INTRODUCTION

Customization of the relative peripheral refractive error (RPRE) has become a research topic with the aim of interfering with myopia progression. Treatments to reduce myopia progression in children are available, mainly contact lenses~~,~~ that induce increased vergence of the light entering the eye at an oblique angle (peripheral or off-axis refraction). Orthokeratology provides this effect by reshaping the anterior corneal surface although this effect is intrinsically dependent on the amount of myopia being corrected.[1,2] This effect also can be achieved with center-distance multifocal contact lenses[3] or spectacles.[4] The use of contact lens is preferred because they follow the ocular movements and remain centered on the visual axis. Thus, there is a demand for customized contact lenses that can change the pattern of the peripheral refraction, irrespective of the axial refractive error. In this manuscript, the terms myopia regulation or myopia control will be used to refer to the decrease in the rate of axial elongation of the eye with different treatments.

We showed in a recent pilot study that experimental rigid and soft contact lenses can induce peripheral myopic defocus irrespective of the patient's baseline axial myopia presented. In that study, the rigid gas permeable (RGP) lens was more effective than the soft lens for creating the peripheral myopic defocus.[5]

The better on-eye stability of the RGP material compared to the soft contact lens materials might explain this outcome. Furthermore, that study showed that a standard aspheric RGP lens might also provide some peripheral myopic defocus. Other investigators recently reported a similar observation.[6]

Purpose of current study was to evaluate the effectiveness of an experimental RGP (ExpRGP) lens to create peripheral myopic defocus in a cohort of myopic patients

compared with a standard RGP (StdRGP) design and determine if the axial refraction affects the outcomes.

METHODS

Subjects and Lenses

Fifty two neophyte myopic subjects were enrolled in the study. Measurements were obtained from the right eye only, initially without a lens (baseline), and then with a StdRGP and an ExpRGP lens intended to change the pattern of the RPRE. The two lenses were worn in randomized order on two different days between 9:00 and 11:00 a.m. and at least 2 hours after awakening.

After receiving an explanation of the nature of the study, each patient signed a consent form before enrollment. The research followed the tenets of the Declaration of Helsinki and the Ethics Committee for Clinical Research at Clínica Teknon, Barcelona, Spain, reviewed and approved the protocol. The inclusion criteria required that the subjects had up to -8.00 D of myopia, astigmatism less than -1.00 diopters of cylinder (DC), did not have a current ocular disease or injury, were not taking any ocular or systemic medications, and had no contraindications to contact lens wear.

The RGP lenses were made of Boston XO2 (hexafocon B) material with nominal properties of oxygen permeability of 141 barrers, according to the polymer manufacturer (Polymer Technology, MA, USA). The central thicknesses varied depending on the back vertex power of the lenses according to the vertex corrected spherical equivalent of the non-cycloplegic subjective refraction of each eye. The overall diameter was 10.60 mm for the ExpRGP lens and 10.50 mm for the StdRGP lens. The base curve radii varied from 7.50 to 8.20mm across the subject group, and the same base curve radius was used for both the StdGP and ExpGP lens for each subject.

An alignment fit was attempted in all eyes by selecting the base curve radius as a function of the flat keratometric reading and corneal eccentricity.

ExpRGP lens was designed using Zemax-EE software v.6 (Radiant ZEMAX, WA, USA). Parameters for theoretical eyes were obtained from the study of Atchison[7] assuming a standard corneal eccentricity of 0.50. ExpRGP lenses has 9 mm aspheric front and back optic zones. This design affords +1.50 D add increase at 2 mm from center (4 mm chord diameter) corresponding to approximately 30º of retinal eccentricity, and achieving around +6.5 D at the edge of the optic zone (9 mm chord diameter) as described in Spanish Patent Application P-201030694.

StdRGP were commercial lenses PRE AS (Precilens, France) with a central spherical surface followed by a peripheral aspheric surface.

StdRGP and ExpRGP lenses were fitted according the topographical information (simK readings measured over the 3 mm of the central cornea and eccentricity over a chord diameter of 9.0 mm). Trial lenses were used to achieve optimal fitting in a pre-study visit. Lenses were ordered based on the vertexed spherical equivalent refraction. Over-refraction was done at the trial visit over the contact lenses and a new lens was ordered if discrepancies over ±0.25 were found. StdRGP and ExpRGP had the same central distance power.

Peripheral Refraction

Measurements of the central and peripheral (off-axis) refractions were obtained with an open-field Auto-Refractometer/Keratometer WAM-5500 (Grand Seiko Co., Ltd., Hiroshima, Japan) up to 30 degrees in the nasal and temporal visual field along the horizontal meridian in 5-degree increments. After lens insertion, peripheral refraction was evaluated after cessation of excessive tearing and once the lens was centered in the

inter-blink interval. This took between 5 to 15 minutes after insertion for all eyes evaluated. Each automated refraction measurement was obtained only 1 to 2 seconds after a blink to allow the lens to center and settle. If a blink occurred in the middle of a measurement, the measurement was repeated. To minimize lens decentration during peripheral fixation, head rotation instead of ocular rotation has been used. We used a previously reported method.[8,9] A laser pointer positioned over the patient's head was oriented toward the primary gaze position. The patient rotated his or her head, avoiding lateral displacement, until the laser pointer reached the given eccentric location while the eyes remained in the primary gaze position.

Descriptive statistics (mean ± standard deviation [SD]) were obtained for the refraction vector components $M=Sph+Cyl/2$, $J0=-Cyl\cdot\cos(2\alpha)/2$ and $J45=-Cyl\cdot\sin(2\alpha)/2$ where Sph, Cyl, and α are the sphere, cylinder, and axis obtained with the autorefractometer, respectively. RPRE was obtained by subtracting the central refractive error from each eccentric measurement.

Statistical Analysis

SPSS software package version19 (SPSS Inc., Chicago, IL) was used for statistical analysis. Kolmogorov-Smirnov test was applied to assess the normality of data distribution. Considering that we are evaluating different conditions on the same subjects (repeated measures) we used repeated measures analysis of variance (RM-ANOVA) and the Friedman non-parametric test to compare the outcomes between the three conditions (baseline, StdRGP, and ExpRGP values) for normally or non-normally distributed variables, respectively. The Bonferroni post-hoc correction for multiple comparisons was applied.

Spearman's rho correlation was applied when normality could not be assumed, and the Pearson correlation was used when normal distribution of data was verified to evaluate the relationship between the RPRE change and baseline refractive error.

For statistical purposes, p value < 0.05 was considered significant.

RESULTS

Average central baseline spherical equivalent was –3.22±1.66 D (range, –0.75 to –8.00 D) of sphere with less than 1.00 DC of refractive astigmatism in the spectacle plane. Mean flat keratometric reading was 7.85±0.25 mm.

Statistical analysis showed an interaction between the type of correction and the eccentricity for M and J0 ($p<0.05$) , but not for J45. For the most peripheral eccentricities, the M and J0 components of refraction became significantly different between the experimental conditions evaluated (no lens, ExpRGP and StdRRP). The comparisons between such conditions at each eccentricity is provided below for M, J0 and J45 components of refraction.

Figure 1A shows the RPRE for the M component of refraction in the no lens condition (baseline) and for the StdRGP and ExpRGP lenses. Statistical analysis showed significant differences in the M component between all examination conditions for the nasal retina beyond 10 degrees (i.e., $p < 0.05$ for 15 degrees and beyond according to ANOVA) and for the temporal retina beyond 5 degrees (i.e., $p < 0.05$ for 10 degrees and beyond according to the Friedman test). Post-hoc tests showed a statistically significant difference between no lens and ExpRGP for all eccentricities beyond 10º in the nasal field and 5º in the temporal field. StdRGP was significantly different from no lens condition for the nasal field beyond 5º of eccentricity and between 15 and 25º of temporal field; however, in this case the differences were much

lower than with the ExpRGP. Differences between StdRGP and ExpRGP were statistically significant beyond 10º of nasal field and beyond 5º of the temporal field.

Figures 1B and C show the RPRE for J0 and J45, respectively, with no lens and with StdRGP and ExpRGP lenses. Regarding changes in the J0 component, all eccentricities except 15 degrees nasal to 5 degrees temporal showed significant differences when compared with the baseline condition. Post-hoc tests showed that ExpRGP presented significantly different RPRE compared with no lens for the nasal eccentricity beyond 10º and for the temporal eccentricity beyond 5º. The same applied for the comparison between StdRGP and ExpRGP. Regarding changes in J45, differences between ExpRGP and no lens or between StdRGP and ExpRGP are not statistically significant and are very low.

Figure 2 shows the relationship between the spherical equivalent axial refraction without lens and the averaged RPRE at 30 degrees of eccentricity (average of 30 degrees nasal and 30 degrees temporal) for the StdRGP and ExpRGP lenses. Correlations were very weak ($r=0.05$; $r=0.19$; $r=0.04$ for no lens, StdRGP and ExpRGP, respectively) and non-significant. The same results were confirmed when the Nasal or Temporal RPRE were evaluated independently, instead of averaged.

Figure 3 shows the relationship between the amount of RPRE induced by the ExpRGP lens (ExpRGP minus Baseline) at the 30º of the temporal and nasal visual field as a function of the baseline axial spherical equivalent. There was negligible or no relationship between central refractive error and RPRE with the ExpRGP lens at the 30º nasal ($r=0.05$;$p<0.05$) or 30º temporal ($r=0.16$;$p<0.001$) eccentricities of the visual field. Despite the statistical significance of the correlation, both showed poor correlation. This means that the RPRE induced was independent of the central refractive error. Overall, in 60% of the eyes, the ExpRGP lens provided a change in RPRE of at least -2.00 D of

myopia at 30º with an average change in this group of -2.83±0.56 D (range, -2.01 to -3.69 D).

Figure 4 shows the averaged nasal and temporal RPRE values for no lens condition (baseline) as well as with StdRGP and ExpRGP lenses. Without lens, only 12% of the eyes presented some degree of relative peripheral refractive myopia. This increased to 29% with the StdRGP lens with most of the eyes showing myopic RPRE below 1.00 D (21%) and a few cases (8%) between 1.00 and 2.00 D. With the ExpRGP lens, up to 89% of the eyes presented some degree of myopic RPRE. In 60% of the eyes, the ExpRGP lens provided at least 1.00 diopter of relative peripheral myopia at the 30º of eccentricity. The total proportion of eyes with RPRE over -1.00 was significantly higher with the ExpRGP compared to StdRGP and no lens conditions ($p<0.05$ for both comparisons, Cochran Q). When the analysis was conducted for the 30º eccentricity in the nasal and temporal fields separately, it was evident that the proportion of eyes with relative peripheral myopia over -1.00 was higher in the temporal visual field (79%) compared to the nasal visual field (43%).

Figure 5 shows the effectiveness of the ExpRGP lens. The following information is depicted in the figure:

- Change induced in RPRE by ExpRGP (ExpRGP minus Baseline)
- Change induced in RPRE by StdRGP (StdRGP minus Baseline)
- Change induced in RPRE attributable to the special design of the ExpRGP (ExpRGP minus StdRGP)

The ExpRGP lens induced a myopic RPRE change of more than 3.00 D in 37% of the eyes, between -2.01 and -3.00 D in 23%, and between -1.01 and 2.00 D in 25%. This makes up to 85% of the eyes with a difference of at least -1.00D of myopic RPRE compared to the no lens condition. Conversely, the StdRGP lens induced such

differences in only 6%, 8%, and 19%, respectively (total 33%). When the analysis was conducted for the 30º eccentricity in the nasal and temporal fields separately, it was evident that the ExpRGP lens provided larger changes in myopic defocus in the temporal field compared to the nasal field. The total amount of eyes presenting changes in RPRE over -1.00 of myopia were 45% when the nasal field was considered and 66% when the temporal field was considered. Those presenting changes of -3.00 D or higher were 15% when the nasal field was considered and 29% when the temporal field was considered.

DISCUSSION

RGP materials are excellent platforms for contact lens design because of their optical properties and resistance to flexure forces while on the eye. They ~~also~~ are considered safe because they are associated with low risks of infection and other adverse events.[10] Despite this, they represent a small part of the contact lens market because of their initial discomfort and the need for longer periods of adaptation compared to soft contact lenses.[11]

The current study showed for the first time that a custom RGP lens might effectively induce relative peripheral myopic defocus across a wide range of values of axial myopia. Contrary to the relationship between induced peripheral myopic defocus and central refractive error in orthokeratology treatments,[1] the amount of myopia induced in the periphery of the visual field with the lens evaluated in the present study is not limited by or related to the axial refraction.

Queiros et al. reported that the relationship between the amount of myopia corrected in the corneal center and the amount of peripheral myopia induced after

199 treatment follows an almost 1:1 pattern, such that for 1.00 D of myopia to be
200 compensated for there is the potential to induce 1.00 D of RPRE at 30 degrees in the
201 extremes of the horizontal visual field.[1] Cho et al. showed that for myopes with less
202 than 2.00 D of myopia, the progression of the axial elongation was very similar to
203 subjects wearing spectacles.[12] Kakita et al. found a similar trend in Japanese myopic
204 children,[13] but this result was not observed in other two recently published studies from
205 Spain[14,15] and Hong Kong.[16]

206 Soft contact lenses currently in use to address myopia regulation incorporate
207 treatments zones of +2.00 diopters including multifocal center-distance, peripheral
208 gradient[17] and dual-focus lens designs.[18] Because the mechanism underlying myopia
209 control through manipulation of the peripheral optics is not fully understood, it is not
210 possible to establish the minimal effective level of peripheral myopia to reduce myopia
211 progression. However, assuming that a difference of at least 2.00 D of the RPRE should
212 be provided by any solution attempting to effectively interfere with myopic progression
213 based on manipulation of the peripheral optics. Our results showed that if at least 2.00 D
214 of relative peripheral myopic defocus might effectively be used to manipulate the
215 relative peripheral myopic defocus, such an effect could be achieved in 60% of eyes
216 evaluated in the current study.

217 While soft contact lenses might result in faster adaptation associated with better
218 comfort and centration with the pupil,[19] RGPs seem to offer the best platform to create a
219 given optical design and maintain such properties while being worn on the eye. Such an
220 effect cannot be provided in the same way using soft contact lens material. In our
221 previous study Proclear center-distance multifocal contact lenses with +4.00 D of add
222 did not show significantly different peripheral myopic defocus compared to the +3.00 D
223 add lenses; similarly, +1.00 D of add did not show any measurable benefit compared

with the naked eye.[3] We reported a similar effect with the same lens in myopic subjects.[20] Recently, Ticak and Walline did not find a significant peripheral myopic defocus effect with the Proclear Multifocal lenses compared with the effect produced by orthokeratology. However, they used an add power of +2.00 D,[21] which in our studies showed only a slight peripheral myopic defocus effect compared with the more effective +3.00 D add. This means that a given increase in the peripheral power addition on a soft contact lens material does not necessarily increase the effect in the same proportion when measured by peripheral refraction. This has been confirmed recently ~~this~~ in a pilot study that compared the peripheral refraction between the current experimental RGP design and the same design manufactured in a hydrogel material.[5] In contrast, it seems that the effect of the RGP lens might be stronger (average change in RPRE, -2.00 D) than the one intended to be reproduced (-1.50 D as expected from the lens design at 30º). In the present work it has been found that the change induced in the RPRE can be over 2.00 or even 3.00 D in a significant proportion of eyes with the ExpRGP lens. This would not be expected as the lens is designed to induce up to 1.5 D of myopic defocus. To find an explanation to the higher spherical equivalent obtained compared to the theoretical peripheral myopic defocus induced by the lens design we have to consider the astigmatism induced by the oblique incidence of light. When computed as spherical equivalent, the astigmatism induced by the optical surfaces for oblique incidence of light into the eye contributes to an overall increase in the myopic defocus that is beyond the change expected due solely to the increase in spherical power by the design of the lens. Additionally, the use of an autorefractor which averages refraction over a 2.3mm diameter measurement ring is likely to give highly myopic readings as the power add continues increasing up to the edge of the optic zone as explained in the methods section.

Ticak and Walline suggested in their recent study, more accurate instruments are needed to measure the power at discrete points in lenses with strong changes in power across their surface while the lenses are on the eye to better understand the refractive effect of orthokeratology treatment and multifocal contact lenses in the context of myopia progression.[21] However, previous studies have shown similar effects of the Proclear center-distance lens using an aberrometer that measures the full pupillary area.[22] Furthermore, because previous studies of orthokeratology and other lenses also have been conducted with the Grand Seiko or the Shin-Nippon instruments, the current results were comparable to those previously reported.

From the results of the present study cannot be assumed that the average peripheral myopic defocus achieved ensures that the entire retina might be under a similar defocus effect. As an example, while over 80% of the eyes will experience a change in RPRE of at least -1.00 D, this amount reduces to 45% when we consider the nasal field. For 29% of the subjects, the amount of the RPRE with the ExpRGP lens ranged from 0.25 to 1.00 D of myopia. The peripheral refraction and probably the retinal shape are not the same between the horizontal and vertical meridians,[21,23] not even between the nasal and temporal sides.[24] Our results show that with the present lenses, higher myopic defocus is usually achieved in the temporal visual field compared to the nasal visual field. We cannot justify these outcomes by the decentration of the lens with gaze changes. However, slight temporal decentration of the RGP lenses is usually observed, even when the lens remains within the accepted levels of centration (0.50 mm).[25] In the present study lens centration was improved using the large diameter lens (10.60 mm for ExpRGP lens and 10.50 mm for the StdRGP lens). This is critical when fitting RGP lenses to maximize the symmetry in the myopic defocus induced

around the foveal area. To maximize centration during the peripheral measurements, head turn instead of eye turn was used to fixate peripheral targets.

Results presented in this study show that the asymmetry between refraction in the nasal and temporal retinal eccentricity was approximately constant without and with lenses. Any significant decentration of the lens during measurements would result in reduction or exaggeration of the asymmetry found. This asymmetry in baseline data has been previously documented.[8,20,26,27] This might be related with the asymmetry in the nasal and tempoeral eye length and corresponding posterior retinal contour in myopia.[24,28] It could be also related with the measuring technique as we centered our measurements on the pupillary center. Asymmetries between nasal and temporal corneal curvature could also account for some differences. Kwok et al found that asymmetries between nasal and temporal peripheral refractive error would be minimized if measurements were referred to the optical axis of the eye instead of the foveal axis.[8] Overall, it can be concluded that lens decentration does not contribute to a change in the asymmetry of the nasal and temporal refraction and the factors previously mentioned should be considered.

Considering that treatments attempting to slow myopia progression should be more effective in younger children, safety becomes a major concern. Different authors have reported that RGP lenses worn overnight during orthokeratology treatment are well tolerated by children [13,14,29] which is probably related to the fast adaptation to this modality.[30] Children also have been shown to successfully adapt to RGP lenses on a daily wear basis in different clinical trials.[19,31] This makes RGP lenses a viable option for controlling myopia progression even if they have to be worn on a daily wear basis. One relevant aspect is the higher drop-out rate that might be present with RGP compared to soft contact lenses. In a randomized clinical trial addressing the potential

efficacy of conventional RGP lenses for myopia progression, Walline et al reported a 70% retention rate in the RGP arm compared with a 93% in the soft contact lens control arm.[31] While the tolerance must be a limitation for patients who previously wore soft contact lenses, this might not be the case for most young children wearing lenses for the first time to control myopia. Finally, the data summarized in the TFOS CLD workshop showed a trend for RGP lenses with larger diameters being more comfortable.[32,33] As in the present study, RGP lenses intended for myopia regulation should be manufactured in larger than average diameters to improve centration and provide a sufficiently large treatment zone over the larger pupil areas of ~~kids~~ children. Furthermore, to overcome the short-term discomfort issues with corneal RGP lenses, other strategies might be considered in the future, such as large diameter scleral or hybrid lenses. These lenses also can provide more lens stability and centration against misalignments related to ocular rotation and blinking.

In summary, the present study showed that RGP lenses can be custom designed to provide myopic RPRE in most of the myopic eyes irrespective of the degree of axial myopia within the range from -1.00 to -8.00 D of spherical equivalent included in this study. Comfort related aspects of this modality compared with soft contact lenses need to be considered. Finally, while the efficacy of this device in providing myopic RPRE has been shown, the efficacy to inhibit myopia progression still needs to be investigated with the appropriate clinical trial.

REFERENCES

Reference List

1. Queiros A, Gonzalez-Meijome JM, Jorge J, Villa-Collar C, Gutierrez AR. Peripheral refraction in myopic patients after orthokeratology. Optom Vis Sci 2010;87:323-9.

2. Charman WN, Mountford J, Atchison DA, Markwell EL. Peripheral refraction in orthokeratology patients. Optom Vis Sci 2006;83:641-8.

3. Lopes-Ferreira D, Ribeiro C, Maia R *et al.* Peripheral myopization using a dominant design multifocal contact lens. J Optom 2011;4:14-21.

4. Sankaridurg P, Donovan L, Varnas S *et al.* Spectacle lenses designed to reduce progression of myopia: 12-month results. Optom Vis Sci 2010;87:631-41.

5. Paune J, Queiros A, Quevedo L, Ferreira-Neves HI, Lopes-Ferreira D, Gonzalez-Meijome JM. Peripheral myopization and visual performance with experimental rigid gas permeable and soft contact lens design. Contact Lens Anterior eye 2014;37:455-60.

6. Shen J, Clark CA, Soni PS, Thibos LN. Peripheral refraction with and without contact lens correction. Optom Vis Sci 2010;87:642-55.

7. Atchison DA. Optical models for human myopic eyes. Vision Res 2006;46:2236-50.

8. Kwok E, Patel B, Backhouse S, Phillips JR. Peripheral refraction in high myopia with spherical soft contact lenses. Optom Vis Sci 2012;89:263-70.

9. Radhakrishnan H, Charman WN. Peripheral refraction measurement: does it matter if one turns the eye or the head? Ophthalmic Physiol Opt 2008;28:73-82.

10. Morgan PB, Efron N, Hill EA, Raynor MK, Whiting MA, Tullo AB. Incidence of keratitis of varying severity among contact lens wearers. Br J Ophthalmol 2005;89:430-6.

11. Fonn D, Gauthier CA, Pritchard N. Patient preferences and comparative ocular responses to rigid and soft contact lenses. Optom Vis Sci 1995;72:857-63.

12. Cho P, Cheung SW, Edwards M. The longitudinal orthokeratology research in children (LORIC) in Hong Kong: a pilot study on refractive changes and myopic control. Curr Eye Res 2005;30:71-80.

13. Kakita T, Hiraoka T, Oshika T. Influence of overnight orthokeratology on axial elongation in childhood myopia. Invest Ophthalmol Vis Sci 2011;52:2170-4.

14. Santodomingo-Rubido J, Villa-Collar C, Gilmartin B, Gutiérrez-Ortega R. Myopia control with orthokeratology contact lenses in Spain (MCOS): study design and general baseline characteristics. Journal of Optometry 2009;2:215-22.

15. Santodomingo-Rubido J, Villa-Collar C, Gilmartin B, Gutierrez-Ortega R. Myopia control with orthokeratology contact lenses in Spain: refractive and biometric changes. Invest Ophthalmol Vis Sci 2012;53:5060-5.

16. Cho P, Cheung SW. Retardation of myopia in Orthokeratology (ROMIO) study: a 2-year randomized clinical trial. Invest Ophthalmol Vis Sci 2012;53:7077-85.

17. Sankaridurg P, Holden B, Smith E, III *et al.* Decrease in rate of myopia progression with a contact lens designed to reduce relative peripheral hyperopia: one-year results. Invest Ophthalmol Vis Sci 2011;52:9362-7.

18. Anstice NS, Phillips JR. Effect of dual-focus soft contact lens wear on axial myopia progression in children. Ophthalmology 2011;118:1152-61.

19. Jones-Jordan LA, Walline JJ, Mutti DO *et al.* Gas permeable and soft contact lens wear in children. Optom Vis Sci 2010;87:414-20.

20. Lopes-Ferreira D, Ribeiro C, Neves H *et al.* Peripheral refraction with dominant design multifocal contact lenses in young myopes. J Optom 2013;6:85-94.

21. Ticak A, Walline JJ. Peripheral optics with bifocal soft and corneal reshaping contact lenses. Optom Vis Sci 2013;90:3-8.

22. Rosen R, Jaeken B, Lindskoog PA, Artal P, Unsbo P, Lundstrom L. Evaluating the peripheral optical effect of multifocal contact lenses. Ophthalmic Physiol Opt 2012;32:527-34.

23. Atchison DA, Pritchard N, Schmid KL. Peripheral refraction along the horizontal and vertical visual fields in myopia. Vision Research 2006;46:1450-8.

24. Faria-Ribeiro M, Queiros A, Lopes-Ferreira D, Jorge J, Gonzalez-Meijome JM. Peripheral refraction and retinal contour in stable and progressive myopia. Optom Vis Sci 2013;90:9-15.

25. Wolffsohn JS, Hunt OA, Basra AK. Simplified recording of soft contact lens fit. Cont Lens Anterior Eye 2009;32:37-42.

26. Lopes-Ferreira D, Ferreira-Neves HI, Faria-Ribeiro A, Queiros A, Fernandes PRB, González-Méijome JM. Peripheral refraction with eye and head rotation with contact lenses. Contact Lens Anterior eye 2014;37:(in press).

27. Lin Z, Martinez A, Chen X *et al.* Peripheral defocus with single-vision spectacle lenses in myopic children. Optom Vis Sci 2010;87:4-9.

28. Logan NS, Gilmartin B, Wildsoet CF, Dunne MC. Posterior retinal contour in adult human anisomyopia. Invest Ophthalmol Vis Sci 2004;45:2152-62.

29. Walline JJ, Jones LA, Sinnott LT. Corneal reshaping and myopia progression. Br J Ophthalmol 2009;93:1181-5.

30. Gonzalez-Meijome JM, Carracedo G, Gonzalez-Perez J, Peral A, Jorge J, Peixoto-de-Matos SC. Comfort and vision scores at insertion and removal during 1 month of wear of Paragon CRT for corneal reshaping. Eye Contact Lens 2011;37:302-6.

31. Walline JJ, Jones LA, Mutti DO, Zadnik K. A randomized trial of the effects of rigid contact lenses on myopia progression. Arch Ophthalmol 2004;122:1760-6.

32. Sorbara L, Mueller K. Effect of lens diameter on lens performance and initial comfort of two types of GP lenses for keratoconus: a pilot study. J Optom 2011;4:22-9.

33. Jones L, Brennan NA, Gonzalez-Meijome J *et al.* The TFOS International Workshop on Contact Lens Discomfort: report of the contact lens materials, design, and care subcommittee. Invest Ophthalmol Vis Sci 2013;54:TFOS37-TFOS70.

LEGENDS

FIGURE 1.

(A) Spherical equivalent component (M) of the relative peripheral refractive error (RPRE) without lenses (baseline), with standard RGP (StdRGP) and an experimental RGP (ExpRGP) lenses. (B, C) Astigmatic component (J0 and J45) of the RPRE without lenses (baseline), with the StdRGP and the ExpRGP lenses. Lines represent the second-order polynomial fitting. The error bars represent the standard error of the mean (SEM).

FIGURE 2.

The correlation between the baseline axial refraction and the amount of relative peripheral refractive error (average between 30 degrees in the nasal and temporal visual fields) at baseline without a lens ($y = -0.0275 x + 1.0227$; $r=0.05$; $p=0.745$ represented by the light grey circles and dashed line) and the standard gas permeable lens ($y = 0.1815 x + 1.2827$; $r=0.19$; $p=0.117$; represented by the dark grey diamonds and dark grey line), and the experimental gas permeable lens ($y = 0.0268 x + 1.3164$ $r=0.04$; $p=0.756$ represented by the black squares and black line).

FIGURE 3.

Correlation between the axial refraction at baseline and the amount of change in relative peripheral refractive error achieved with the experimental gas permeable lens compared to baseline for 30 degrees of eccentricity in the nasal (30 degrees nasal; $y = -0.0715 x – 2.585$; $r=0.05$; $p<0.05$; black diamonds, black line) and temporal (30 degrees temporal; $y = 0.1802 x – 2.0931$; $r=0.16$; $p<0.001$; grey circles, grey line) visual fields.

FIGURE 4.

The proportion of eyes with a given relative peripheral refractive error (RPRE) (average between 30 degrees in the nasal and temporal visual fields) at baseline, with the standard gas permeable and the experimental gas permeable lenses. Negative values indicate myopic RPRE and positive values indicate hyperopic RPRE.

FIGURE 5.

The proportion of eyes with a given change in relative peripheral refractive error (RPRE) (average between 30 degrees in the nasal and temporal visual fields) for the paired comparisons between baseline, the standard gas permeable lens and the experimental gas permeable lens. Negative values indicate myopic RPRE and positive values indicate hyperopic RPRE.