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The effectiveness of three-step treatment for keratoconus with correction of associated ametropia

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Abstract

Background. Keratoconus is a progressive ectatic disease with thinning and bulging of the cornea structure. It is characterized by a bilateral and usually asymmetric course, which is manifested by the formation of irregular astigmatism. Several different combinations of treatments are currently being used to stop the progression of keratoconus and increase visual acuity.

Aim. To assess the effectiveness of three-step treatment for progressive keratoconus to stabilize the cornea, eliminate its irregularity and achieve maximum visual acuity.

Material and methods. A triple combined treatment was applied to 48 patients (24 women and 24 men) with stage 2–3 keratoconus (67 eyes) aged 16–31 years (mean age 24.4±0.21 years) at the National Center of Ophthalmology named after Academician Zarifa Aliyeva between 2017 and 2019. It consisted of intrastromal corneal ring implantation, corneal crosslinking after 24 hours, and topography-guided transepithelial photorefractive keratectomy (PRK) after 8 months. All patients underwent complex examinations: uncorrected visual acuity and best spectacle-corrected visual acuity, autorefractometry, non-contact tonometry, corneal topography, tomography, optical coherence tomography of the anterior segment, ultrasound pachymetry. The statistical significance of the difference between the data before and after treatment was assessed by using analysis of variance in the “data analysis” package of the Microsoft Excel software.

Results. Uncorrected visual acuity before surgery was 0.2±0.041 and ranged between 0.04 and 0.3. Twelve months after surgery, uncorrected visual acuity significantly improved in all patients; its average value was 0.5±0.048 and ranged between 0.2 and 0.7. An improvement was observed in best spectacle-corrected visual acuity, which ranged between 0.2–0.5 before surgery and 0.4–0.8 after surgery. After intrastromal corneal ring implantation + corneal crosslinking + topography-guided transepithelial-PRK, residual refractive errors of the cornea were eliminated. The maximum keratometry (Kmax) decreased from 46.1–57.3 D to 42.1–49.9 D (M and SD before surgery 50.0±1.5 and after surgery 45.2±1.4, p=0.009), astigmatism also decreased from 5.25–9.25 to 0.5–3.25 cyl (M and SD before surgery 4.61±0.50 and after surgery 4.18±0.48, p=0.025). No complications were observed during and in the postoperative period.

Conclusion. The three-step treatment of progressive keratoconus will avoid the need for keratoplasty and achieve maximum visual acuity, minimize the number of aberrations and halts the progression of keratoconus.

Keywords: keratoconus, intrastromal rings, transepithelial topographic photorefractive keratectomy, collagen crosslinking.

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Background

Keratoconus is a progressive ectatic disease with cornea thinning and protrusion and is characterized by a bilateral and usually asymmetric course, which is manifested by irregular astigmatism formation. The disease progresses from adolescence to the age of 30–40 years. Recently, the age limit of the disease is considered 8–38 years.

Rigid gas-conducting or hybrid contact lenses are widely used in keratoconus, but surgical methods must be used to prevent disease progression [1–5]. The surgical treatment aimed to stop the progression of ectasia, correct corneal irregularities, minimize refractive index, and improve visual acuity. Corneal crosslinking is widely used to stop the progression and stabilize the cornea.

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Intracorneal ring implantation is necessary to reduce irregular astigmatism. Topographic transepithelial photorefractive keratectomy and intraocular lens implantation are alternative methods of surgical correction of residual refractive index [6–10].

During the intrastromal ring implantation, the central corneal region flattens. In the central 5 mm optical zone, the difference between astigmatism values is minimized along each meridian. The corneal apex, which is displaced due to paracentral ectasia, returns to its physiological position [11, 12].

During corneal crosslinking, strong bond formation between collagen molecules in the cornea results in hard fibrils and lamellae formation. This induces the reconstruction of the corneal plates and the surrounding matrix, thereby strengthening the bonds between cells and fibers. This method is considered an important procedure in preventing ectasia progression[13, 14].

Keratocytes and plates formed after the crosslinking reaches their morphological and functional density in terms of quantity and quality after 8 months. After ensuring complete corneal stability, residual refraction can be eliminated by topographic ablation (topographic photorefractive keratectomy) or appropriate intraocular lens implantation [9–11, 14].

Several treatment combinations are currently used in the field of ophthalmology to stop keratoconus progression and increase visual acuity. In each case, the works aim to improve the patient's visual acuity with or without correction and avoid the need for keratoplasty [12–14].

Aim

The study aimed to evaluate the efficiency of triple-staged treatment in progressive keratoconus to stabilize the cornea, eliminate its irregularity, and achieve maximum visual acuity.

Materials and methods of research

In 2017–2019 at the Academician Zarifa Aliyeva National Center of Ophthalmology (Baku), a triple-combined treatment was used in 48 patients (67 eyes). It consisted of intrastromal ring implantation, corneal crosslinking 24 h later, and topographic transepithelial photorefractive keratectomy 8 months later. All patients underwent comprehensive examinations, including uncorrected and best-corrected visual acuities, TOMEY RC-5000 autorefractometry, TOMEY FT-1000 non-contact tonometry, Pentacam corneal topography, Wavelight Oculyzer (ALCON), Topolyzer VARIO tomography (ALCON), optical coherence tomography of the anterior segment using Cirrus HD-OCT 5000 (Zeiss, Germany), and ultrasonic pachymetry.

The examined group included 24 females and 24 males with stage 2–3 keratoconus according to M. Amsler classification [15]. The age range of patients was 16–31 years (mean age 24.4 ± 0.21 years).

The study included patients with a transparent central optical zone and a thickness of the thinnest part of the cornea of >400 microns. In these patients, uncorrected visual acuity was 0.04–0.3 and the best-corrected visual acuity was 0.2–0.5.

Surgical technique. Under local anesthesia, a tunnel with an inner diameter of 4.4 mm and an outer diameter of 5.6 mm was created using a Wavelight femtosecond laser (FS200). The KeraRing intrastromal ring (Mediphacos, Belo Horizonte, Brazil) was implanted in each eye at an 80% depth of the thinnest part of the cornea, corresponding to the corneal thickness and meridian axes (Fig. 1, 2).

The corneal deepithelialization was performed in a 7-mm zone under local anesthesia 24 h after the KeraRing implantation. A 0.1% solution of riboflavin was instilled onto the cornea (riboflavin Medio Cross) for 30 min using UV-X, with six stages of 5 min. At the end of the surgery, a contact lens was applied. Thus, using the rings, the maximum flattening of the corneal central zone was created and strengthened with crosslinking.

Changes in the keratometric and refractive parameters of the cornea in patients were regularly monitored for 8 months. After obtaining stable refractive results, topographic photorefractive keratectomy was performed to correct refractive residual indices and achieve the best vision. During topographic photorefractive keratectomy, the corneal epithelium was mechanically removed under local anesthesia. Then, ablation (photorefractive keratectomy on the stroma) was performed following the standard technique.

The obtained data of visual acuity and keratometric measurements was statistically processed using the analysis methods of quantitative indicators, and the median, mean value, variance, and standard deviation were calculated. The statistical significance of differences between the data before and after the treatment was assessed using the analysis of variance with the Excel data analysis package [16].

Results

Visual acuity and keratometry indicators before and after staged treatment are presented in Table 1. Uncorrected visual acuity before surgery was 0.2 ± 0.041 (range, 0.04–0.3). The average value of the uncorrected visual acuity significantly improved in all patients, accounting for 0.5 ± 0.048 (range, 0.2–0.7) after 12 months postoperatively. A similar improvement was registered in best-corrected visual

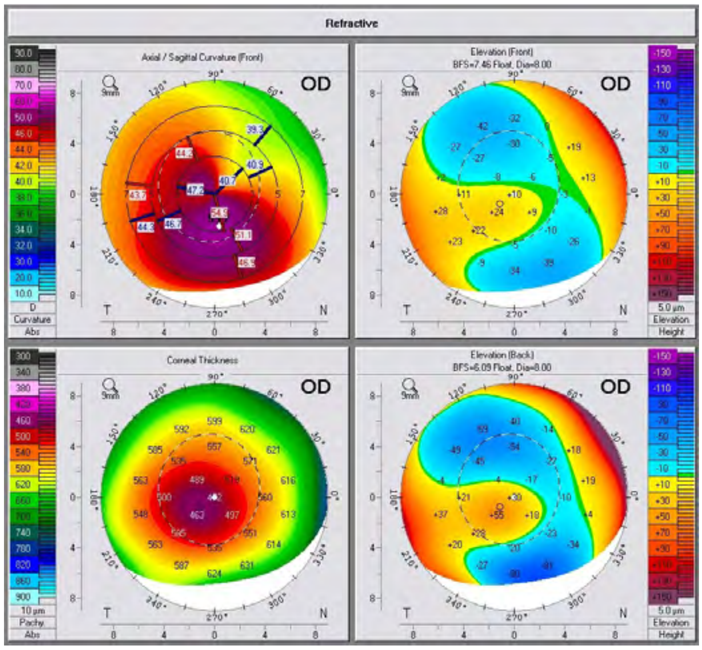

Fig. 1. Primary topography of a patient with keratoconus.

acuity, which ranged from 0.2–0.5 before surgery to 0.4–0.8 after surgery.

The topographic studies after the intracorneal ring implantation with corneal crosslinking revealed a significantly decreased difference between the keratometric index values along each meridian. According to Pentacam's findings, an increased anterior chamber angle from 32.24° ± 4.12° to 34.18° ± 2.35° and a decreased anterior chamber depth from 3.47 ± 0.21 mm to 3.28 ± 0.24 mm were detected. Thus, the difference of 45.0–51.9 D decreased to 42.7–45.7 D. After the intracorneal ring implantation with corneal crosslinking and topographic photorefractive keratectomy, corneal residual refractive defects were eliminated (Fig. 3).

After the combined treatment, refractometric parameters also decreased. After the intracorneal ring implantation with corneal crosslinking, visual acuity increased following the refraction stabilization, and eliminating the residual refractive astigmatism and increasing visual acuity to maximum values was possible after topographic photorefractive keratectomy.

The pachymetric result analysis revealed a decreased corneal thickness before the topographic transepithelial photorefractive keratectomy in the center from 455.2 ± 17.12 nm to 416.35 ± 19.23 nm, which eliminated the refractive defects of a maximum of 50 µm.

K_{max} values decreased from 46.1–57.3 D to 42.1–49.9 D (M and SD before surgery were 50.0 ± 1.5 and after surgery were 45.2 ± 1.4; $p = 0.009$), and astigmatism decreased from 5.25–9.25 cyl to 0.5–3.25 cyl (M and SD before surgery were 4.61 ± 0.50 and after surgery were 4.18 ± 0.48; $p = 0.025$). The comparison of spherical and cylindrical refraction indices and the most important keratometric coefficients before and after surgery also confirms the achievement of a stable organ of vision functional state improvement. Moreover, no complications were registered during the surgery and in the postoperative period.

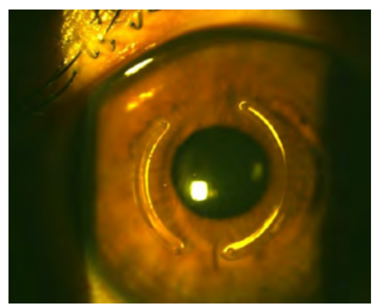

Fig. 2. Implanted intracorneal segments.

Discussion

Simultaneous corneal collagen crosslinking can stop the keratoconus progression, of which the mechanism is well understood. The isolated use of intrastromal corneal ring implantation also provides a good result by another mechanism. Direction 3 in keratoconus treatment is topographic photorefractive keratectomy, which changes the curvature of the corneal outer surface, thereby providing a beneficial refractive effect. The combination of these methods in various options provided optimal results [9–11, 14]. Additionally, according

Table 1. Changes in visual acuity and keratometric coefficients before and 8 months after the staged intrastromal ring implantation, corneal crosslinking, and topographic transepithelial photorefractive keratectomy (48 patients, 67 eyes).

Parameters	Before surgery, M ± SD	After surgery, M ± SD	*p*-values
Anterior chamber angle	32.24 ± 4.12	34.18 ± 2.35	0.014
Anterior chamber depth, mm	3.47 ± 0.21	3.28 ± 0.24	0.045
Corneal thickness in the center, nm	455.2 ± 17.12	416.35 ± 19.23	0.009
K_{max} (D)	50.0 ± 1.5	45.2 ± 1.4	0.009
Astigmatism (interval)	4.61 ± 0.50	4.18 ± 0.48	0.025
Uncorrected visual acuity	0.2 ± 0.041	0.5 ± 0.048	0.014
Best-corrected visual acuity	0.4 ± 0.09	0.6 ± 0.12	0.048
Cylindrical refraction	–6.11 ± 1.52	–2.11 ± 0.14	0.008
Spherical refraction	–13.38 ± 2.15	–9.98 ± 2.12	0.013
Spherical equivalent (D)	–5.48 ± 0.32	5.14 ± 0.30	0.035
Anterior surface keratometry on the steep axis (D)	48.0 ± 2.61	42.2 ± 1.94	0.008
Posterior surface keratometry on the steep axis (D)	–8.04 ± 0.21	7.66 ± 0.24	0.045
Corneal volume, mm^3	55.8 ± 0.8	53.4 ± 0.8	0.033
Dispersion index	94.8 ± 14.0	76.81 ± 9	0.012
Vertical asymmetry index	1.11 ± 0.12	0.78 ± 0.11	0.037
Keratoconus index	1.28 ± 0.06	1.18 ± 0.03	0.041
Regularity index	1.28 ± 0.24	0.89 ± 0.18	0.009
Surface asymmetry index	2.8 ± 0.21	2.0 ± 02	0.045

Note: M—the average value; SD—standard deviation; K_{max}—the maximum keratometric index.

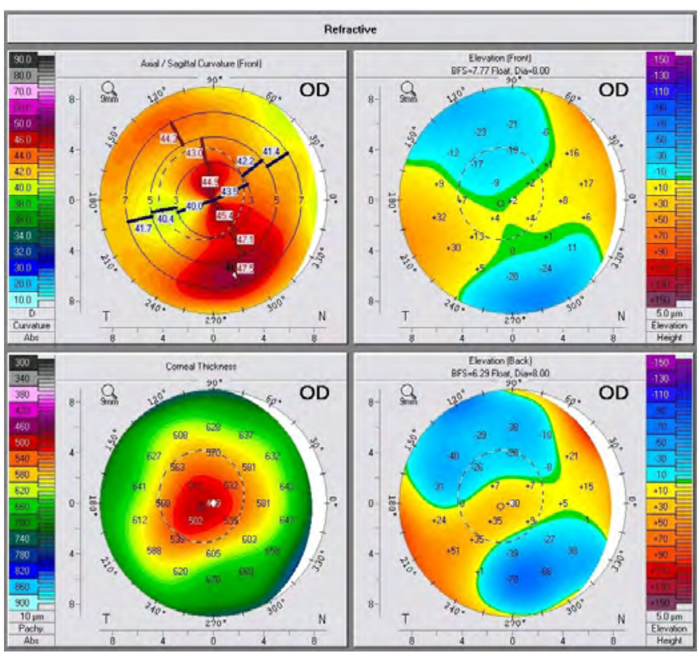

Fig. 3. Final topography of the same patient after a three-stage procedure.

to Efekan Coshkunseven [14], it enables to achieve more significant results, although the author monitored a small number of patients.

In our work, the scope of observation is larger and the criteria for treatment efficiency are extensive, which show improvement both in terms of visual acuity (from 0.2 ± 0.041 to 0.5 ± 0.048) and refractive effects (cylindrical refraction from −6.11 ± 1.52 to −2.11 ± 0.14, spherical refraction from −13.38 ± 2.15 to −9.98 ± 2.12).

Thus, after three surgeries, uncorrected and best-corrected visual acuities in patients (from 0.4 ± 0.09 to 0.6 ± 0.12) increased compared to the baseline. Keratometric and refractive indices were reduced (Table 1).

In addition to preventing ectasia progression during keratoconus, reshaping the cornea, i.e., reducing the central curvature and eliminating corneal irregularity, achieves high results in the disease treatment. Residual refractive ametropia correction and topographic photorefractive keratectomy to achieve best-corrected visual acuity achieve better visual acuity.

Conclusions

1. Staged treatment of keratoconus using intracorneal implants, corneal crosslinking, and topographic photorefractive keratectomy improves the biomechanical properties and shape of the cornea, which is associated with keratometric parameters changes, decreased astigmatism, and an increased visual acuity.

2. The obtained results at a follow-up period of 8 months after the treatment recommended this method for progressive keratoconus treatment.

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Conflict of interest. The authors declare no conflict of interest.

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