Short-term visual performance of soft multifocal contact lenses for presbyopia

Desempenho visual de curto prazo de présbitas usando diferentes lentes de contato multifocais hidrofílicas

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ABSTRACT

Purpose: To compare visual acuity (VA), contrast sensitivity, stereopsis, and subjective visual performance of Acuvue® Oasys® for Presbyopia (AOP), Air Optix® Aqua Multifocal (AOMF), and Air Optix® Aqua Single Vision (AOSV) lenses in patients with presbyopia.

Methods: A single-blinded crossover trial was conducted. Twenty patients with mild presbyopia (add ≤+1.25 D) and 22 with moderate/severe presbyopia (add ≥+1.50 D) who wore lenses bilaterally for 1 h, with a minimum overnight washout period between the use of each lens. Measurements included high- and low-contrast visual acuity (HCVA and LCVA, respectively) at a distance, contrast sensitivity (CS) at a distance, HCVA at intermediate (70 cm) and near (50 cm & 40 cm) distances, stereopsis, and subjective questionnaires regarding vision clarity, ghosting, overall vision satisfaction, and comfort. The test variables were compared among the lens types using repeated-measures ANOVA.

Results: Distance variables (HCVA, LCVA, and CS) were significantly worse with multifocal lens than with AOSV lens ($p \leq 0.008$), except for AOMF lens in the mild presbyopia group in which no significant difference was observed ($p > 0.05$). Multifocal lenses had significantly greater HCVA at 40 cm than AOSV lens ($p \leq 0.026$). AOMF lens had greater intermediate HCVA than AOP lens ($p < 0.03$). AOP lens demonstrated greater improvements in stereopsis than AOMF and AOSV lens in the moderate/severe presbyopia group ($p \leq 0.03$). Few significant differences in subjective variables were observed, with no significant difference in the overall vision satisfaction observed between lens types ($p > 0.05$). The proportions of patients willing to buy AOSV, AOMF, and AOP lenses were 20%, 40%, and 50%, respectively, in the mild presbyopia group and 14%, 32%, and 23%, respectively, in the moderate/severe presbyopia group; however, these differences were not statistically significant ($p \geq 0.159$).

Conclusions: Further development of multifocal lenses is required before significant advantages of multifocal lenses over single vision lens are observed in patients with presbyopia.

Keywords: Presbyopia; Contact lenses; Adaptation, ocular; Visual acuity

RESUMO

Objetivo: *Comparar a acuidade visual, sensibilidade ao contraste, estereopsia e desempenho visual subjetivo de présbitas usando lentes de contato Acuvue Oasys para presbiopia (AOP), Air Optix Aqua Multifocal (AOMF) e Air Optix Aqua Single Vision (AOSV).*

Método: *Foi realizado estudo mascarado simples, cruzado. Vinte pacientes com presbiopia baixa (adição ≤+1,25 D) e 22 com presbiopia média/alta (adição ≥+1,50 D) usaram cada lente bilateralmente durante 1 hora, com descanso mínimo de uma noite entre as diferentes lentes. As medições incluíram acuidade visual para distância em alto e baixo contraste (HCVA, LCVA), sensibilidade ao contraste para distância (CS), HCVA para distância intermediária (70 cm) e para perto (50 cm e 40 cm), estereopsia e questionários subjetivos sobre nitidez visual, fantasmas, satisfação visão geral e conforto. As variáveis foram comparadas entre os tipos de lentes, utilizando medidas repetidas ANOVA.*

Resultados: *As variáveis para distância (HCVA, LCVA, CS) foram significativamente piores com as multifocais em relação a AOSV ($p \leq 0{,}008$), exceto para AOMF no grupo de baixa adição, que não foi significativamente diferente ($p > 0{,}05$). As multifocais foram significativamente melhores do que a AOSV para HCVA em 40 cm ($p \leq 0{,}026$). AOMF superou AOP para HCVA intermediária ($p < 0{,}03$). AOP superou AOMF e AOSV em relação à estereopsia no grupo de presbiopia médio/alto ($p \leq 0{,}03$). Houve poucas diferenças significativas nas variáveis subjetivas, mas a satisfação visual global não foi significativamente diferente entre as lentes ($p > 0{,}05$). A disposição para comprar lentes AOSV, AOMF e AOP foi: 20%, 40%, 50%, respectivamente, no grupo de presbiopia baixa; 14%, 32%, 23% no grupo de presbiopia média/alto, mas essas diferenças não foram estatisticamente significativas ($p \geq 0{,}159$).*

Conclusões: *Melhorias futuras parecem ser necessárias para produção de uma lente multifocal que forneça aos présbitas uma vantagem significativa sobre a lente de visão única.*

Descritores: *Presbiopia; Lentes de contato; Adaptação ocular; Acuidade visual*

INTRODUCTION

More than one third of the world's population is over 40 years[1] and is the age at which presbyopia generally begins developing. Presbyopia is an age-related condition that causes the eye to progressively lose its ability to focus on near objects. The correction of presbyopia traditionally involves either multifocal or separate reading spectacles; however, there has been considerable interest in using contact lenses because of their suitability for sports, cosmetic appeal, or simply a patient's dislike for spectacles.

Concurrent with an aging global population, the prevalence of presbyopia is estimated to increase from 1.2 billion in 2010 to 1.8 billion in 2050[2]. Accordingly, the age of the average contact lens wearer is increasing, revealing a growing market for presbyopic contact lenses[3]. In an international survey conducted in 2011, Morgan *et al.* reported

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that patients with presbyopia represent just 16% of all contact lens wearers and of these, multifocal contact lenses were prescribed in less than a third of patients with presbyopia because the majority were prescribed lenses for either distance correction only or monovision[4]. In 2013-2014, the proportion of presbyopic contact lens wearers with multifocal contact lenses was reported to have increased to approximately 50%[5,6]. The high proportion of presbyopic contact lens wearers prescribed single vision or monovision lenses may be related to the practitioners' common perception that multifocal contact lenses are more challenging to fit to provide acceptable vision and/or the perceived visual performance by the contact lens wearers themselves[4].

Multifocal contact lenses, which use simultaneous imaging, often cause visual disturbances, such as ghosting and haloes, because the optical zones for intermediate- and near-distance focusing are positioned over the pupil[7-10]. These disturbances can occur at any distance and are often exacerbated in low-contrast or low-illumination conditions. Such effects range from mild to severe and have been demonstrated to be associated with pupil size, lens decentration, lens design, and inherent spherical aberration[11-14].

Many currently used multifocal contact lenses are designed to satisfy the complex visual requirements of patients with presbyopia while minimizing the negative effects. Vasudevan *et al.*[15] reported no significant differences in the subjective and objective visual performance of three current multifocal lenses: Air Optix® Aqua Multifocal, Acuvue® Oasys® for presbyopia, and Biofinity Multifocal. However, their study only included patients with early presbyopia who were fitted with low-add lens designs.

In this study, we included patients with moderate and severe presbyopia and compared visual acuity (VA), contrast sensitivity, stereopsis, and subjective visual performance obtained with two commercially available multifocal lenses and one spherical lens, the latter of which served as a negative control. We further investigated factors associated with the patients' satisfaction and willingness to buy each lens type.

METHODS

Study design

This study was a prospective, patient-blinded, crossover clinical trial that was conducted at the Brien Holden Vision Institute, Sydney, Australia, in which lenses were worn bilaterally. Inclusion criteria were as follows: age over 40 years; spectacle add ≥+0.75 D; astigmatism ≤-1.00DC; and vision correctable to at least 6/12 (0.3 logMAR) or better in each eye with contact lenses. Exclusion criteria were previous corneal refractive surgery or any contraindications to wearing contact lens. Study protocols and informed consent were reviewed and approved by an independent ethics committee, and the study followed the tenets of the Declaration of Helsinki. The trial was registered in the Australian New Zealand Clinical Trials Registry (ACTRN12613001380785).

Patients attended a baseline visit to determine distance refraction and spectacle add requirement. The add was defined as the minimum correction required to comfortably read the 20/25 paragraph (0.1 logMAR) on an MNREAD Acuity Chart card (Precision Vision, IL USA) at a distance of 40 cm in a well-lit clinical room (minimum of 350 lux at the patients' eye position).

All patients wore Air Optix® Aqua Single Vision (AOSV) lenses as a negative control immediately following the baseline visit. Other lens types were randomized and tested during the assessment visits on different days with a minimum overnight washout period between visits. Allocated lenses were inserted, and the assessments were initiated after at least 10 min to allow the patients' vision to completely settle. Distance over-refraction was performed with loose lenses in a trial frame, with the endpoint defined as the maximum plus at which patients deemed vision was acceptable when binocularly observing a 6/6 line (0.0 logMAR) at 6 m. Vision between the two eyes was maintained within 4 letters to avoid modified monovision.

Lens allocation procedures

The lenses evaluated in this study were AOSV (lotrafilcon B: Alcon, USA), Air Optix® Aqua Multifocal (AOMF; lotrafilcon B: Alcon, USA), and Acuvue® Oasys® for Presbyopia (AOP, senofilcon A: Johnson & Johnson, USA).

Patients were fitted with low-, medium-, and high-add lens designs on the basis of spectacle add power in accordance with manufacturers' fitting guides[16,17]. Lenses were power matched to the patients' spherical equivalent subjective distance refraction.

Vision assessments

All vision measurements were assessed under high room illumination (minimum of 350 lux at the patients' eye position), with over-refraction placed in a trial frame when found. The following variables were measured at each visit (best corrected at baseline and with test lenses at lens assessment visits): high- and low-contrast visual acuity (HCVA and LCVA, respectively) measured with a computerized logMAR letter chart (Test Chart 2000 Pro, Thompson Software Solutions, Hertfordshire UK) at 6 m with letters of 100% and 10% contrast, respectively; contrast sensitivity (CS) at 18 cycles/degree measured with the Pelli-Robson chart at 6 m; HCVA at 70 cm, 50 cm, and 40 cm measured with the MN Read Acuity chart; and stereopsis measured with the Stereo Fly Test Circles (Stereo Optical, Il USA) at 40 cm. HCVA at intermediate and near distances were measured on the basis of the smallest print that patients were able to comfortably read rather than the smallest print possible.

Patient questionnaires

Patients completed a questionnaire relating to the performance of lenses that were worn. Variables were rated on a 1-10 numeric rating scale in 1-point steps (Table 1). Furthermore, patients were asked to indicate whether they would buy lenses (yes/no response) on the basis of their visual experience alone.

Assessments of contact lens fit

Lens fits were evaluated using a Zeiss SL-120 slit lamp (Carl Zeiss Meditec, Jena, Germany) with an eyepiece graticule at 10× magnification. Lenses were assessed for decentration with respect to the limbus (horizontal and vertical), primary gaze movement, and primary gaze lag using the graticule and lens tightness with the push-up test.

Statistical analyses

A minimum of 10 patients were estimated to be required to demonstrate a statistically significant paired difference between lenses and each iteration in VA of 0.1 ± 0.1 logMAR units at a significance level of 5% and power of 80%.

Data were summarized as mean ± standard deviation for variables that were measured on an interval scale and as percentages for categorical variables. Study variables were compared between lens types

Table 1. Subjective variables rated by patients

Study questionnaire		
Subjective variable	**Anchor point 1**	**Anchor point 10**
Vision clarity at distance/intermediate/near	Blurred/hazy	Clear/sharp
Magnitude of ghosting at distance/ intermediate/near	No ghosting	Severe ghosting
Overall vision satisfaction	Unsatisfactory	Satisfactory
Ocular comfort	Uncomfortable	Comfortable

using repeated measures ANOVA. Associations between willingness to buy and study variables were analyzed using logistic regression with robust estimate of variance. A multiple logistic model to identify factors independently associated with the willingness to buy was created using significant variables identified by univariate analyses. Backward elimination was used to select variables that were followed by forward entry of variables. Pearson's correlation was used to determine the univariate association of overall vision satisfaction with an objective vision. Only correlations with p values ≤0.01 and R values ≥±0.3 were considered statistically significant. Post-hoc multiple comparisons were corrected using the Bonferroni correction. All analyses were performed using SPSS 21 software (IBM, USA).

For simplicity, the scale used to rate ghosting has been revised in the analyses to be consistent with the other scales in which greater numbers are represented by higher values. This variable was referred to as "lack of ghosting" in the results section.

RESULTS

Patient demographics

Demographic data are presented in table 2. Because of the low number of patients (n=9) with at least add +2.00 D, data from patients with moderate and severe presbyopia were combined for analyses. Results are summarized in tables 3 and 4.

Visual acuity, contrast sensitivity, and stereopsis variables in the mild presbyopia group

As expected, AOSV lens had the highest mean values for distance variables, i.e., HCVA, LCVA, and CS. AOSV lens was significantly better than AOP lens for all distance variables (p≤0.007), with no statistically significant difference observed compared with AOMF lens (p≥0.213) or between the two multifocal designs (p≥0.115). At the intermediate distance, AOMF lens had significantly higher HCVA values compared with AOP lens (p=0.012), with no significant differences were observed between AOSV lens and either of the multifocal lenses (p≥0.058). At 50 cm, AOSV lens had significantly worse HCVA compared with AOMF lens (p=0.011), with no significant difference observed compared with AOP lens (p=0.302). No significant differences in HCVA were observed between AOMF and AOP lenses (p=0.115). At 40 cm, AOSV lens had significantly lower HCVA compared with both AOMF and AOP lenses (p≤0.026), with no significant differences observed between the two multifocal designs (p=0.577). No significant differences in stereopsis were observed between the lens types (p=0.519).

Table 2. Demographic factors for patients with mild and moderate or severe presbyopia

Patient demographics		
Factor	**Mild presbyopia n=20**	**Moderate or severe presbyopia n=22**
Age (years)	49 ± 3	58 ± 6
Range (years)	45-56	47-70
Female: male (%)	60: 40	46: 54
Neophytes: experienced wearers (%)	35: 65	32: 68
Ethnicity (%) caucasian: asian: others	55: 10: 35	82: 9: 9
Myopes	**n=12**	**n=8**
Refraction: spherical (dioptres)	-2.31 ± 1.37	-2.34 ± 1.75
Refraction: cylinder (dioptres)	-0.47 ± 0.32	-0.30 ± 0.25
Keratometry: flat power (dioptres)	43.93 ± 1.24	43.81 ± 1.13
Keratometry: steep power (dioptres)	44.41 ± 1.36	44.34 ± 1.29
Hyperopes	**n=8**	**n=14**
Refraction: spherical (dioptres)	1.35 ± 0.44	1.64 ± 0.66
Refraction: cylinder (dioptres)	-0.39 ± 0.35	-0.41 ± 0.32
Keratometry: flat power (dioptres)	42.86 ± 1.29	42.96 ± 1.26
Keratometry: steep power (dioptres)	43.63 ± 1.35	43.55 ± 1.29

Table 3. Mean ± SD values for acuity and stereopsis variables for each lens

Acuity and stereopsis results			
Study variables	**AOSV**	**AOMF**	**AOP**
Mild presbyopia group			
Distance HCVA (logMAR)	-0.09 ± 0.01	-0.09 ± 0.03	-0.06 ± 0.04*
Distance LCVA (logMAR)	0.15 ± 0.07	0.18 ± 0.08	0.22 ± 0.09*
Distance CS (log units)	1.16 ± 0.14	1.07 ± 0.19	1.00 ± 0.17*
Intermediate HCVA (logMAR)	0.24 ± 0.14	0.12 ± 0.15^	0.23 ± 0.18
Near HCVA 50 cm (logMAR)	0.47 ± 0.17	0.32 ± 0.21*	0.40 ± 0.20
Near HCVA 40 cm (logMAR)	0.67 ± 0.16	0.49 ± 0.21*	0.55 ± 0.21*
Stereopsis (sconds of Arc)	124 ± 93	116 ± 85	104 ± 85
Moderate and severe presbyopia group			
Distance HCVA (logMAR)	-0.08 ± 0.03	-0.04 ± 0.06*	-0.02 ± 0.09*
Distance LCVA (logMAR)	0.17 ± 0.06	0.28 ± 0.08*	0.31 ± 0.12*
Distance CS (log Units)	1.08 ± 0.13	0.90 ± 0.18*	0.82 ± 0.27*
Intermediate HCVA (logMAR)	0.35 ± 0.17	0.12 ± 0.12*^	0.21 ± 0.15*
Near HCVA 50 cm (logMAR)	0.58 ± 0.17	0.30 ± 0.18*	0.36 ± 0.17*
Near HCVA 40 cm (logMAR)	0.77 ± 0.19	0.48 ± 0.20*	0.52 ± 0.22*
Stereopsis (seconds of Arc)	163 ± 176	148 ± 131	100 ± 84*^

*= indicates a significant difference the MFCL versus the single vision lens; ^= indicates a significant difference between MFCL types.

Table 4. Mean ± SD for subjective variables and willingness to buy (proportion of patients in each group willing to buy each test lens)

Subjective questionnaire results			
Subjective variable	**AOSV**	**AOMF**	**AOP**
Mild presbyopia group			
Clarity of vision (distance, 1-10)	8.8 ± 1.3	8.5 ± 1.1	7.8 ± 1.8
Clarity of vision (intermediate, 1-10)	7.5 ± 2.0	7.9 ± 2.2	6.9 ± 2.3
Clarity of vision (near, 1-10)	4.9 ± 2.8	6.4 ± 2.5^	4.9 ± 2.9
Lack of ghosting (distance, 1-10)	9.9 ± 0.4	9.7 ± 0.6	9.4 ± 0.9
Lack of ghosting (intermediate, 1-10)	9.2 ± 1.3	8.7 ± 2.1	9.1 ± 1.7
Lack of ghosting (near, 1-10)	8.6 ± 1.6	8.7 ± 2.1	8.8 ± 2.0
Overall visual satisfaction (1-10)	5.9 ± 2.3	7.2 ± 2.1	6.6 ± 2.6
Ocular comfort (1-10)	8.9 ± 1.5	8.6 ± 1.7	9.3 ± 0.7
Willingness to buy (% of patients)	20	40	50
Moderate and severe presbyopia group			
Clarity of vision (distance, 1-10)	8.6 ± 1.3	7.6 ± 1.5	6.0 ± 2.5*
Clarity of vision (intermediate, 1-10)	5.9 ± 2.4	7.5 ± 1.7*	6.9 ± 2.2
Clarity of vision (near, 1-10)	3.5 ± 2.2	6.3 ± 2.3*	5.1 ± 2.5
Lack of ghosting (distance, 1-10)	9.8 ± 0.7	8.6 ± 1.6*	7.0 ± 2.9*
Lack of ghosting (intermediate, 1-10)	8.6 ± 1.7	8.7 ± 1.9	8.5 ± 1.6
Lack of ghosting (near, 1-10)	8.7 ± 1.9	8.0 ± 1.8	7.7 ± 1.8
Overall visual satisfaction (1-10)	5.2 ± 1.9	6.0 ± 2.1	5.3 ± 2.7
Ocular comfort (1-10)	8.3 ± 1.7	7.8 ± 2.3	8.8 ± 1.1
Willingness to buy (% of patients)	14	32	23

*= indicates a significant difference the MFCL versus the single vision lens; ^= indicates a significant difference between MFCL types.

Visual acuity, contrast sensitivity, and stereopsis variables in the moderate and severe presbyopia group

HCVA, LCVA, and CS at distance were higher with AOSV lens than with AOMF and AOP lens (p≤0.008), with no significant differences observedbetween the two multifocal designs (p≥0.894). At the intermediate distance, AOMF lens performed significantly better than AOSV and AOP lenses (p≤0.023), and AOP lens performed significantly better than AOSV lens (p=0.010). At both near distances, AOSV lens had significantly worse HCVA than both AOMF and AOP lens (p≤0.001), while no significant differences was observed between the two multifocal designs (p≥0.329). AOP lens had significantly better improvements in stereopsis compared with other lenses (p≤0.030); however, no difference was found between AOSV and AOMF lens (p=1.00).

Subjective variables and willingness to buy lens in the mild presbyopia group

No significant differences in most subjective variables were observed between the lens types (p>0.05); however, AOMF lenses were rated as significantly more clear at near distances than AOP lens (p=0.005). AOP lens had the highest buy willingness in the mild presbyopia group, with 50% patients expressing willingness to buy them, whereas AOSV lenses had the lowest willingness to buy; however, this difference was not statistically significant (p=0.159). The decision to buy in this group was associated with near VA at 40 cm [odds ratio (OR), 2.31; p=0.002] and overall vision satisfaction (OR, 7.16; p<0.001).

Subjective variables and willingness to buy lens in the moderate and severe presbyopia group

AOSV lens was rated highest in terms of clarity and lack of ghosting at a distance, thereby performing significantly better than AOP lens in the former (p<0.001) and significantly better than both AOP and AOMF lenses in the latter (p≤0.010). AOSV lens was rated lowest in terms of clarity at both intermediate and near distances, with both significantly lower than AOMF lens (p≤0.039). No significant differences in any subjective variable, including overall visual satisfaction and ocular comfort, were observed between AOMF and AOP lenses (p>0.05). AOMF lens had the highest willingness to buy in the moderate and severe presbyopia group, whereas AOSV lens had the lowest willingness to buy; however, this trend was not statistically significant (p=0.385). The decision to buy in this group was associated with an overall vision satisfaction (OR, 2.52; p<0.001).

Correlations between HCVA and vision satisfaction

In the mild presbyopia group, strong correlations were observed between intermediate and near HCVA and overall vision satisfaction (-0.67≤R≤-0.62; p<0.001). In the moderate and severe presbyopia group, a weaker correlation was observed between intermediate HCVA and overall vision satisfaction (R=-0.33; p=0.007).

Lens fit

AOMF lens had significantly more primary gaze movement than AOSV and AOP lenses (p≤0.019); however, the mean difference was not clinically relevant at 0.03 mm. No other differences in any other lens fitting measure were observed between the lens types (p>0.05).

DISCUSSION

This study aimed to compare VA, contrast sensitivity, stereopsis, and subjective visual performance of AOP, AOMF, and AOSV lenses in patients with presbyopia in a cross-over trial. The single vision lens, which acted as a negative control, had the best performance at distance in the majority of cases, as expected. In the mild presbyopia group, AOMF lens was the only multifocal design that was able to match the distance performance of the single vision lens. However, while the other lens types had statistically significantly worse HCVA at a distance compared with AOSV lens, the differences were within 1 line of letters and were not considered clinically significant. Nevertheless, differences were more apparent when observing LCVA and CS at a distance, indicating that in the majority of cases, patients with presbyopia who wear multifocal contact lenses that were used in this study experienced a degree of distance visual compromise that may not be have been apparent in high-contrast situations but may manifest in real-life, low-contrast conditions. At near distances, multifocal lenses provided better VA when compared with the single vision lens, as expected, because of its monofocal design. VA at an intermediate distance and stereopsis with AOSV lens were comparable with both AOP and AOMF lenses in the mild presbyopia group, which is likely because of the residual accommodation in younger patients with presbyopia.

Despite different optical designs, AOMF and AOP lenses similarly performed in the majority of variables. AOMF lens is a continuous aspheric, center-near lens that is designed to provide good near vision through the central zone of the lens, good intermediate vision through the mid-peripheral zone, and good distance vision in the periphery. AOP is a center-distance design featuring distance and near concentric rings that are designed to provide consistent vision regardless of pupil size and also incorporating negative spherical aberration[18].

A comparison of visual performance between multifocal contact lenses and a single vision contact lens (distance corrected) has not been previously conducted, although a comparison of AOMF and AOP lenses was reported by Vasudevan *et al.*[15] In their study, no significant differences were observed in any objective or subjective variable between the lenses; however, their study only included patients with early presbyopia who were fitted with low-add lens designs. We extended our investigation to include patients with moderate and severe presbyopia, in addition to those with early presbyopia, and observed similar performance of AOMF and AOP lenses for the majority (but not all) objective and subjective variables in both the groups under the test conditions.

Interestingly, considerably lower rates of stereopsis were achieved with multifocal designs in this study than those reported for the same designs in previous studies (21-54 seconds of arc)[15,19], even when considering only the mild presbyopia group in this study. We believe that this discrepancy may attributable to the inclusion of a wider age range of patients with presbyopia in this study who fell into the mild presbyopia group and the different evaluation methods used. However, variability in stereopsis measurements for multifocal lenses has been previously reported[15,20,21]. In this study, HCVA at near distances that were recorded with all lenses were lower than previously reported values[15,20-25], which is primarily attributable to the difference in methodology. Unlike other studies, we sought to measure the smallest paragraph that patients could "comfortably" read, which involved an additional subjective element in the objective resolution task. Given the assumption that reading speeds at near distance are maximal at 0.4-0.6 logMAR, it is expected that the values reported by patients with all test lenses converged toward 0.5 logMAR for near distances[26]. Therefore, we recommend investigators pay more attention to differences between test and control subjects rather than absolute measures.

In this study, while few variables were found to differ between multifocal designs and AOSV lens, no significant differences in the patients' overall satisfaction with the lenses or willingness to buy were observed. For the mild presbyopia group, the larger sample size may have led to a significant difference in the overall visual satisfaction or willingness to buy; however, differences were much smaller in the moderate and severe presbyopia group, indicating MFCL designs for this group did not overall perform substantially better than the single vision lens. In general, at least half of the patients with mild presbyopia and two-thirds of the patients with moderate or severe presbyopia were unwilling to buy the lenses that were tested in this

study after wearing them for 1 h. It is clear that despite advances in multifocal technology in recent years, further improvements are still required to achieve a multifocal lens that provides significant advantages over a simple single vision lens, particularly in patients with moderate and severe presbyopia.

Because of the simplistic nature and short duration of this study, we did not set-up a separate experiment to validate our subjective questionnaires. This study aimed to evaluate subjective responses between different lens types. Given that the study was a randomized, cross-over trial, the reliability, content, and/or criterion bias (if any) remains constant throughout all the repeated administrations of the questionnaire. Thus, bias (if any) will be diminished when considering differences between subjective ratings with different lens types.

A secondary objective of our study was to investigate relationships between variables to determine the factors related to the patients' satisfaction and willingness to buy the specific lenses. Papas *et al.* previously reported that objective findings have little value for this purpose, and clinicians should rely on subjective findings to predict success[9]. We found that patients with better HCVA at intermediate, and occasionally near, distances tended to have higher satisfaction with overall vision, which in turn was a factor that influenced the patients' willingness to buy. In this study, a 1 unit higher rating in the overall vision satisfaction produced a 7-fold increase in the willingness to buy in patients with mild presbyopia and a 2.5-fold increase in patients with moderate or severe presbyopia. In practice, clinicians commonly measure VA at 40 cm; however, our data demonstrate that measuring VA at slightly greater distances may be important in predicting patient success with multifocal contact lenses. This study was limited by the small adaptation period. While this imitates what often occurs when patients first fit multifocal contact lenses in practice, changes in lens performance may occur over 4-15 days[9,22]. Longer term studies are required to determine if these study measures continue to predict performance over a longer period of time.

CONCLUSION

Under the short-term testing conditions, both AOMF and AOP lenses similarly performed for the majority of acuity measurements and subjective variables. The findings of this study indicate that further improvements are required to achieve a multifocal lens that provides significant advantages over a simple single vision lens, particularly in patients with moderate and severe presbyopia.

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