



Clinical evaluation of different types of contact lenses in keratoconus management



Özge Saraç, Meltem Ece Kars*, Berke Temel, Nurullah Çağıl

Yıldırım Beyazıt University, Ankara Atatürk Training and Research Hospital, Ophthalmology Department, Üniversiteler Mahallesi Bilkent Caddesi No: 1, Ankara, Turkey

ARTICLE INFO

Keywords:
Contact lens
Cross-linking
Keratoconus

ABSTRACT

Purpose: To compare the clinical and topographical findings of the keratoconus patients according to the prescribed contact lens type and to investigate the effects of corneal collagen cross-linking (CXL) and cone location on lens selection.

Methods: The records of 301 eyes of 195 keratoconus patients who were prescribed contact lenses were analyzed retrospectively. The eyes were grouped according to the lens type: Soft toric contact lens (STCL), rigid gas-permeable contact lens (RGPCL), hybrid contact lens (HCL) and mini-scleral contact lens (MSCL). The history of having CXL, ophthalmological examination findings, and the topographical findings were compared between the groups. Brown-Forsythe, Chi-square, and post-hoc tests were used to compare the groups. Mann-Whitney *U* test was used for subgroup analysis. Comparison of the lens-corrected visual acuity (LCVA) and spectacle-corrected visual acuity (SCVA) levels was made with Wilcoxon signed-ranks test.

Results: There was no significant difference between the groups regarding topographical cone location, CXL history, spherical refraction, and LCVA. The difference between spectacle-corrected visual acuity and LCVA was higher in RGPCL and MSCL groups than STCL group ($p=0.01$). Keratometry of RGPCL and MSCL groups were higher than STCL and HCL groups ($p=0.01$, $p < 0.001$). In RGPCL group, eyes with central cones had a higher increase in visual acuity with contact lenses compared to eyes with paracentral cones ($p=0.043$). STCL and MSCL were mostly prescribed in mild and severe keratoconic eyes, respectively. In RGPCL group, the increase in visual acuity with contact lens was higher in eyes treated with CXL ($p < 0.01$).

Conclusions: While STCL and HCL were mostly prescribed in mild keratoconus, RGPCL and MSCL were selected for moderate or advanced disease. If appropriately chosen, all types of contact lenses could result in a good visual acuity level. CXL history did not affect the prescribed lens type. Having central cone location and CXL history in RGPCL group improved visual acuity more efficiently.

1. Introduction

The rehabilitation of vision in keratoconus patients requires different treatment approaches according to the stage of their ectasia. In the early stages of keratoconus, spectacles can correct regular astigmatism. However, spectacles are no longer beneficial in moderately or severely affected patients with irregular astigmatism and contact lenses become the best option in the visual rehabilitation of these patients along with the surgical options [1]. In advanced stages of the disease, invasive treatment options including, intrastromal corneal ring segments, lamellar or penetrating keratoplasty might be performed for the rehabilitation of vision [2]. Contact lenses have been fitted in keratoconic eyes successfully to decrease the irregularity of the cornea and to

create a new regular front surface to the optical system in every stage of the disease [3]. Corneal rigid gas permeable contact lenses (RGPCLs) have been the mainstay of contact lens correction of keratoconus for many decades [4]. In recent years, soft toric lenses (STCLs), hybrid contact lenses (HCLs), and scleral lenses have been introduced into the clinical practice for vision correction in keratoconic eyes [5].

Contact lens fitting is more difficult in an irregularly shaped cornea than fitting to a normal cornea. Therefore, it is challenging in keratoconus patients to decide the type of contact lens to start with. All contact lens types have their own advantages and disadvantages in severely affected eyes [3]. Customized STCLs have a very limited role to correct the irregular cornea in keratoconus, although they can achieve higher comfort levels for the keratoconus patients compared to other

* Corresponding author. Present address: Department of Molecular Biology and Genetics, Faculty of Science, Bilkent University, Ankara, Turkey.

E-mail addresses: drozgesarac@gmail.com (Ö. Saraç), meltemeceozcan@gmail.com (M.E. Kars), berketemel@gmail.com (B. Temel), drcagil@gmail.com (N. Çağıl).

<https://doi.org/10.1016/j.clae.2019.02.013>

Received 15 September 2018; Received in revised form 14 February 2019; Accepted 19 February 2019

1367-0484/ © 2019 British Contact Lens Association. Published by Elsevier Ltd. All rights reserved.

lenses [4]. RGPCLs have superiority for improving corneal irregularities and decreasing higher-order aberrations. However, it is difficult for some patients to tolerate these lenses [3]. HCLs have a rigid central part with a soft peripheral skirt, and they are designed for both to reduce discomfort and to increase the visual acuity. However, they have higher complication rates when compared to other types of lenses [6]. Scleral and mini-scleral contact lenses (MSCLs) have advantages for patients with more irregular corneas. They improve comfort and visual acuity and delay the need for keratoplasty in advanced keratoconic eyes. The different insertion and the removal technique and the care regimen of them are their disadvantages [5].

Corneal cross-linking (CXL) is a procedure that alters the biomechanical properties of the corneal collagens by using the ultraviolet-A (UVA) and riboflavin (vitamin B2) [7]. It has been used in the treatment of corneal ectatic disorders including progressive keratoconus, pellucid marginal degeneration, and post-refractive corneal ectasia for years. It has been revealed by numerous studies that, after CXL procedure, cornea flattens and the maximum keratometry value decreases significantly in keratoconic eyes [7]. The effects of the flattening occurred after CXL treatment on contact lens fitting and patient comfort have been investigated in a few studies [7–9]. Increased fitting score and tolerance with RGPCL achieved after CXL treatment were reported in a few of these reports [8,9]. However, the effects of CXL on the fitting of other types of contact lenses have never been investigated.

This study aimed to evaluate the association of the clinical and topographical findings of the keratoconus patients with the prescribed contact lens types (STCL, RGPCL, HCL, and MSCL) in order to see the effect of these parameters on contact lens fitting. Since having CXL treatment has an impact on corneal curvature and subsequently, it might affect fitting of the contact lenses, the effects of having CXL treatment and the cone location on the fitted contact lens type were also investigated [7–9]. The most significant point of this study is that the results might serve as a reference in the process of selecting the appropriate contact lens types for keratoconus patients.

2. Methods

This single-center retrospective study was conducted in compliance with the institutional and government review board regulations, informed consent regulations, and the Declaration of Helsinki. The records of the 195 patients (301 eyes) who were diagnosed with keratoconus and were prescribed a contact lens for the first time between January 2011 and May 2017 were analyzed retrospectively. Topcon KR 8000 Autorefractor Keratometer and Snellen chart were used in the assessment of refractive errors and visual acuity levels of the patients. Keratoconic eyes were diagnosed clinically and with the corneal tomography (Sirius® Scheimpflug tomography, Italy). Aside from the topographic appearance of the map, patients had at least one of the following clinical signs: Munson’s sign, scissors reflex during retinoscopy, corneal thinning, Fleischer’s ring, Vogt’s striae, increased visibility of the corneal nerves, and/or Rizzutti’s sign [10,11]. Although no strict criteria were followed for contact lens trial, it was mostly performed as follows: Ophthalmological examination findings and topographical

findings were examined for each patient. STCL was chosen as the initial contact lens type unless keratoconus was in the very advanced stage or the preferences of the patient were different. The duration of the tests differed among patients until the most appropriate type of contact lens was determined for each of them. Contact lens fitting examinations were performed by an experienced ophthalmologists O.S. Exclusion criteria included those younger than 18 years, the presence of any ophthalmological or systemic disease, active ophthalmic inflammation or infection, and previous contact lens usage. The eyes were grouped according to the prescribed contact lens type as follows: STCL, RGPCL, HCL, and MSCL.

Patients, who had been treated with CXL previously, were prescribed contact lenses at least six months after the treatment to make sure the progression of the keratoconus ceased. Prescribed contact lenses were as follows: STCL: Kerasoft IC® (UltraVision), Toris-K 12 and 34 (SwissLens); RGPCL: Rose K (Menicon Co., Ltd.), Orbiflex-K (SwissLens), Netlens NL 75 GP (Netlens), and ConflexAir (Zeiss); HCL: Airflex (Swiss lens), and Eyebrid (LCS); MSCL: Mini-Misa (Misa). Age, gender, having a CXL history, and contact lens-related complications were examined and noted. Ophthalmological examination findings at the day of contact lens trial including uncorrected visual acuity (UCVA), spectacle-corrected visual acuity (SCVA), contact lens-corrected visual acuity (LCVA), and the difference between the LCVA and the SCVA (in Snellen chart), as well as manifested refraction spherical equivalent (MRSE), and slit-lamp examination findings were analyzed. If the patient read more than half of the letters on a line of Snellen chart, that particular line, otherwise the previous line was accepted as the patient’s visual acuity level. Topographical findings including topographical astigmatism, maximum keratometry (Kmax), mean keratometry (Kmean), central corneal thickness (CCT), thinnest corneal thickness (TCT), and the location of the cone were also examined. Cone location was determined using tangential curvature topographic map of the anterior cornea as central (located within the central 3 mm zone) or paracentral (located outside of the central 3 mm zone) [12]. The severity of the keratoconus was graded with the Amsler-Krumeich classification to compare the fitted contact lens type with the severity of the disease [13].

Statistical analysis was performed using IBM SPSS v. 20 (IBM Corp., Armonk, NY, USA). Normality of the data was assessed with the Kolmogorov-Smirnov test. Homogeneity of variances was evaluated with Levene’s test. Brown-Forsythe, Chi-square, post-hoc Games-Howell and Bonferroni tests were used for comparing the groups in terms of visual acuity levels, topographical findings, cone location, and CXL history. Mann-Whitney *U* test was used for subgroup analysis, and comparison of LCVA and SCVA was made with Wilcoxon signed-ranks test. A *p* value less than 0.05 was considered statistically significant.

3. Results

Three hundred and one eyes of 195 patients were included in the study. The mean age was 28.46 ± 8.13 (18–56) years, and 194 patients (64.5%) were male. Two hundred and seven eyes (68.8%) had been treated with CXL previously. The demographics of the individuals

Table 1
The Demographics, Cone Localization and CXL Status of the Patients According to the Prescribed Contact Lens Type.

	STCL	RGPCL	HCL	MSCL	<i>p</i>
<i>n</i> (%)	125 (41.5%)	98 (32.5%)	44 (14.5%)	34 (11.5%)	
Age	28.34 ± 7.78	29.50 ± 9.71	26.36 ± 6.07	28.62 ± 6.32	0.144*
Sex (F/M)	46/79	31/67	18/26	12/22	0.731†
Cone location (central/paracentral)	105/20	82/16	34/10	30/4	0.614†
CXL (+/-)	80/45	64/34	38/6	25/9	0.036†

STCL: soft contact lens, RGPCL: rigid gas-permeable contact lens, HCL: hybrid contact lens, MSCL: mini-scleral contact lens. CXL: corneal cross-linking.

* Brown Forsythe test.

† Chi-square test, *p* cut off value for multiple comparisons is 0.00625.

Table 2
Between-Group Comparisons of the Mean Differences in Visual Acuity Levels, Refractive Values, and Topographical Findings.

	STCL	RGPCl	HCL	MSCL	p*	p†
UCVA (logMAR)	0.8 ± 0.47	0.96 ± 0.46	0.86 ± 0.43	1.11 ± 0.56	< 0.05	< 0.01‡
SCVA (logMAR)	0.25 ± 0.24	0.37 ± 0.33	0.32 ± 0.24	0.63 ± 0.38	< 0.01	< 0.01‡
LCVA (logMAR)	0.1 ± 0.11	0.08 ± 0.11	0.06 ± 0.93	0.12 ± 0.12	0.125	0.93
Increase in visual acuity (Snellen lines)	1.43 ± 1.69	2.38 ± 1.8	1.97 ± 1.69	2.82 ± 1.94	< 0.01	< 0.05‡
MRSE (D)	-3.75 ± 3.64	-4.79 ± 3.94	-3.57 ± 3.33	-5.66 ± 4.66	< 0.05	0.06
Kmax (D)	55.82 ± 7.49	60.33 ± 12.11	56.01 ± 4.85	68.91 ± 17.97	< 0.01	< 0.01‡
Kmean (D)	48.12 ± 4.99	50.21 ± 4.85	48.03 ± 3.51	53.88 ± 7.31	< 0.01	< 0.01‡
CCT (µm)	444.91 ± 56.39	412.84 ± 57.16	414.16 ± 47.41	399.69 ± 60.36	< 0.01	< 0.01‡
TCT (µm)	430.54 ± 58.86	395.79 ± 59.14	395.86 ± 46.18	372.84 ± 64.79	< 0.01	< 0.01‡
Topographic astigmatism (D)	-3.27 ± 1.66	-3.68 ± 1.73	-3.57 ± 1.23	-4.43 ± 2.53	< 0.05	< 0.01‡

STCL: soft contact lens, RGPCl: rigid gas-permeable contact lens, HCL: hybrid contact lens, MSCL: mini-scleral contact lens. UCVA: Uncorrected visual acuity, SCVA: Spectacle corrected visual acuity, LCVA: Lens corrected visual acuity. Kmax: Maximum keratometry, Kmean: Mean keratometry, CCT: Central corneal thickness, TCT: Thinnest corneal thickness.

- * Brown-Forsythe test.
- † Post-hoc test for comparison of the STCL and MSCL groups.
- ‡ Games Howell test.
- § Bonferroni test.

in each contact lens group were shown in Table 1.

There were no statistically significant differences between the groups regarding age, sex, cone location, having CXL history, MRSE, and LCVA. (Tables 1 and 2) The mean UCVA [$F_{(3, 131.08)} = 3.96, p < 0.05$], SCVA [$F_{(3,127.03)} = 13.17, p < 0.01$] and the increase in the visual acuity with contact lens fitting [$F_{(3,141.62)} = 7.38, p < 0.01$] in the four groups were statistically significantly different. The mean UCVA (logMAR) of the MSCL group was higher than the STCL group (Games Howell test, $p < 0.05$). The mean SCVA (logMAR) of all groups were lower than the MSCL group (Games Howell test, $p < 0.05$ for RGPCl and MSCL comparison, $p < 0.01$ for the other comparisons). Increase in visual acuity was lower in the SCTL group when compared to the RGPCl and MSCL groups (Bonferroni test, $p < 0.05$ for both comparisons). Brown-Forsythe test revealed a statistically significant difference between the four groups regarding the MRSE ($p < 0.05$) however, binary comparisons with post-hoc analysis showed no statistically significant difference between the groups (Table 2).

The topographical values of the four groups were statistically significantly different including Kmax [$F_{(3,73.71)} = 11.76, p < 0.01$], Kmean [$F_{(3,103.96)} = 11.67, p < 0.01$], CCT [$F_{(3,168.52)} = 9.69, p < 0.01$], TCT [$F_{(3,159.25)} = 12.44, p < 0.01$], and the topographical astigmatism [$F_{(3,104.68)} = 12.48, p < 0.05$]. The mean Kmax of the STCL group was lower than those of the RGPCl and MSCL groups (Games Howell test, $p < 0.01$ for both comparisons). The mean Kmax of the RGPCl group was higher than that of the HCL group and lower than that of MSCL group (Games Howell test, $p < 0.05$ and < 0.01 , respectively). The mean Kmean of the STCL group was lower than those of the RGPCl and MSCL groups (Games Howell test, $p < 0.05$ and < 0.01 , respectively). The mean Kmean of the RGPCl group was higher than that of the HCL group and lower than that of the MSCL group (Games Howell test, $p < 0.05$ and < 0.01 , respectively). The mean CCT and TCT of the STCL group were higher than those of the other groups (Bonferroni test, $p < 0.01$ for all comparisons). The mean topographic astigmatism of the MSCL group was higher than that of the STCL group (Bonferroni test, $p < 0.01$). (Table 2)

Cone location did not affect the prescribed contact lens type statistically ($p = 0.614$, Chi-square test). Also, it did not affect the LCVA of any group ($p = 0.12$). However, in RGPCl, eyes with centrally located cones had lower SCVA, so the difference between SCVA and LCVA was higher in Snellen chart compared to the eyes with paracentral cones (p values were < 0.01 and < 0.05 respectively, Mann-Whitney U test). In other groups, cone location did not affect the increase in visual acuity. (Table 3)

Eyes were classified according to Amsler-Krumeich classification. Statistical analysis according to the Amsler stages could not be

performed because some of the groups did not have enough number of samples. Numbers and percentages of the prescribed contact lenses according to the Amsler classification were shown in Table 4. In Amsler stage 1, mostly STCL, in stage 2 and 3, primarily RGPCl, and in stage 4, mostly MSCL were prescribed.

CXL history did not affect the type of the prescribed contact lens ($p = 0.036$, Chi-square test, Bonferroni correction for multiple comparisons p cut off value is 0.00625). However, the increase in the visual acuity with contact lens was significantly higher in eyes which had CXL previously (2.67 ± 1.68 Snellen lines) than eyes with no CXL history (1.78 ± 1.91 Snellen lines) in the RGPCl group (Mann-Whitney U test, $p < 0.05$). (Table 5)

Four patients (1.32%) experienced contact lens-related complications and ceased contact lens usage according to the medical reports of the patients. One (0.32%) patient who was using a RGPCl had culture-negative microbial keratitis, three (0.99%) patients who were using MSCL had limbal vascularization. Except for the patients who had the problems with affording a contact lens, the remaining continued to use the prescribed contact lenses.

4. Discussion

In 1888, Adolf Fick first introduced contact lenses into clinical practice for correction of visual acuity in keratoconus patients [3]. Over the years, new contact lens designs and materials have been developed to improve visual acuity and increase patient comfort. Today, STCL, RGPCl, HCL, MSCL, scleral and piggy-back contact lenses are widely used to increase the visual acuity levels and the quality of life in keratoconus patients [14]. In the present study, the association between the prescribed contact lens types including STCLs, RGPClS, HCLs, and MSCLs and the refractive and topographical parameters of keratoconus patients, their CXL history and cone location were investigated.

Each type of contact lenses has its own advantage and disadvantages. The most common advantage of STCL is their comfort [3]. Traditional soft contact lenses (spherical or toric) can be used only in early keratoconic eyes because of their limited effect of correcting higher-order aberrations [3]. Customized-soft lenses specially designed for keratoconus can control higher-order aberrations and result in higher levels of visual acuity gain comparable with RGPCl in mild or moderate keratoconus [15,16]. They improve the visual acuity because of their greater central thickness that prevents changing their shapes on the irregular cornea. However high central thickness of these lenses decreases the oxygen permeability which may cause hypoxia-related complications [14]. Rathi et al. revealed in their review that it is often difficult to fit soft contact lenses in advanced keratoconus patients [4].

Table 3
Visual Acuity Levels According to Cone Localization and Contact Lens Type.

UCVA (logMAR)	STCL	<i>p</i>	RGPCl	<i>p</i>	HCL	<i>p</i>	MSCL	<i>p</i>
Central	0.82 ± 0.47	0.121	1.01 ± 0.46	< 0.05*	0.93 ± 0.42	< 0.05*	1.14 ± 0.58	0.444
Paracentral	0.64 ± 0.41		0.71 ± 0.35		0.59 ± 0.38		0.88 ± 0.34	
SCVA (logMAR)								
Central	0.27 ± 0.24	< 0.05*	0.40 ± 0.34	< 0.01*	0.33 ± 0.23	0.447	0.64 ± 0.40	0.624
Paracentral	0.15 ± 0.17		0.19 ± 0.16		0.27 ± 0.28		0.51 ± 0.23	
LCVA (logMAR)								
Central	0.11 ± 0.11	0.135	0.09 ± 0.12	0.065	0.06 ± 0.11	0.858	0.12 ± 0.12	0.647
Paracentral	0.06 ± 0.07		0.04 ± 0.05		0.05 ± 0.05		0.07 ± 0.08	
Increase in visual acuity (Snellen lines)								
Central	1.66 ± 1.73	0.059	2.55 ± 1.79	< 0.01*	2.03 ± 1.67	0.494	2.64 ± 1.93	0.281
Paracentral	0.80 ± 1.39		1.50 ± 1.63		1.77 ± 1.85		4.00 ± 1.82	

STCL: soft toric contact lens, RGPCl: rigid gas-permeable lens, HCL: hybrid lens, MSCL: mini-scleral contact lens.

UCVA: Uncorrected visual acuity, SCVA: Spectacle-corrected visual acuity, LCVA: Lens-corrected visual acuity.

* Shows statistically significant values (Mann-Whitney *U* Test).

Table 4
The relationship of the Severity of the Keratoconus with the Prescribed Contact Lens Type.

	STCL	RGPCl	HCL	MSCL	Total
Amsler 1	76 (54.7%)	30 (21.6%)	22 (15.8%)	11 (7.9%)	139
Amsler 2	33 (32.0%)	43 (41.7%)	21 (20.4%)	6 (5.8%)	103
Amsler 3	12 (28.6%)	19 (45.2%)	1 (2.4%)	10 (23.8%)	42
Amsler 4	4 (23.5%)	6 (35.3%)	0	7 (41.7%)	17

STCL: soft contact lens, RGPCl: rigid gas-permeable contact lens, HCL: hybrid contact lens, MSCL: mini-scleral contact lens.

On the contrary, Sultan et al. showed in their study that Toris K soft contact lenses can be used in advanced stages of keratoconus [17]. In the present study, STCL were prescribed mostly in stage 1 keratoconic eyes (54.7%). In contrast with this finding, it was observed that some severe keratoconus patients having stage 4 disease had good visual acuity gain with STCL, and they were prescribed with these lenses.

RGPCl were the most preferred type of contact lenses until the last decade [2]. This type of contact lenses creates a thin lacrimal lens between itself and cornea and corrects astigmatism caused by the corneal surface [3]. Since the traditional RGPCl fitting might be challenging in advanced keratoconus, customized corneal RGPCl have been introduced in clinical practice [18]. However, these lenses can decrease the vision-related quality of life in keratoconus patients with eyes over 52D keratometry values according to the study of Wu et al. [18]. The mean Kmax value of RGPCl group (60.33 ± 12.11) was higher in this study compared to the study population of Wu et al. and they were mostly prescribed to stages 2 (41.7%) and 3 (45.2%) eyes. The vision-

related quality of life of the patients was not investigated in the present study.

HCLs are relatively new contact lens choices for keratoconus patients. They are composed of the central rigid zone and peripheral soft skirt [2]. The superiority of the HCLs on RGPCl is their comfort and centralization [3]. However, HCLs have a higher rate of complications such as giant papillary conjunctivitis, severe epithelial edema, corneal vascularization, and circular corneal clouding [6,14,19]. It was demonstrated in a previous study that, patients wearing clear-cone HCL gained similar visual acuity levels with the ones wearing corneal RGP lenses, but the patients with HCLs had a higher vision-related quality of life scores compared to the corneal RGP wearers [20]. In this study, it was found that HCLs were mostly fitted to eyes at stages 1 (15.8%) and 2 (20.4%). Additionally, although visual acuity, corneal thickness and topographic astigmatism values were not different from RGPCl group, the HCL group had significantly lower keratometry values than RGPCl group.

Scleral contact lenses and MSCLs rest on sclera but do not touch cornea or limbus, so have advantages including comfort and stability [3]. These types of lenses might cause visual a disturbance when the turbidity of the tear meniscus between the cornea and contact lens increases. Appropriate ophthalmic solutions should be used to prevent this complication [14]. MSCLs are strong alternatives to the RGPCl and HCLs for visual rehabilitation of challenging corneas [21]. In this study, it was detected that MSCLs were the most preferred lens type in stage 4 (41.7%) eyes. MSCL group had significantly lower SCVA level compared to other groups, and higher keratometry values compared to STCL and HCL groups. Interestingly, it was noted that nearly 23.5% of stage 1 eyes were only fitted appropriately with MSCLs. These results

Table 5
Visual Acuity Levels According to CXL status and Contact Lens Type.

UCVA (logMAR)	STCL	<i>p</i>	RGPCl	<i>p</i>	HCL	<i>p</i>	MSCL	<i>p</i>
CXL +	0.79 ± 0.47	0.819	0.94 ± 0.48	0.544	0.83 ± 0.43	0.319	1.12 ± 0.48	0.455
CXL -	0.82 ± 0.50		1.00 ± 0.41		1.02 ± 0.45		1.05 ± 0.78	
SCVA (logMAR)								
CXL +	0.24 ± 0.19	0.915	0.37 ± 0.31	0.271	0.31 ± 0.24	0.972	0.61 ± 0.35	0.890
CXL -	0.28 ± 0.29		0.35 ± 0.34		0.32 ± 0.25		0.68 ± 0.48	
LCVA (logMAR)								
CXL +	0.11 ± 0.11	0.319	0.07 ± 0.19	0.311	0.06 ± 0.09	0.790	0.10 ± 0.10	0.603
CXL -	0.09 ± 0.11		0.11 ± 0.14		0.05 ± 0.07		0.16 ± 0.16	
Increase in visual acuity (Snellen lines)								
CXL +	1.33 ± 1.61	0.921	2.67 ± 1.68	< 0.05*	1.93 ± 1.76	0.620	3.09 ± 1.87	0.205
CXL -	1.62 ± 1.83		1.78 ± 1.91		2.20 ± 1.30		2.00 ± 2.08	

STCL: soft toric contact lens. RGPCl: rigid gas-permeable lens. HCL: hybrid lens. MSCL: mini-scleral contact lens.

CXL: Corneal collagen cross-linking. UCVA: Uncorrected visual acuity. SCVA: Spectacle-corrected visual acuity. LCVA: Lens-corrected visual acuity.

* Shows statistically significant values (Mann-Whitney *U* Test).

showed that there might be some factors other than topographic parameters for the appropriate contact lens fitting in keratoconic eyes.

The results demonstrated both clinically and statistically significant improvement in the visual acuity with all contact lens types in keratoconus patients. Although the final visual acuity was similar with all contact lens types, RGPCL and MSCL groups showed the highest improvement and the STCL group had the lowest improvement in visual acuity levels. The differences between SCVA and LCVA in HCL, RGPCL, MSCL, and STCL groups were nearly 2, 2.4, 2.8, and 1.4 Snellen lines, respectively. In a previous study, Lim and Vogt investigated the characteristics of keratoconus patients and the visual acuity gain with the contact lenses including RGPCL, STCL and scleral contact lenses [22]. Their patients had 6/9 or a better level of visual acuity with contact lenses and improvement was at least 0.6 logMAR. They did not analyze the visual acuity levels according to lens type in contrast with the present study.

It was also observed that the difference between SCVA and LCVA of the eyes with central cones was more prominent compared to eyes with paracentral cones, with RGPCL application. Similar to current findings, Nejabat et al. showed that eyes with central cones had a higher difference between SCVA and LCVA levels with RGPCL usage in contrast to paracentral cones [23]. Additionally, in RGPCL group, the difference between SCVA and LCVA was higher in eyes previously treated with CXL. Similar to these findings, there are other studies also demonstrating higher LCVA, lens fitting scores and increased contact lens tolerance with the RGPCL in eyes that had CXL treatment [8,9].

This study clearly has some limitations and strengths. The first and major limitation is its retrospective design. As its design was retrospective, the vision-related quality of life of the patients could not have been investigated. Second, the number of eyes in each group was not equal, so performing the statistical tests was challenging. To decrease the type 1 error, the Brown-Forsythe test was chosen, because it is a robust test for one-way ANOVA. Large sample size and comparing four different types of contact lenses are the strengths of the study. Also, the patients who were prescribed piggy-back contact lenses were excluded from this study. Because most of them used contact lenses previously and nowadays piggy-back contact lenses are not prescribed in the clinic where the study was performed as much as before since there are other types of effective contact lens choices. This study is the first one evaluating the association of all types of keratoconus lenses with the visual and topographical parameters in keratoconic eyes.

In conclusion, the present study revealed that eyes at early stages of keratoconus were mostly fitted with STCL, and advanced keratoconus eyes mostly benefited from MSCL. If appropriately chosen, all types of contact lenses can result in a good final visual acuity. While cone location and having CXL treatment did not affect the type of prescribed contact lens, in corneal RGPCL group, eyes with central cones and having a history of CXL treatment had a higher increase in their visual acuity levels obtained with contact lenses. With the results of this study, the duration for choosing the appropriate contact lens type for the keratoconus patients could be shorter, since the results might help the ophthalmologists to determine where to start. Further prospective studies with larger cohorts are needed for evaluating the fitting and

efficacy of different kinds of contact lenses for keratoconus patients.

Declarations of interest

None.

References

- [1] C.N. McGhee, B.Z. Kim, P.J. Wilson, Contemporary treatment paradigms in Keratoconus, *Cornea* 34 (Suppl 10) (2015) S16–23.
- [2] M.M. Moschos, Contact lenses for keratoconus- current practice, *Open Ophthalmol J* 11 (2017) 241–251.
- [3] L.E. Downie, R.G. Lindsay, Contact lens management of keratoconus, *Clin Exp Optom* 98 (2015) 299–311.
- [4] V.M. Rathi, P.S. Mandathara, S. Dumpati, Contact lens in keratoconus, *Indian J Ophthalmol* 61 (2013) 410–415.
- [5] M. Barnett, M.J. Mannis, Contact lenses in the management of keratoconus, *Cornea* 30 (2011) 1510–1516.
- [6] Y.F. Abdalla, A.F. Elsahn, K.M. Hammersmith, E.J. Cohen, SynergEyes lenses for keratoconus, *Cornea* 29 (2010) 5–8.
- [7] D.P. O'Brart, P. Patel, G. Lascaratos, V.K. Wagh, C. Tam, J. Lee, et al., Corneal cross-linking to halt the progression of Keratoconus and corneal ectasia: seven-year follow-up, *Am J Ophthalmol* 160 (2015) 1154–1163.
- [8] K. Singh, M. Bhattacharyya, R. Arora, S. Dangda, A. Mutreja, Alterations in contact lens fitting parameters following cross-linking in keratoconus patients of Indian ethnicity, *Int Ophthalmol* 38 (2018) 1521–1530.
- [9] M. Unlu, E. Yuksel, K. Bilgihan, Effect of corneal cross-linking on contact lens tolerance in keratoconus, *Clin Exp Optom* 100 (2017) 369–374.
- [10] K. Zadnik, J.T. Barr, T.B. Edrington, D.F. Everett, M. Jameson, T.T. McMahon, et al., Baseline findings in the collaborative longitudinal evaluation of keratoconus (CLEK) study, *Invest Ophthalmol Vis Sci* 39 (1998) 2537–2546.
- [11] Y.S. Rabinowitz, Videokeratographic indices to aid in screening for keratoconus, *J Refract Surg (Thorofare, NJ : 1995)* (11) (1995) 371–379.
- [12] A.J. Munsamy, V.R. Moodley, A correlation analysis of cone characteristics and central keratometric readings for the different stages of keratoconus, *Indian J Ophthalmol* 65 (2017) 7–11.
- [13] M. Naderan, S. Shoar, M.A. Kamaledin, M.T. Rajabi, M. Naderan, M. Khodadadi, Keratoconus clinical findings according to different classifications, *Cornea* 34 (2015) 1005–1011.
- [14] L. Rico-Del-Viejo, Nonsurgical procedures for keratoconus management, *J Ophthalmol* 2017 (2017).
- [15] A. Jinabhai, H. Radhakrishnan, C. Tromans, C. O'Donnell, Visual performance and optical quality with soft lenses in keratoconus patients, *Ophthalmic Physiol Opt* 32 (2012) 100–116.
- [16] F.J. Fernandez-Velazquez, Kerasoft IC compared to Rose-K in the management of corneal ectasias, *Cont Lens Anterior Eye* 35 (2012) 175–179.
- [17] P. Sultan, C. Dogan, G. Iskeleli, A retrospective analysis of vision correction and safety in keratoconus patients wearing Toris K soft contact lenses, *Int Ophthalmol* 36 (2016) 799–805.
- [18] Y. Wu, Q. Tan, W. Zhang, J. Wang, B. Yang, W. Ma, et al., Rigid gas-permeable contact lens related life quality in keratoconic patients with different grades of severity, *Clin Exp Optom* 98 (2015) 150–154.
- [19] F.J. Fernandez-Velazquez, Severe epithelial edema in ClearKone SynergEyes contact lens wear for keratoconus, *Eye Contact Lens* 37 (2011) 381–385.
- [20] H. Hashemi, N. Shaygan, S. Asgari, F. Rezvan, S. Asgari, ClearKone-SynergEyes or rigid gas-permeable contact lens in keratoconic patients: a clinical decision, *Eye Contact Lens* 40 (2014) 95–98.
- [21] C. Suarez, V. Madariaga, B. Lepage, M. Maleceza, P. Fournie, V. Soler, et al., First experience with the ICD 16.5 mini-scleral Lens for optic and therapeutic purposes, *Eye Contact Lens* 44 (2018) 44–49.
- [22] N. Lim, U. Vogt, Characteristics and functional outcomes of 130 patients with keratoconus attending a specialist contact lens clinic, *Eye (London, England)* 16 (2002) 54–59.
- [23] M. Nejabat, M.R. Khalili, C. Dehghani, Cone location and correction of keratoconus with rigid gas-permeable contact lenses, *Cont Lens Anterior Eye* 35 (2012) 17–21.