1. INTRODUCTION

The term corneal ectasia includes a group of conditions characterized by progressive thinning, bulging and distortion of the cornea. Keratoconus (KC) is the most prevalent corneal ectasia which affects the surface, structure and transparency contributing towards the conical shape of the cornea [1]. Laser-assisted refractive procedures have become very popular in the last decades. As a result, some patients present altered corneal properties. Similar to KC, ectasia after refractive surgery shows topographic asymmetric inferior corneal steepening [2].

The progression of ectasia increases low-order aberrations (LOA), including myopic spherocylindrical refractive values, and high-order aberrations (HOA). This mainly produces vertical coma aberration due to the loss of rotational symmetry of corneal surfaces. When the cone is displaced inferiorly, the vertical coma is negative, which is induced by the anterior corneal surface [3]. The increase in HOA, reduces the optical quality and therefore the quality of life in comparison with healthy subjects [4]. Surgery treatments, with the goal of stabilization include cross-linking, intrastromal corneal ring segments (ICRS) and keratoplasty. The fitting of rigid gas permeable contact lenses (RGP) is the gold standard treatment of ectasias. The front surface of corneal RGP on an ectatic cornea provides a refractive surface much more regular profile and a post-RGP lens tear film that has the capability to mask both LOA and HOA [5-7]. However, it is difficult for some patients to tolerate these lenses for enough hours to perform their activities [8]. When this occurs, the alternative contact lens options include soft contact lenses (SCL), piggy-back, hybrid and scleral lenses.

In recent years, scleral RGP prescribing has increased due to significant advantages over corneal RGP including improved comfort and stability. Scleral RGP are designed to vault over the cornea and limbus. This create a fluid reservoir between the lens and the cornea neutralizing surface irregularities [9]. While scleral lenses offer several advantages, in some cases their size and application and removal sometimes pose a problem.

Previous studies have shown that the visual acuity (VA) achieved using a SCL is often better than the outcome predicted by aberrometry coefficients. Moreover, they can achieve higher comfort levels compared to other lenses [10-12]. Carballo-Alvarez et al. [13] reported that soft toric contact lenses (STCL) are a viable option for good vision in keratoconic eyes with moderate irregularity after ICRS implantation. Several reports indicate that a high central thickness of the SCL seems to decrease the HOA and to improve the visual function in irregular cornea [7, 14-16]. To fully correct the HOA of both anterior and posterior corneal surfaces in keratoconic patients, customized wavefront-guided contact lens designs have been developed as an option to improve optical quality in KC [12, 17-22]. Other authors used asymmetric SCL to correct vertical coma aberration in keratoconic patients [23-25].

As previously observed in eyes with an irregular cornea [10, 11], the clinical experience indicates that in some patients, STCL besides offering high comfort, leads to better visual function than predicted by corneal HOA indicators and could be an alternative to RGP lens. The purpose of this study was to assess the feasibility of STCL fitting in corneal ectasias and their impact on optical quality and visual performance.

2. METHODS

The sample includes twenty participants, all of them previously successfully fitted with the molded STCL used in this study. The group with irregular cornea included 11 eyes of 9 subjects with previously diagnosed corneal ectasia with moderate irregularity, corneal RGP intolerant and transparent central cornea. In order to analyse the STCL fitting differences between ectatic and healthy corneas, a group of 11 eyes of 11 patients with regular and healthy cornea was included.

Participants were recruited from the Optometry Clinic of the Complutense University of Madrid (UCM). Exclusion criteria were a history of any systemic conditions and any other co-existing forms of ocular disease as well as the use of systemic or topical ophthalmic medications. This study was conducted in accordance with the tenets of the Declaration of Helsinki and was approved by the institutional review board of the Hospital Clínico San Carlos of Madrid (code 18/537-E). All participants were voluntarily included in the study after signing written informed consent forms.

2.1 Soft toric contact lenses

A molded STCL (Biofinity toric, CooperVision, USA) was fitted. These silicone-hydrogel lenses with a prism-ballast design are made of comfilcon A (48% water), 8.7mm of base curve, overall diameter of 14.50 mm, Young's modulus value of 0.75 MPa and Oxygen Transmissibility of 116 Dk/t (at -3.00 D). The design features of the STCL are described in patent (US6467903B1) [26]. The design shows a prism ballast and a thickness profile. The anterior surface of the lens shows a peripheral zone, an inner zone circumscribed by the peripheral zone, and a central optic zone. The ballast portion increases in thickness along a superior-inferior line parallel to a vertical meridian. Due to the thickness profile, the inferior portion of the inner zone presents 250 μm more than the upper. Theoretically, the optic zone is independent of the thickness profile, however Sulley et al. [27] reported that it presents a trend of 0.77 ± 0.05 base-down prismatic diopters (for -3.00 sph -1.25 cyl x 180º). Moreover, the analysis with NIMO TR 1504 (Lambda-X, Belgium) shows hat the prismatic effect increases progressively from the upper to the lower zone, which has the highest prismatic power. The sagittal height of the fitted STCL presents a high value compared with other frequent replacement silicone hydrogel lenses [28], this could advantage an adequate lens behavior in ectatic corneas. Moreover, the design presents the greatest thickness close to the inferiorly displaced corneal apex. Probably, this could improve the anterior corneal surface regularization.

Initial lens power was calculated from the refraction obtained after referencing the corneal plane. After ten minutes of fitting, a slit-lamp evaluation was performed to check that each lens was positioned acceptably in terms of centration and toric marker alignment. Next, over-refraction was evaluated and if a VA improvement was observed, a new STCL was prepared based on the lens power plus the over-refraction, with a new sphere, cylinder and axis.

2.2 Ocular aberrations, pupillometry and keratometry

The measurement of ocular aberrations, expressed by Zernike polynomials, was captured from the 2nd to the 5th order by using the sensor of the Visionix-VX110 system (Luneau Technology, France). It combines a Hartmann-Shack aberrometer and a Placido disk corneal topographer. In order to measure the aberrations, under mesopic conditions for physiological pupil diameter, the instrument decreased the illumination level of the Placido disc rings projected onto the corneal surface with the room lighting turned off. Furthermore, the aberrometric values were calculated for a 3mm pupil diameter. Pupillometry, keratometry over the anterior surface of the cornea (3mm central zone) and symmetry index of front corneal curvature were assessed using the same instrument. The symmetry index defined as the difference (expressed in diopters) between the mean power of two circular zones centered in the vertical axis. Positive values indicate a steeper inferior hemisphere, whereas negative values indicate a steeper superior hemisphere

The study used the right-hand coordinate reference frame and the double-index convention for naming Zernike coefficients and polynomials recommended by the Optical Society of America/Vision Science and its Applications Standards Taskforce. The signs of bilaterally asymmetrical Zernike coefficients in left eyes affected by enantiomorphism (Oblique primary astigmatism 45º; horizontal coma; oblique trefoil; oblique quadrafoil and oblique secondary astigmatism) were reversed to allow comparison between right eyes and left eyes [29].

2.3 Visual performance

Visual performance was measured with best spectacle correction and after STCL fitting under photopic (85 cd/m^2) and mesopic (≤3 cd/m^2) conditions. High-(96%)

and low-(10%) contrast visual acuity (HCVA and LCVA respectively) were assessed using an ETDRS illumination cabinet (Precision Vision, USA) placed at 4 m. For the mesopic luminance level required, illumination was reduced by using a large filter designed for use in the ETDRS cabinet with the room lighting turned off. For photopic conditions, the normal room lighting was left on.

The cylinder axis values affected by enantiomorphism were recalculated in left eyes (180 minus axis value) to allow comparison between right and left eyes. Next, the relative power vector values of M, J_0, and J_{45} were obtained. The method uses 3 fundamental vectors, including $M = S + C/2$, $J_0 = (-C/2) \cos 2\alpha$, and $J_{45} = (-C/2) \sin 2\alpha$, where S is the sphere power, C is the cylinder power, α is the cylinder axis, and J is the Jackson astigmatic vector. M is the spherical lens equal to the spherical equivalent of the refractive error. J_0 value is the cylinder power set at 90 and 180 degrees and J_{45} value refers to a cross-cylinder set at 45 and 135 degrees.

Contrast sensitivity (CS) was assessed using the Pelli-Robson chart (Clement Clarke International, UK) placed at 1 m distance. The test was externally illuminated with a halogen lamp behind a screen and connected to a potentiometer to adjust the exact voltage needed to reach an adequate mesopic luminance level with the room lighting turned off. This setup provided uniform luminance over the entire chart. For photopic conditions, the normal room lighting was left on. Luminance measurements for the tests were obtained using a Mavo-Spot 2 USB luminance meter (Gossen, Germany).

3. STATISTICAL ANALYSIS

All statistical tests were performed using Statgraphics Centurion-XVIII software. Descriptive statistics, including the mean and standard deviations of the quantitative data, were calculated. The normality of all data samples was checked using the Saphiro-Wilk test. A paired t-test was used for normally distributed data. Non-normally distributed data were evaluated with the Wilcoxon signed-ranks test. Statistical significance was set at a level of 0.05 (*$p<0.05$; **$p<0.005$; ***$p<0.001$).

4. RESULTS

The study evaluated 22 eyes: 11 eyes with corneal ectasia, intolerant to corneal RGP contact lenses and satisfactorily fitted with STCL (5 eyes of 5 patients with a KC grade I according to the Amsler-Krumeich classification. [30] 4 eyes of 2 patients with KC grade I in one eye and KC grade II, with flattened keratometric parameters after ICRS implantation, in the contralateral eye and 2 eyes of 2 patients with corneal ectasia post refractive surgery). The healthy group included the eye with better visual acuity of 11 subjects with regular cornea and refractive cylinder from -0.75 D to -2.25 D.

The baseline characteristics including physiological pupil diameters and keratometric powers in the 3mm anterior corneal central zone are detailed in Table 1. In the eyes with corneal ectasia, mean mesopic pupil diameter was 1.28 mm smaller ($p=0.01$), whereas mean corneal power was 1.74 D ($p=0.03$) and 1.65 D ($p=0.02$) higher in K1 and K2 respectively. The symmetry index was higher in the ectatic corneas (p=0.002) with a steeper inferior hemisphere, whereas the healthy corneas showed a steeper superior hemisphere

Table 1: Baseline characteristics in both groups of eyes . Mean ± SD.

	Corneal ectasia	**Healthy cornea**
n	11	11
Male/Female	2/9	3/8
Age (years)	37.9 ± 7.2	30.2 ± 9.2
Right/left eye	7/4	4/7
Photopic pupil diameter(mm)	2.96 ± 0.61	3.12 ± 0.58
Mesopil Pupil diameter(mm)	4.96 ± 1.04	6.25 ± 0.96
K1 (D)	44.96 ± 1.75	43.22 ± 1.78
K2 (D)	46.87 ± 2.04	44.85 ± 1.66
Symmetry Index (D)	2.47 ± 3.96	-0.28 ± 1.00

K1:flatter keratometry value. K2:steeper keratometry value (3mm central zone)

In five eyes with corneal ectasia, the spherical and/or cylindrical contact lens values were adjusted after over-refraction to achieve the best VA. In the healthy corneas, it was not necessary to change the contact lens refractive parameters after over-refraction in any case. Table 2 shows the obtained relative power vector values M, J_0 and J_{45} in both groups of eyes. Statistically and clinically significant differences were found between ectatic and healthy corneas regarding M (p=0.04 and p=0.04 comparing spectacles and contact lens values respectively).

Table 2. Relative power vector values M, J_0 and J_{45} in both group of eyes. Mean± SD.

Refraction (D)	**Corneal ectasia**		**Healthy cornea**	
	Spectacles	**Contact lens**	**Spectacles**	**Contact lens**
M	-3.55 ± 1.52	-3.25 ± 1.25	-0.98 ± 3.48	-0.88 ± 3.33
J_0	-0.37 ± 0.79	-0.18 ± 0.77	0.25 ± 0.67	0.19 ± 0.65
J_{45}	0.29 ± 0.52	0.12 ± 0.24	0.03 ± 0.13	-0.07 ± 0.12

Table 3 shows the aberrometric values with statistically significant difference pre and after contact lens fitting, assessed with 3mm and the different mesopic pupil diameters between both groups. With respect to LOA, statistically significant differences were only found in the group with corneal ectasia: mean oblique astigmatism increased with a change of 0.15 ± 0.17μm and 0.34 ± 0.36μm for 3mm and mesopic pupil diameter, respectively. However, mean defocus decreased 1.41 ± 0.36μm and 2.17 ± 0.85μm for the same diameters.

With respect to HOA, vertical trefoil showed a statistically significant decrease in the healthy corneas with a mean change of 0.03 ± 0.04μm for mesopic pupil diameter. Moreover, more positive values of vertical coma were found after contact lens fitting in the ectatic corneas with a mean change of 0.05 ± 0.06μm and 0.12 ± 0.10μm for 3mm and mesopic pupil diameters respectively as well as in the healthy corneas for mesopic pupil diameter with a mean change of 0.18 ± 0.10μm. With respect to horizontal coma, a statistically significant increase only emerged in the healthy group for mesopic pupil diameter with a mean change of 0.06 ± 0.08μm.

In addition, other statistically significant changes were found in mesopic conditions. In the healthy group, mean oblique secondary astigmatism increased 0.02 ± 0.03μm, whereas mean horizontal secondary coma changed -0.02 ± 0.02μm. Finally, mean vertical secondary trefoil worsened -0.04 ± 0.06μm in the ectatic corneas. Comparing mean changes between both groups, with 3mm pupil aperture, statistically significant differences were detected in oblique astigmatism (p=0.01), defocus (p<0.001), vertical secondary trefoil (p=0.01) and horizontal secondary coma (p=0.03).

Table 3: Aberrometric values with statistically significant difference assessed with 3mm and mesopic pupil diameters pre and after STCL fitting in both groups of eyes. Mean ± SD.

ZERNIKE (µm)	**Pupil diameter**	**Corneal ectasia**	**Corneal ectasia after STCL fitting**	**Healthy cornea**	**Healthy cornea after STCL fitting**
Z_2^{-2}	**3mm**	0.01 ± 0.38	0.16 ± 0.37	0.01 ± 0.11	-0.01 ± 0.09
		p=0.01*		P=0.30	
Oblique astigmatism	**Mesopic**	-0.02 ± 0.62	0.32 ± 0.74	0.03 ± 0.18	0.06 ± 0.32
		p=0.004 **		p=0.74	
Z_2^{0}	**3mm**	1.67 ± 0.50	0.26 ± 0.37	0.30 ± 1.13	-0.06 ± 0.17
		p<0.001***		p=0.33	
Defocus	**Mesopic**	2.74 ± 0.98	0.57 ± 0.93	0.57 ± 2.80	-0.09 ± 0.71
		p<0.001***		p=0.50	
Z_3^{-3}	**3mm**	0.03 ± 0.09	0.06 ± 0.09	-0.02 ± 0.04	0.00 ± 0.03
		p=0.11		p=0.05	
Vertical Trefoil	**Mesopic**	0.05 ± 0.17	0.07 ± 0.16	-0.07 ± 0.07	-0.04 ± 0.09
		p = 0.12		p = 0.04*	
Z_3^{-1}	**3mm**	-0.10 ± 0.09	-0.05 ± 0.08	0.02 ± 0.04	0.04 ± 0.03
		p=0.02*		p=0.17	
Vertical Coma	**Mesopic**	-0.22 ± 0.24	-0.10 ± 0.22	0.10 ± 0.13	0.28 ± 0.18
		p=0.003**		p<0.001***	
Z_3^{1}	**3mm**	0.004 ± 0.06	0.008 ± 0.09	-0.01 ± 0.04	0.01 ± 0.03
		p=0.73		p=0.01*	
Horizontal Coma	**Mesopic**	-0.006 ± 0.18	-0.008 ± 0.23	0.01 ± 0.09	0.07 ± 0.14
		p=0.94		p = 0.02*	
Z_4^{-2} Oblique	**3mm**	-0.02 ± 0.03	-0.01 ± 0.01	0.00 ± 0.01	0.004 ± 0.007
		p=0.36		p=0.32	
secondary astigmatism	**Mesopic**	-0.05 ± 0.05	-0.04 ± 0.05	-0.001 ± 0.03	0.02 ± 0.03
		p=0.60		p=0.02*	
Z_5^{-3} Vertical	**3mm**	0.003 ± 0.006	-0.007 ± 0.01	0.001 ± 0.003	0.00 ± 0.004
		p=0.06		P=0.51	
secondary Trefoil	**Mesopic**	0.002 ± 0.02	-0.04 ± 0.07	0.002 ± 0.02	-0.005 ± 0.03
		p=0.04*		p=0.22	
Z_5^{1} Horizontal	**3mm**	0.00 ± 0.02	-0.01 ± 0.02	0.005 ± 0.01	0.00 ± 0.003
		P=0.20		P=0.16	
secondary Coma	**Mesopic**	-0.006 ± 0.03	-0.02 ± 0.04	0.01 ± 0.02	-0.01 ± 0.03
		p=0.15		p=0.03*	

Statistically significant difference: *p<0.05; **p<0.005; ***p<0.001.

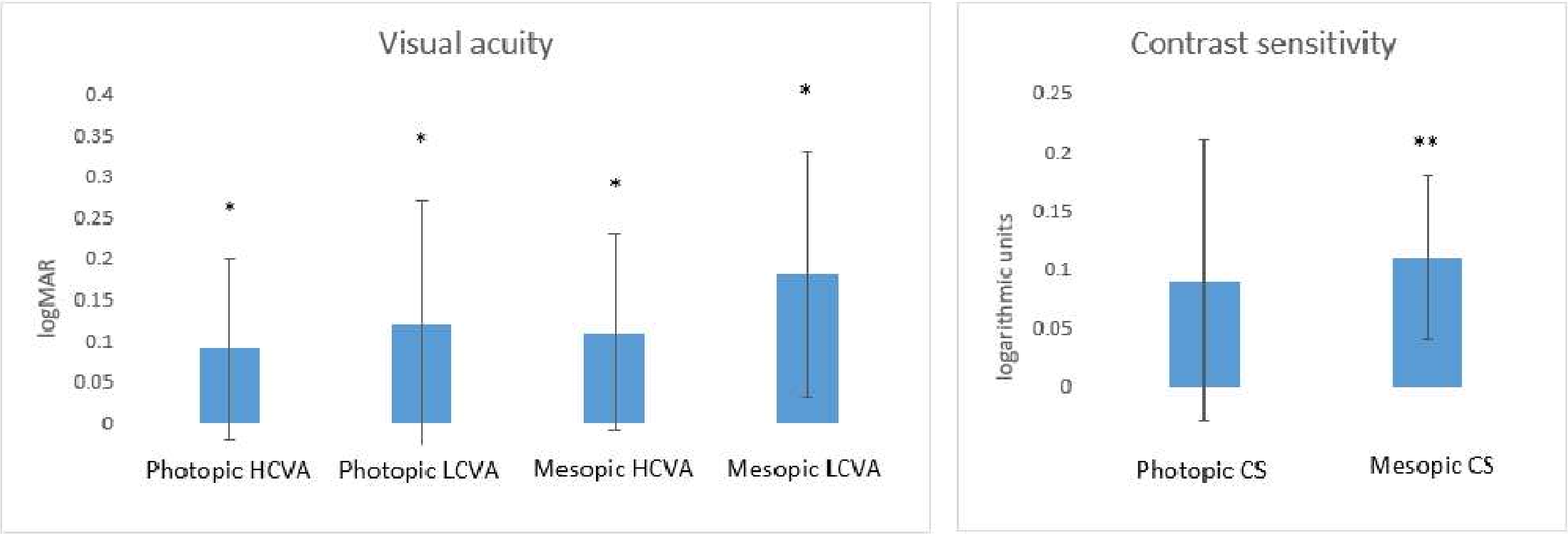
Mean differences in HCVA, LCVA and CS are shown in Table 4. Significant improvements (Figure 1) were found in the ectatic corneas after STCL fitting for all outcome measures, except photopic CS which was close to significance (p=0.05). Thus, mean photopic HCVA increased 0.09 ± 0.11 logMAR (4.5 letters, near to clinical significance) and mean photopic LCVA improved 0.12 ± 0.15 logMAR (6 letters). In mesopic conditions, mean HCVA, LCVA and CS improved 0.11 ± 0.12 logMAR (5.5 letters), 0.18 ± 0.15 logMAR (9 letters) and 0.11 ± 0.07 log. units, respectively. Regarding the spectacles outcomes, all the mean values were significantly better in the healthy group. When the contact lens outcomes were compared, mean values in photopic LCVA, photopic CS, mesopic HCVA and mesopic LCVA were significantly better in the healthy group, whereas photopic HCVA and mesopic CS did not show significant differences.

Table 4: High- and Low- contrast visual acuity (logMAR) and contrast sensitivity (log. units) assessed in both eyes groups, in photopic and mesopic conditions, pre and after STCL fitting. Mean ± SD.

	Photopic conditions								
	HCVA			**LCVA**			**CS**		
	Spectacles	STCL		Spectacles	STCL		Spectacles	STCL	
Corneal ectasia	0.08 ± 0.22	-0.01 ± 0.14	p=0.02*	0.36± 0.26	0.24 ± 0.20	p=0.03*	1.62 ± 0.10	1.71 ± 0.13	p=0.05
Healthy cornea	-0.06 ± 0.07	-0.06 ± 0.05	P=0.86	0.07 ± 0.07	0.05 ± 0.04	P=0.49	1.97 ± 0.06	1.98 ± 0.04	P=1.00
	p=0.03*	p=0.59		p=0.008*	p=0.008*		P<0.001***	P<0.001***	
	Mesopic conditions								
	HCVA			**LCVA**			**CS**		
	Spectacles	STCL		Spectacles	STCL		Spectacles	STCL	
Corneal ectasia	0.32 ± 0.28	0.21 ± 0.19	p=0.02*	0.62 ± 0.26	0.44 ± 0.19	p=0.005*	1.48 ± 0.14	1.59 ± 0.09	p=0.001**
Healthy cornea	0.06 ± 0.08	0.06 ± 0.05	P=0.88	0.32 ± 0.12	0.29 ± 0.11	P=0.54	1.67 ± 0.15	1.67 ± 0.09	P=1.00
	p=0.01*	p=0.02*		p=0.005**	p=0.04*		p=0.007*	p=0.06	

HCVA: High Contrast Visual Acuity. LCVA: Low Contrast Visual Acuity. CS: Contrast sensitivity. Statistically significant difference: *p<0.05; **p<0.005; ***p<0.001.

Figure 1: Visual improvements in photopic and mesopic conditions produced after STCL fitting compared to spectacle values in the group with corneal ectasia. Vertical lines indicate standard deviation.



HCVA: High Contrast Visual Acuity. LCVA: Low Contrast Visual Acuity. CS: Contrast sensitivity. Statistically significant change: *$p<0.05$; **$p<0.005$

5. DISCUSSION

In the present study, non-customized STCL were fitted in ectatic and healthy corneas. Although theoretically, standard STCL have limited effectiveness for the irregular cornea patient, further benefits of these STCL are an easy manufacturing process thereby reducing costs, many replacement options, their easy access, along with acceptable comfort. Only a few studies have addressed molded STCL fitting in eyes with corneal ectasia, and most have examined only a small number of eyes [10, 11].

In five eyes with corneal ectasia, the refractive results of the STCL were not as predicted by spectacles power (after referencing to the corneal plane). In no case was necessary to fit a STCL cylinder higher than 2.25D, even when the spectacle cylinder was greater. A possible explanation for this is that the optical quality of the eye plus contact lens, besides depending on the optics of the eye, will also depend on the optical properties of the lens and its interaction with the cornea and tear film. Further influential factors include partial correction of anterior corneal surface HOA, which is related to the modulus of the contact lens, the thickness profile [10, 14, 16], and the interactions between LOA and HOA [31-33]. Theoretically, it would be possible to change the final power with different materials and designs. Nepomuceno et al. [11] described a case of a keratoconic patient after Intacs implantation fitted with a molded disposable STCL (Etalfincon A). Spectacle refraction was −1.25 sph −5.00 cyl and VA was 0.12 logMAR. However, final STCL power was −2.00 sph −1.25 cyl and VA was −0.08 logMAR. Roncone [10] fitted a postoperative LASIK keratoectasia patient with high and irregular astigmatism with a disposable STCL (Methafilcon B). The final STCL sphere was +1.00D more positive than the spectacles and the VA improved from

0.60 to 0.00 logMAR. In the study of Carballo-Alvarez et al. [13], 23 keratoconic eyes were fitted satisfactorily with STCL (Hioxyfilcon A) after ICRS implantation. In agreement with the findings of this study, STCL refractive power and the significantly improved VA were not those expected for STCL in eyes with regular cornea [13]. The studies of Jinabhai et al. [34] and Katsoulos et al. [23] with customized and non-customized STCLs fitted in keratoconic patients, found that the lower-order sphere and cylinder terms, measured objectively using Hartmann–Shack aberrometry, did not correspond with the sphere and cylinder powers measured during a subjective refraction. Jinabhai et al. attributed this variability at the wavefront sensors and described the importance of a subjective over-refraction result to determine the powers of the STCL.

The eyes with ectatic cornea of this study showed moderate degrees of corneal irregularity and mesopic pupil diameters, which leads to moderate values of 3rd order coma aberration [4]. Vertical coma results in the ectatic corneas after STCL fitting both with 3mm pupil aperture and mesopic conditions were similar to those reported by Naderal et al. [35] in 150 healthy eyes (-0.05 ± 0.25 μm), although with a large degree of variability in mesopic conditions. The more positive vertical coma values showed after STCL fitting, are probably related to the optic zone of the STCL presents a prismatic power base-down. Berntsen et al. [36] fitted 30 healthy eyes with the spherical and toric SCL of four different brands. The only toric lens with a dual thin-zone stabilization design showed the lower amount of on-eye vertical coma (-0.04μm; 6mm aperture) compared with the three prism-ballast design toric lenses, which ranged from 0.11 to 0.23μm. In addition, the three STCLs with prism-ballast designs had a clinically greater vertical coma than their sphere counterparts and showed better HCVA than the STCL with a thin-zone design. As several authors concluded [31, 33], one possible explanation is that other aberrations combined with coma can result in better image quality. Carpena-Torres et al. [25] proved that base-down prismatic soft contact lenses generate a statistically significant decrease in defocus which was directly proportional to prism value as well as an increase in vertical coma, which is positive and is directly proportional to prism value. This supposes the possibility of partially correcting the HOA associated with irregular corneas, whose visual performance is mainly affected by negative vertical coma aberration, with STCL. Nevertheless, Katsoulos et al. [23] suggested that in order to correct the corneal negative vertical coma, the thicker part of the optical zone of the contact lens should be the upper one, and the thinnest part should be the lower one. Jeong et al. [37] measured a conventional STCL (-4.50 sph -1.75 cyl) with a Hartmann-Shack wave-front sensor. The contact lenses showed a prismatic stabilization (base-down) and were placed in a wet cell filled with lens solution. In accordance with the aforementioned suggestion of Katsoulos et al. a negative vertical coma of -0.20 ± 0.04µm was observed by the authors. Nonetheless, previous reports [22, 25] and the clinical experience, shows that once the STCL with base-down prism has been fitted in contact with the anterior corneal surface, a significant positive shift is found in the ocular vertical coma.

Although the coma correction found in the group with corneal ectasia was not complete, previous studies seem to confirm than partial HOAs correction could be more appropriate than total correction to achieve better visual performance. As Chen and Yoon [32] reported, on average, 22%, 24%, and 14% of the anterior corneal coma were compensated by the posterior cornea in the advanced, moderate, and mild keratoconic eyes, respectively. Furthermore, crystalline lens may be responsible for some of the residual aberrations measures after RGP or customized contact lens fitting. This may explain the relatively poor VA obtained in some eyes with RGP contact lenses, which correct only anterior corneal aberrations [32]. Other studies with customised lenses suggested that overcorrect vertical coma generates residual aberration that decreases the visual performance. Furthermore, the decentration and rotation of a partial correction of optics aberrations produces a greater visual benefit than total correction or sphero-cylindrical corrections [12, 38, 39].

Regarding the group with corneal ectasia, an improvement in visual performance after STCL fitting was detected. The photopic CS (1.71 ± 0.13 log. Units) was lower than reported by Puell et al. [40] (1.93 ± 0.04 log. units) for healthy subjects at the same age range. Conversely, mean mesopic HCVA (0.21 ± 0.19 logMAR) was better than the values reported by Hiraoka et al. [41] (0.39 ± 0.12 logMAR) for healthy subjects, although such differences may be due to the different test used between these the studies.

As clinical experience demonstrates, the visual function and hence the quality of life of patients with aberrated eyes is more affected in low contrast and mesopic conditions. However, mean results of mesopic LCVA (0.44 ± 0.19 logMAR) and mesopic SC (1.59 ± 0.09 log.units) after STCL fitting in the ectatic corneas were similar to those described in previous studies of healthy eyes. Barrio et al. [42] reported a mean measurement of 0.44 ± 0.11 logMAR in mesopic LCVA, meanwhile Puell et al. [40] found a mean value of 1.60 ± 0.07 log. units in mesopic CS at the same age range as this study. [40]

The present study has some limitations that could be improved upon in future studies. It would be necessary: to increase the sample, to examine corneal surface interactions between low and high order aberrations, long-term neural adaptation and the use of different materials and designs of STCL.

Unlike the group with healthy cornea, the obtained visual performance in the experimental group was improved over spectacles. Probably, they did not match the visual performance improvement of other modalities like corneal or scleral RGP contact lenses. However, it was possible to achieve a satisfactory visual performance after molded STCL fitting besides offering high comfort and easy handling. In conclusion, the analyzed molded soft toric contact lens is a feasible option for good vision in corneal ectasia with moderate irregularity and negative vertical coma.

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