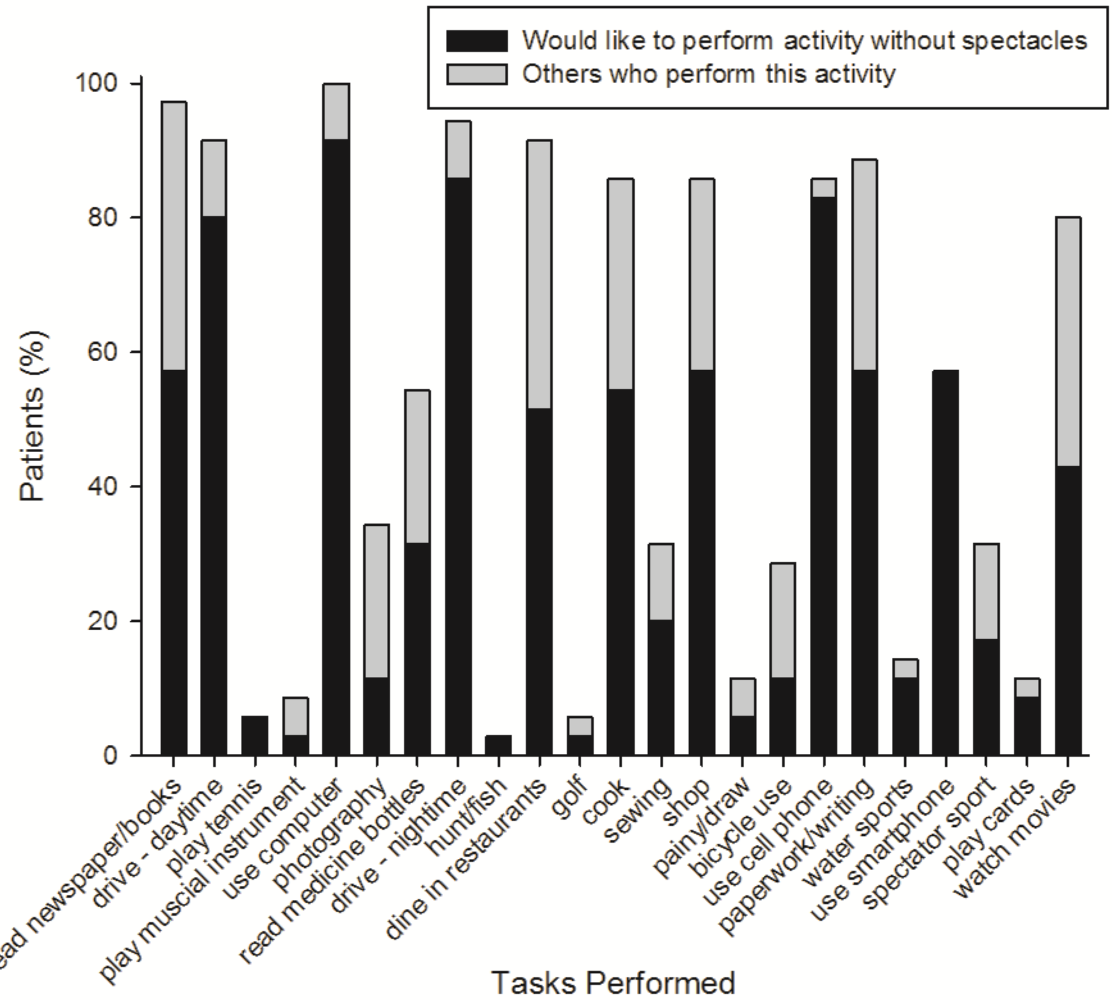

Figure 1: Proportion of participants who perform each activity listed (complete bar) and the percentage of participants who would like to perform each activity without glasses (dark portion of bar). N=35.

- ***Personality***

Most participants rated their personalities as grade 6 (median, range 2-10), indicating a leaning towards participants considered themselves to have perfectionist traits. Personality grading was not indicative of presbyopic contact lens preference (F=1.182, *p*=0.323).

- ***Pupil size and decentration***

Contact lens preference was not dependent on pupil size (F=0.910, *p*=0.471) or ocular dominance (F=1.174, *p*=0.342). The pupil of the dominant eye was significantly larger than the pupil of the non-dominant eye (5.27 ± 0.99 mm versus 5.08 ± 1.01 mm; F=4.206, *p*=0.049). Additionally, contact lens preference was not dependent on pupil decentration (magnitude and direction) relative to the visual axis (F=0.641, *p*=0.638) and no interaction with ocular dominance was exhibited (F=0.435, *p*=0.782).

- ***Aberrations***

Naked eye aberrations were not predictive of contact lens preference (Table 1).

Aberrations	**Overall**		**With eye dominance**		**With optical component (cornea, lens, whole eye)**	
	F value	***p value***	**F value**	***p value***	**F value**	***p value***
Astigmatism	1.535	0.217	1.416	0.253	1.196	0.317
Higher Order Aberrations	0.703	0.596	1.266	0.305	0.591	0.782
3rd Order Aberrations	0.673	0.616	1.267	0.305	0.601	0.774
4th Order Aberrations	0.882	0.486	1.199	0.332	0.907	0.517
Trefoil	0.689	0.605	1.203	0.33	0.939	0.492
Coma	0.598	0.667	1.308	0.29	0.746	0.651
Tetrafoil	1.001	0.423	1.717	0.172	1.38	0.224
2nd Order Astigmatism	1.04	0.403	0.88	0.488	0.887	0.533
Spherical	1.225	0.321	0.415	0.797	0.919	0.508

Table 1: Analysis of variance (ANOVA) results comparing naked eye ocular aberrations according to contact lens preference.

Is contact lens preference based on an individual's better performance with this lens compared to other designs (intra-subject) or better performance with a particular lens design compared to other participants (inter-subject)?

- ***Visual acuity***

Visual acuity after 4 weeks of adaptation was not related to inter-subject contact lens preference (Table 2), apart from one instance at low contrast under photopic conditions, where the visual acuity of participants who preferred Purevision 2 multifocal lenses was superior to the visual acuity of the remaining cohort attained wearing Purevision 2 lenses. The only intra-subject difference was at high contrast under photopic conditions, where participants who preferred the Biofinity multifocal lenses attained significantly better visual acuity than achieved wearing the other lenses trialled (Table 2). Inter-subject differences represent a comparison between the metrics of participants who preferred one lens type compared to the remaining cohort who did not prefer the lens. Intra-subject differences represent comparisons between the metrics of each participant who preferred one lens type compared to their results attained wearing the other lens types. A bold significance value indicates statistical significance.

	Binocular BDCVA (logMAR)	Photopic CS 95% (logMAR)	Photopic CS 12.5% (logMAR)	Mesopic CS 95% (logMAR)	Mesopic CS 12.5% (logMAR)	Stereopsis (min/arc)
			Biofinity Multifocal			
Preferred n=12	0.04 ± 0.11	0.04 ± 0.11	0.18 ± 0.11	0.06 ± 0.13	0.23 ± 0.16	200.0 ± 141.5
Non-preferred n=23	0.11 ± 0.15	0.11 ± 0.15	0.29 ± 0.20	0.15 ± 0.23	0.33 ± 0.28	231.7 ± 106.2
Significance of inter-subject differences	0.179	0.077	0.179	0.248	0.224	0.460
Significance of intra-subject differences	0.494	**0.024**	0.521	0.132	0.182	**0.029**
			Purevision 2 Multifocal			
Preferred n=7	0.07 ± 0.15	0.07 ± 0.10	0.12 ± 0.14	0.09 ± 0.14	0.22 ± 0.12	252.9 ± 91.4
Non-preferred n=28	0.08 ± 0.09	0.08 ± 0.15	0.25 ± 0.11	0.14 ± 0.12	0.29 ± 0.12	255.0 ± 113.6
Significance of inter-subject differences	0.777	0.887	**0.007**	0.352	0.196	0.963
Significance of intra-subject differences	0.595	0.067	0.311	0.459	0.495	**0.038**
			Monovision			
Preferred n=10	0.05 ± 0.10	0.06 ± 0.09	0.22 ± 0.11	0.10 ± 0.15	0.23 ± 0.16	309.0 ± 131.2
Non-preferred n=25	0.05 ± 0.08	0.05 ± 0.10	0.19 ± 0.15	0.08 ± 0.10	0.22 ± 0.11	351.6 ± 140.0
Significance of inter-subject differences	0.999	0.855	0.615	0.566	0.887	0.414
Significance of intra-subject differences	0.245	0.567	0.469	0.255	0.704	**0.050**

Table 2: Mean ± standard deviation binocular best distance corrected visual acuity (BDCVA), acuity at high (95%) and low (12.5%) contrast under photopic and mesopic conditions and stereopsis in participants preferring Biofinity multifocal lenses, Purevision 2 lenses and monovision lenses.

Reading

No difference in reading speed emerged between participants who preferred Biofinity multifocal lenses (155.3 ± 17.8 wpm versus 154.3 ± 24.4 wpm; *p*=0.897) or Purevision 2 multifocals (147.0 ± 17.7 wpm versus 157.5 ± 20.9 wpm; *p*=0.231) or monovision lenses (159.1 ± 20.3 wpm versus 160.5 ± 24.4 wpm; *p*=0.877) when individually compared to the rest of the cohort who did not prefer each particular lens type (inter-subject). Critical print size (CPS) of participants preferring Biofinity multifocal lenses was significantly smaller than those who preferred the other lenses (0.13 ± 0.11 logMAR versus 0.28 ± 0.15 logMAR; p=0.004), however the same relationship was not observed in participants who preferred the Purevision 2 (0.30 ± 0.12 logMAR versus 0.30 ± 0.18 logMAR; p=0.999) or monovision (0.22 ± 0.14 logMAR versus 0.22 ± 0.18 logMAR; p=0.951) lenses when individually compared to the rest of the cohort who did not prefer each particular lens type.

Considering intra-subject differences, the reading speed and CPS of participants who preferred the Biofinity multifocal (reading speed p=0.867; CPS p=0.891) or Purevision 2 multifocal (reading speed p=0.717; CPS p=0.074) or monovision lenses (reading speed p=0.202; CPS p=0.272) was not significantly different to the results attained whilst each participant wore the other contact lens trialled.

Subjective near evaluation

There was no difference in NAVQ rating (34.0 ± 16.7 versus 42.9 ± 16.8; p=0.146), iPhone image clarity (7.8 ± 1.7 versus 7.3 ± 2.6; p=0.496) or the distance at which the iPhone was held (39.6 ± 7.5 cm versus 39.3 ± 5.9 cm; p=0.890) between participants who preferred Biofinity lenses to those who did not (inter-subject). Considering the participants who preferred the Purevision 2 multifocal, there was also no difference in NAVQ rating of near performance (36.2 ± 16.3 versus 43.3 ± 24.7; p=0.477), iPhone image clarity (7.6 ± 2.5 versus 6.4 ± 2.5; p=0.273) or the distance at which the iPhone was held (39.9 ± 7.1 cm versus 39.3 ± 6.3 cm; p=0.826) between those preferring this lens type and those who did not. Additionally, there was no difference in NAVQ rating of near performance (39.9 ± 16.5 versus 46.0 ± 19.3; p=0.387), iPhone image clarity (8.0 ± 1.5 versus 7.1 ± 2.2; p=0.256) or the distance at which the iPhone was held (38.5 ± 4.7 versus 39.7 ± 7.0; p=0.617) between those preferring monovision to those who did not.

Intra-subject comparison revealed no significant difference in NAVQ rating amongst participants who preferred Biofinity multifocal lenses (p=0.534) or Purevision 2 lenses (p=0.873) or monovision lenses (*p*=0.272) when compared to the results attained when the same participants wore the other lenses trialled (intra-subject). No significant difference in iPhone image quality was reported amongst participants who preferred Purevision 2 (*p*=0.276) or monovision lenses (*p*=0.459), however iPhone image clarity reported by participants who preferred the Biofinity multifocal lenses was superior to the level attained when the same participants wore monovision lenses (*p*=0.025).

Defocus Curves

Participants who preferred Biofinity multifocal lenses did not demonstrate significantly different defocus curve profiles to participants who preferred the other lens types (F=1.246, *p*=0.272; inter-subject) and no interaction was present with the level of defocus (F=0.475, *p*=0.915). Participants who preferred Purevision 2 multifocal lenses also had similar defocus curve profiles to participants who preferred the other lens types (F=0.259, *p*=0.720), and no interaction existed with the level of defocus (F=0.471, *p*=0.940). However, participants who preferred monovision lenses had significantly different defocus curve profiles to the remaining cohort when they wore monovision lenses (F=4.102, *p*=0.001; Figure 2), and an interaction was present with the level of defocus (F=2.127, *p*=0.012).

No significant intra-subject differences emerged based on the defocus curve profile or level of defocus attained whilst each participant wore their favourite lens type when compared to when they wore the other lens types (Biofinity multifocals: defocus curve profile F=1.418, *p*=0.280, level of defocus F=1.254, *p*=0.200; Purevision 2 multifocal: defocus curve profile F=2.719, *p*=0.088, level of defocus F=1.312, *p*=0.147; monovision lenses: defocus curve profile F=0.426, *p*=0.659, level of defocus F=1.428, *p*=0.088).

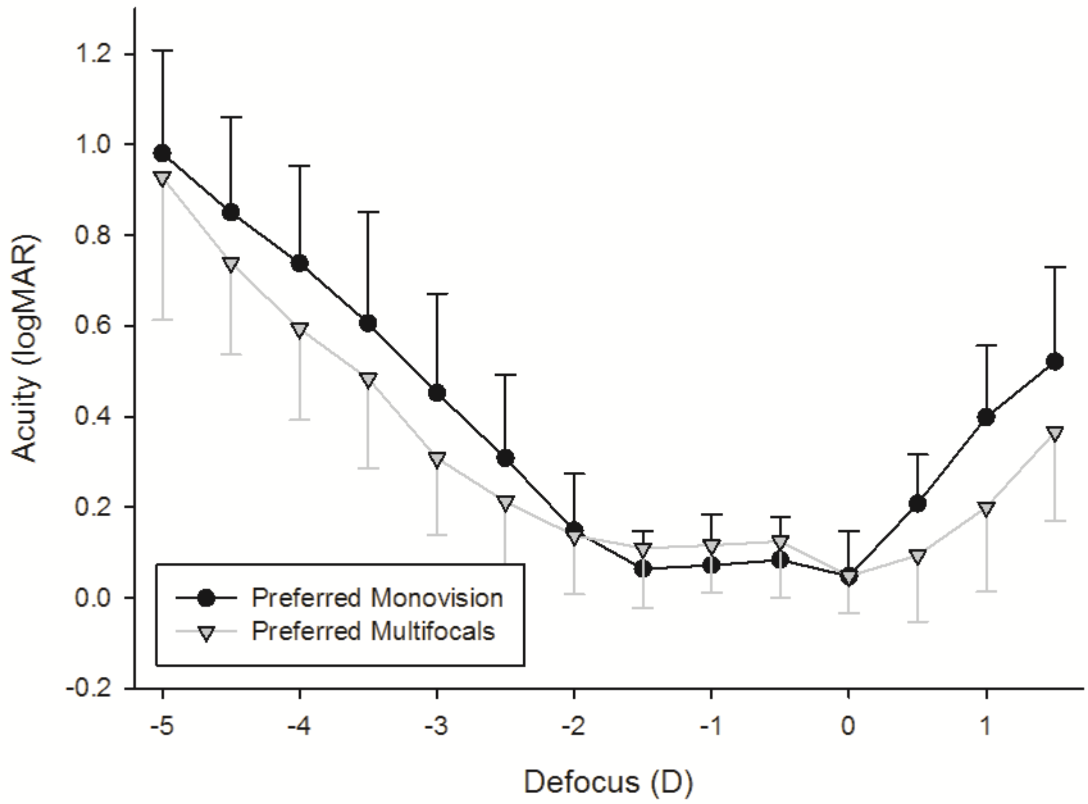

Figure 2: Mean binocular defocus curve profile with randomised logMAR high contrast letter sequences and lens presentation of participants who preferred monovision lenses (black circles; n=10) compared to the participants who did not prefer monovision lenses (red triangles; n=25) with 1 standard deviation error bars.

Stereopsis

Stereoacuity was not statistically different in participants preferring one contact lens type when compared to participants who preferred the other contact lens types (inter-subject - Table 2). As expected, stereoacuity was significantly worse in monovision lenses when compared to the multifocal lenses (intra-subject - Table 2).

Halometry

Halo size and angle of eccentricity were not significantly dependent on the preference of Biofinity multifocal lenses (halo size F=0.817, *p*=0.373; eccentricity F=0.707, *p*=0.666) or Purevision 2 multifocal lenses (halo size F=0.312, *p*=0.580; eccentricity F=0.795, *p*=0.592) when individually compared to the remaining cohort (inter-subject). Similarly, halo size was not significantly different in participants who preferred monovision lenses (F=1.556, *p*=0.221), however an interaction with the angle of eccentricity emerged when compared to the remaining cohort who did not prefer monovision lenses (F=2.761, *p*=0.011).

No significant intra-subject differences emerged based on the halo size or angle of eccentricity whilst each participant wore their favourite lens type when compared to when they wore the other lens types (Biofinity multifocals: halo size F=0.195, *p*=0.824, eccentricity F=1.117, *p*=0.347; Purevision 2 multifocals: halo size F=2.186, *p*=0.155, eccentricity F = 0.894, *p*=0.568; monovision lenses: halo size F=1.490, *p*=0.252, eccentricity F=1.589, *p*=0.091).

Pupil size and decentration

Pupil size and centration in the dominant and non-dominant eye were not statistically different in participants preferring one lens type compared to the participants who preferred other lens types (inter-subject - Table 3). Intrasubject comparison revealed no significant differences between pupil size and decentration relative to the visual axis in the dominant and non-dominant eye in participants wearing their favourite lens type compared to when they wore the other lens types (Table 3). This was also the case if decentration direction rather than just magnitude was taken into account.

	Pupil Size		Pupil decentration	
	Dominant	***Non-Dominant***	***Dominant***	***Non-Dominant***
		Biofinity Multifocal		
Preferred n=12	4.6 ± 0.9	4.6 ± 0.9	0.4 ± 0.2	0.3 ± 0.1
Non-preferred n=23	4.7 ± 1.1	4.7 ± 1.1	0.4 ± 0.2	0.3 ± 0.2
Significance of inter-subject differences	0.779	0.897	0.786	0.960
Significance of intra-subject differences	0.717	0.999	0.178	0.529
		Purevision 2 Multifocal		
Preferred n=7	5.3 ± 1.0	5.1 ± 1.0	0.5 ± 0.1	0.3 ± 0.2
Non-preferred n=28	5.1 ± 0.8	4.9 ± 0.8	0.4 ± 0.2	0.3 ± 0.2
Significance of inter-subject differences	0.537	0.641	0.632	0.684
Significance of intra-subject differences	0.867	0.368	0.867	0.867
		Monovision		
Preferred n=10	5.0 ± 1.0	5.0 ± 1.3	0.4 ± 0.2	0.4 ± 0.1
Non-preferred n=25	5.1 ± 0.9	4.9 ± 0.9	0.3 ± 0.2	0.3 ± 0.2
Significance of inter-subject differences	0.773	0.800	0.244	0.184
Significance of intra-subject differences	0.926	0.905	0.670	0.301

Table 3: Mean ± standard deviation pupil size and decentration in the dominant and non-dominant eye of participants preferring Biofinity multifocal lenses, Purevision 2 multifocal lenses or monovision lenses.

Aberrations

Considering ocular aberrations without a contact lens *in situ,* there was no significant difference in aberrations between those who preferred Biofinity multifocal lenses and the remaining cohort (F=0.100, p=0.754) and no interaction with eye dominance (F=0.414, p=0.524) or ocular component (F=0.531, p=0.591). Participants preferring Purevision 2 multifocal lenses also demonstrated no significant difference in aberrations when compared to the remaining cohort (F=0.171, p=0.682). No interaction was evident with eye dominance (F=0.402, p=0.531) or ocular component (F=1.022, p=0.366). Aberrations were not significantly different in participants who preferred monovision lenses compared with the remaining cohort (F=0.046, p=0.831). Additionally, no interaction with eye dominance (F=0.061, p=0.807) or ocular component (F=0.138, p=0.872) was found.

Considering intra-subject differences, corneal (F=0.333, *p*=0.721), lens (F=0.684, *p*=0.607) and overall ocular aberrations (F=1.287, *p*=0.296) were not significantly different in participants who preferred Biofinity multifocal lenses compared to the results when the same participants wore the other lens types. However, an interaction emerged with ocular dominance (F=5.124, *p*=0.015) and overall ocular aberrations (F=3.733, *p*<0.001). Corneal aberrations (F=0.226, *p*=0.816), ocular dominance (F=0.081, *p*=0.922) and overall ocular aberrations (F=1.341, *p*=0.284) were not significantly different in participants who preferred Purevision 2 multifocal lenses compared to the results when the same participants wore the other lens types, but an interaction with overall ocular aberrations was present (F=2.723, p<0.001). Corneal aberrations (F = 0.246, p = 0.784), ocular dominance (F = 1.309, p = 0.295) and overall ocular aberrations (F = 0.954, p = 0.445) were not significantly different in participants who preferred monovision lenses compared to the results when the same participants wore the other lens types, but an interaction with overall ocular aberrations was present (F=2.810, *p*=0.009).

Ocular physiology

Bulbar hyperaemia, limbal hyperaemia, palpebral hyperaemia and fluorescein corneal staining were not statistically different amongst participants who preferred one lens type compared to the remaining cohort (inter-subject - Table 4). Additionally, no intra-subject differences were evident (Table 4).

	Bulbar Hyperaemia	Limbal Hyperaemia	Palpebral Hyperaemia	Corneal Staining
	Biofinity Multifocal			
Preferred n=12	2.2 ± 0.8	1.8 ± 0.7	1.6 ± 0.8	0.0 ± 0.0
Non-preferred n=23	1.6 ± 1.4	1.5 ± 1.2	1.3 ± 1.1	0.1 ± 0.3
Significance of inter-subject differences	0.217	0.356	0.520	0.202
Significance of intra-subject differences	0.206	0.733	0.273	0.368
	Purevision 2 Multifocal			
Preferred n=7	1.6 ± 1.0	1.6 ± 1.0	1.7 ± 0.8	0.1 ± 0.4
Non-preferred n=28	2.4 ± 1.0	2.3 ± 1.2	2.1 ± 0.9	0.1 ± 0.3
Significance of inter-subject differences	0.058	0.169	0.285	0.789
Significance of intra-subject differences	0.293	0.387	0.080	0.368
	Monovision			
Preferred n=10	2.7 ± 1.1	2.3 ± 0.9	2.2 ± 1.0	0.3 ± 0.5
Non-preferred n=25	2.2 ± 1.4	2.0 ± 1.4	1.8 ± 1.2	0.2 ± 0.4
Significance of inter-subject differences	0.346	0.528	0.306	0.364
Significance of intra-subject differences	0.074	0.061	0.195	0.174

Table 4: Mean ± standard deviation bulbar hyperaemia, limbal hyperaemia, palpebral redness and fluorescein corneal staining grading (Efron scale) of participants preferring Biofinity multifocal lenses, Purevision 2 multifocal lenses or monovision lenses

Discussion

The current investigation is the first double-masked randomised controlled crossover trial to examine whether it is possible to predict the success of fitting a range of modern silicone-hydrogel presbyopic contact lenses using a range of clinical and non-clinical indicators. While there was no wash-out period between lens designs, the four weeks of wear before clinical assessment of each design should have been more than adequate to negate the effect of any previous contact lens wear on ocular physiology.

Clinical measurement of ocular aberrations prior to lens insertion were not predictive of lens preference after 4 weeks of wear of a range of designs, however, a large variation in ocular aberrations between individuals was evident, as reported previously [23,24]. Indeed, the variation in ocular aberrations between individuals largely masked the differences in optics induced whilst the presbyopic contact lenses were *in situ* and therefore may explain why no lens design preference was evident.

The range of pupil size, task distance and ageing [25-27] significantly impact the area of the contact lens optic exposed and therefore influence the visual performance of multifocal contact lens designs, however pupil size and pupil centration were found to be independent of overall lens preference in the current study. Additionally, pupil size and centration with each contact lens *in situ* was not related to lens preference. Therefore aberrometry and pupil metrics appear to provide poor indicators of current presbyopic contact lens success. However, the aberrometer measures pupil size with infrared light and fixation of an illuminated target was require, which may not be indicative of the typical pupil size of an individual. Soft contact lens centration is normally considered compared to the limbus rather than the pupil and pupil decentration relative to the visual axis may not be strongly associated with the former.

Considering participant lifestyle, contact lens preference was not dependent on whether participants frequently drove, used a computer, cooked, shopped, used a mobile phone, watched movies, drove at night or spent time working and reading at near. In accordance with the reported increase in activity of the new generation of presbyopic individuals [1], it was not possible to group participants with regard to whether they mostly partook in distance, intermediate or near orientated activities. Indeed, the initial questionnaire elicited the primary aim of many participants was to be able to drive during the day and night, use a computer and use a mobile phone without the aid of glasses, indicating that having clear vision for distance, intermediate and at near whilst wearing presbyopic contact lenses was a priority. This desire for clear vision without spectacles for a wide range of task with varying visual demands meant it was unlikely that lens preference would align with the lens designs' balance of light split between distance, intermediate and near zones.

Poor subjective visual satisfaction due to visual fluctuations, inadequate visual quality, halos and ghosting are commonly cited as reasons for presbyopic contact lens rejection [4,28]. Indeed, a trend emerged in the present investigation for some multifocal lens type preference to align with the lens offering the best distance visual acuity after 4 weeks of wear. Participants who preferred PureVision 2 lenses achieved significantly better low contrast visual acuity under photopic conditions than the other participants wearing PureVision 2 lenses, indicating lens performance at low contrast may be an important factor in determining lens success. Furthermore, participants who preferred Biofinity multifocal lenses achieved significantly better high contrast distance visual acuity under photopic conditions than attained wearing the other lens types trialled. Additionally, participants who preferred the Biofinity multifocal lenses reported superior iPhone image clarity wearing the Biofinity lenses when compared to the monovision lenses. Therefore the quality of photopic visual acuity at distance and near, once lenses are worn, appears to be useful clinical indicators of multifocal contact lens success. However, significant differences were not evident for participants who preferred the other lenses trialled and no differences emerged based on NAVQ rating or reading speed, suggesting other factors may be important for overall participant satisfaction. There is some controversy as to whether visual acuity achieved in multifocal lenses typically improves with adaptation; Papas et al[4] found improvements over the first 4 days wear in near acuity and range of clear vision; Woods et al[27] highlighted subjective comfort and visual satisfactions over 2 weeks of wear, but did not analyse objective changes over this time period; Fernandes et al[29] showed an improvement in high and low contrast distance and near visual acuity (only for the nondominant eye in distance visual acuity) with a multifocal lens design but not monovision after 15 days; and Sheedy et al found improvements in task performance over 8 weeks of bifocal contact lens wear, but not in clinical measures of visual acuity and stereoacuity; therefore visual acuity measurements obtained after initial fitting may provide practitioners with a poor indicator of future contact lens success.

Driving at night is commonly reported as one of the most challenging activities to perform whilst wearing presbyopic contact lenses [31,32,28]. The current study found lens preference was not dependent on participation in night driving, which corresponded with the lack of relationship between lens preference and subjective halo size or mesopic visual acuity at high and low contrast recorded clinically. However, the current cohort only reported driving at night occasionally in general, therefore visual performance whilst undertaking other activities may have been more influential in the decision of lens preference. Nevertheless, whether a patient frequently drives at night should still be an important consideration when discussing presbyopic contact lens options with a patient because it is likely visual acuity attained wearing lens designs with abrupt discontinuities between optic zones will be degraded due to glare [33].

Within a similar age group (41 to 64 years), Richdale *et al.* [9] found 76% of participants preferred Bausch and Lomb SofLens multifocal lenses (aspheric centre-near design) to monovision (SofLens 59) lenses. Richdale and colleagues hypothesised the disparity in lens preference may be due to the comparable visual acuity and superior stereoacuity afforded by multifocal lenses. The present investigation confirmed stereoacuity was significantly better in multifocal lenses compared to monovision lenses, however monovision lenses were more commonly preferred than some of the centre-near multifocal lenses trialled. Participants preferring monovision lenses also attained worse visual acuity across a range of distances than the remaining participants achieved wearing monovision lenses. Therefore it is feasible lens preference may have been driven by parameters which were not measured by this study, such as visual comfort with monocular suppression in single vision lenses compared to simultaneous vision in multifocal lenses. It would be interesting to follow-up a cohort wearing each of these lens types longitudinally to monitor long-term satisfaction and modality of wear, particularly as the reading add power increases, the refractive disparity between eyes increases and the depth of focus provided by monovision contact lenses reduces. Indeed, the current investigation found older individuals (62.8 ± 3.9 years) preferred Air Optix Aqua centre-near lenses to monovision lenses (51.0 ± 6.7 years). A previously reported comparison after 6 months wear of Acuvue bifocal contact lenses and 6 months wear of Acuvue single vision lenses found no difference in subjective or objective tear film results or the changes in ocular physiology, though lens crossover was not employed [34]. The current study also found ocular physiology was not dependent on lens preference and each lens had minimal impact on the ocular surface, therefore the lens thickness profile is unlikely to provide a useful indicator for presbyopic lens success.

In conclusion, participant lifestyle and personality, ocular optics, contact lens visual performance and ocular physiology provided poor indication of the preferred lens type between monovision and the four silicone hydrogel multifocal lens designs after four weeks of wear. This may be due to the wide range of task visual demands of presbyopes along with the minimal difference between current multifocal contact lens designs when combined with an individual's natural optical aberrations [35].

Disclosure: The authors report no conflicts of interest and have no proprietary interest in any of the materials mentioned in this article.

Acknowledgments: No financial assistance was obtained for this study.

References

[1] Gifford P, Cannon T, Lee C, Lee D, Lee HF, Swarbrick HA. Ocular aberrations and visual function with multifocal versus single vision soft contact lenses. Cont Lens Anterior Eye. 2013;36:66-73.

[2] Morgan PB, Efron N, Woods CA, The international contact lens prescribing survey C. An international survey of contact lens prescribing for presbyopia. Clin Exp Optom. 2011;94:87-92.

[3] Woods J, Woods CA, Fonn D. Early Symptomatic Presbyopes—What Correction Modality Works Best? Eye Contact Lens. 2009;35:221-6.

[4] Papas EB, Decenzo-Verbeten T, Fonn D, Holden BA, Kollbaum PS, Situ P, et al. Utility of short-term evaluation of presbyopic contact lens performance. Eye Contact Lens. 2009;35:144-8.

[5] Plainis S, Atchison DA, Charman WN. Power Profiles of Multifocal Contact Lenses and Their Interpretation. Optom Vis Sci. 2013;90:1066-77.

[6] Martin JA, Roorda A. Predicting and assessing visual performance with multizone bifocal contact lenses. Optom Vis Sci. 2003;80:812-9.

[7] Peyre C, Fumery L, Gatinel D. Comparison of high-order optical aberrations induced by different multifocal contact lens geometries. J Fr Ophtalmol. 2005;28:599-604.

[8] Patel S, Fakhry M, Alió JL. Objective assessment of aberrations induced by multifocal contact lenses in vivo. Eye Contact Lens. 2002;28:196-201.

[9] Richdale K, Mitchell GL, Zadnik K. Comparison of multifocal and monovision soft contact lens corrections in patients with low-astigmatic presbyopia. Optom Vis Sci. 2006;83:266-73.

[10] Gupta N, Naroo SA, Wolffsohn JS. Visual comparison of multifocal contact lens to monovision. Optom Vis Sci. 2009;86:E98-E105.

[11] Du Toit R, Ferreira JT, Nel ZJ. Visual and nonvisual variables implicated in monovision wear. Optom Vis Sci. 1998;75:119-25.

[12] Erickson DB, Erickson P. Psychological factors and sex differences in acceptance of monovision. Percept Motor Skill. 2000;91:1113-9.

[13] Macalister GO, Woods CA. Monovision versus RGP translating bifocals. Cont Lens Anterior Eye. 1991;14:173-8.

[14] Nichols JJ, Mitchell GL, Saracino M, Zadnik K. Reliability and Validity of Refractive Error–Specific Quality-of-Life Instruments. Arch Ophthalmol. 2003;121:1289-96.

[15] Woods RL, Colvin CR, Vera-Diaz FA, Peli E. A relationship between tolerance of blur and personality. Invest Ophthalmol Vis Sci. 2010;51:6077-82.

[16]du Toit R, Ferreira JT, Nel ZJ. Visual and non visual variables implicated in monovision wear. Optom Vis Sci 1998;75:119-25.

[17] Pointer JS. Sighting versus sensory ocular dominance. J Optom. 2012;5:52-5.

[18] Kingsnorth A, Wolffsohn JS. Mobile app reading speed test. Br J Ophthalmol. 2015; 99, 536-539.

[19] Buckhurst PJ, Wolffsohn JS, Gupta N, Naroo SA, Davies LN, Shah S. Development of a questionnaire to assess the relative subjective benefits of presbyopia correction. J Cataract Refract Surg. 2012;38:74-9.

[20]Gupta N, Wolffsohn JS, Naroo SN. Optimising measurement of subjective amplitude of accommodation with defocus curves. J Cataract Refract Surg 2008;34:1329-38.

[21] Buckhurst PJ, Wolffsohn JS, Shah S, Naroo S, Davies LN. Evaluation of dysphotopsia with multifocal intraocular lenses. Invest Ophtalmol Vis Sci. 2011;52:6185.

[22] Armstrong RA, Eperjesi F, Gilmartin B. The application of analysis of variance (ANOVA) to different experimental designs in optometry. Ophthal Physiol Opt. 2002;22:248-56.

[23] Porter J, Guirao A, Cox IG, Williams DR. Monochromatic aberrations of the human eye in a large population. J Opt Soc Am. 2001;18:1793-803.

[24] Artal P, Berrio E, Guirao A, Piers P. Contribution of the cornea and internal surfaces to the change of ocular aberrations with age. J Opt Soc Am. 2002;19:137-43.

[25] Winn B, Whitaker D, Elliott DB, Phillips NJ. Factors affecting light-adapted pupil size in normal human subjects. Invest Ophthalmol Vis Sci. 1994;35:1132-7.

[26] Bradley A, RAHMAN HA, SONI PS, ZHANG X. Effects of target distance and pupil size on letter contrast sensitivity with simultaneous vision bifocal contact lenses. Optom Vis Sci. 1993;70:476-81.

[27] Borish I. Pupil dependency of bifocal contact lenses. Am J Optom Physiol Opt. 1988;65:417-23.

[28]Woods J, Woods C, Fonn D. Visual performance of a multifocal contact lens versus monovision in established presbyopes. Optom Vis Sci. 2015;92:175-82.

[29] Fernandes PR, Neves HI, Lopes-Ferreira DP, Jorge JM, González-Meijome JM. Adaptation to multifocal and monovision contact lens correction. Optom Vis Sci. 2013;90:228-35.

[30] Sheedy JE, Harris MG, Gan CM. Does the presbyopic visual system adapt to contact lenses? Optom Vis Sci. 1993;70:482–86.

[31] Gispets J, Arjona M, Pujol J, Vilaseca M, Cardona G. Task oriented visual satisfaction and wearing success with two different simultaneous vision multifocal soft contact lenses. J Optom. 2011;4:76-84.

[32] Chu BS, Wood JM, Collins MJ. The effect of presbyopic vision corrections on nighttime driving performance. Invest Ophthalmol Visual Sci. 2010;51:4861-6.

[33] García-Lázaro S, Ferrer-Blasco T, Madrid-Costa D, Albarrán-Diego C, Montés-Micó R. Visual Performance of Four Simultaneous-Image Multifocal Contact Lenses Under Dim and Glare Conditions. Eye Contact Lens. 2015;41:19-24.

[34] Du Toit R, Situ P, Simpson T, Fonn D. The effects of six months of contact lens wear on the tear film, ocular surfaces, and symptoms of presbyopes. Optom Vis Sci. 2001;78:455-62.

[35] Sivardeen A, Laughton D, Wolffsohn JS. Randomised crossover trial of silicone hydrogel presbyopic contact lenses. Optom Vis Sci. 2016;93:141-9.