ICRS Plus Crosslinking

This combination results in greater improvements versus Keraring implantation alone.

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Although intrastromal corneal ring segment (ICRS) implantation improves visual acuity in patients with keratoconus, its effect on inhibiting the progression of keratoconus is still unclear. On the other hand, corneal collagen crosslinking (CXL) appears to slow or stop the progression of keratoconus by providing corneal biomechanical stability and improving spherical equivalent, astigmatism, and maximal keratometry (K). Recently, the question has been posed: Can a combination of these two procedures offer an enhanced treatment option?

Although corneal transplantation is an established and effective treatment for patients with keratoconus who can no longer be treated with rigid contact lenses, the invasiveness of the surgical procedure and the risk of complications can be discouraging for patients.[1-3] Therefore, ICRS implantation has been investigated, with studies establishing its safety and efficacy with improvements in visual acuity and refraction and minimal potential complications.[4,5] These ring segments regularize the front surface of the cornea by building tissue in the midperiphery and maintaining the biomechanical condition within the underlying stroma.

The Keraring (Mediphacos, Belo Horizonte, Brazil) is one such ring segment. Characterized by a triangular cross section that induces a prismatic effect on the cornea, this device significantly improves visual acuity, spherical equivalent, and keratometric values without posing the risk of extensive complications.[4-6] However, the inhibiting effect of ICRS implantation on the progression of keratoconus remains unclear.

CXL with riboflavin and UV-A for the treatement of keratoconus has been reported as a safe procedure that appears to stop the progression of the disease by increasing corneal biomechanical stability.[7,8] This mode of treatment strengthens corneal tissue by using riboflavin as a photosensitizer and UV-A to promote the formation of intra- and interfibrillar covalent bonds through photosensitized oxidation.[9]

Wollensak et al reported the first in vivo controlled study of CXL for the treatment of patients with moderate or advanced keratoconus, concluding that CXL effectively stopped progression for up to 4 years.[10] However, although CXL treatment for the management of patients with keratoconus has shown promise to reduce the spherical equivalent, astigmatism, and maximal K, only been modest improvements in visual acuity have been seen. Studies on ICRS implantation for the treatment of keratoconus have shown more than two lines of improvement in visual acuity.[4,11,12] A combination of these two treatments would, therefore, theoretically provide optimal results because the benefits of the two procedures would complement each other.

A WINNING COMBINATION?

In a retrospective case series, Chan et al compared the results of 12 eyes that underwent ICRS implantation with the results of 13 eyes that underwent a combined treatment of ICRS implantation followed by CXL.[13] Significantly greater improvements in cylinder and maximal K values were reported in the combined treatment group.

We also studied the combination of ICRS implantation with CXL treatment in patients with keratoconus, implanting the Keraring in 21 eyes and performing CXL approximately 7 months later. Mean UCVA improved from 0.11 preoperatively to 0.26 after Keraring implantation and 0.32 after CXL. Mean BCVA improved from 0.22 preoperatively to 0.49 and 0.54 following Keraring implantation and CXL treatment, respectively. The spherical equivalent, cylinder, and mean K showed significant improvements after Keraring implantation and further improvements following CXL treatment, demonstrating the efficacy of the combined treatment.

THE RIGHT SEQUENCE

The combination of the two treatments has shown promising results thus far; however, in which order should the two treatments be performed? In our initial experience, we performed CXL first. ICRS implantation followed 6 months later because we believed that the UV-A could potentially damage the ring segments. We then investigated the effects of implanting the ICRS first, followed by CXL treatment. Patients had progressive keratoconus and a corneal thickness of 400 µm. In our series, we had to remove the ring segments from one eye because of superficial migration. To avoid migration in the second eye, which had the same corneal thickness, we performed CXL. It is now 1 year later, and there have

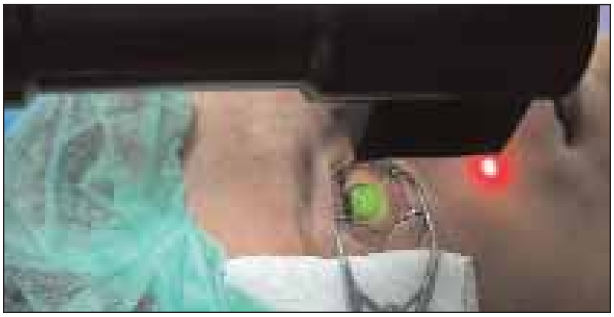

Figure 1. During corneal collagen crosslinking treatment, 0.1% riboflavin solution in 20% dextran is applied every 3 minutes for 30 minutes, and UV-A irradiation is performed for 30 minutes.

Figure 2. Implantation of the Keraring followed by CXL treatment approximately 7 months later was achieved with excellent visual and refractive outcomes and no significant intraoperative complications.

been no further problems with migration, melting, or any other complications in the second eye. We concluded that UV-A does not, in fact, damage the implanted ICRS.

We then compared the results of both sequences. In this prospective study, 48 eyes of 43 patients with progressive keratoconus (grades one through three) in the past 6 months were included. All were over the age of 18 years, were contact lens intolerant, and had a corneal thickness of 450 µm at the corneal tunnel. Exclusion criteria included K reading of more than 65.00 D, severe atopy, corneal dystrophies, corneal opacities, herpetic keratitis, grade four keratoconus, and concomitant systemic disease. A total of 27 eyes received CXL treatment followed by Keraring implantation (group 1), and 21 eyes received Keraring implantation followed by CXL (group 2). The mean interval between the two treatments for all eyes was 7 months, and the mean follow-up time was 6 months.

For CXL treatment, following the abrasion of a 7-mm diameter area of the corneal epithelium, 0.1% riboflavin solution in 20% dextran was applied on the cornea every 3 minutes for 30 minutes (Figure 1). UV-A irradiation was performed for 30 minutes using Koehler illumination, with seven UV-A diodes with a potentiometer in series to enable the regulation of voltage (3 mW/cm^2 corresponding to a surface dose of 5.4 J/cm^2). For ICRS implantation, all segment channels were created with the 60-kHz IntraLase femtosecond laser (Abbott Medical Optics, Inc., Santa Ana, California) in approximately 10 seconds. The channel depth was programmed to 80% of the thinnest point at the channel location; the corneal incision was made on the steep axis.

The mean outcomes for group 1 are detailed in Table 1. After CXL, the mean UCVA increased by more than 0.5 lines, and BCVA increased by 0.5 lines. The spherical equivalent (SE) decreased by 1.39 D (P<.05), cylinder decreased by 0.44 D, and mean K decreased by 0.88 D. After Keraring implantation, there were further improvements: UCVA and BCVA increased by one line, SE decreased by 2.76 D, cylinder decreased by 1.32 D, and mean K decreased by 3.28 D (P<.001).

After Keraring implantation in group 2 (Table 2 and Figure 2), UCVA increased by two lines and BCVA increased by three lines; decreases in SE, cylinder, and mean K were 3.31 D, 2.05 D, and 2.94 D (P<.01), respectively. Following CXL, additional improvements were noted: UCVA increased by one line and BCVA increased by 0.5 lines, SE decreased by 0.93 D, and the mean K decreased by 1.08 D (P<.01).

When comparing the two groups, it is apparent that group 2 experienced a greater improvement in UCVA, BCVA, cylinder, and SE; however, there was no significant difference between the two groups for the mean K astigmatism.

ICRS followed by CXL in patients with keratoconus achieved better results in our series. This minimally invasive combined procedure entails fewer risks than corneal

TABLE 1. IMPROVEMENTS IN MEAN VISUAL AND REFRACTIVE OUTCOMES (GROUP 1)

	Preop	Post-CXL	Post-ICRS
UCVA	0.07 ±0.09	0.14 ±0.12	0.25 ±0.12
BCVA	0.24 ±0.11	0.29 ±0.16	0.41 ±0.20
Spherical equivalent (D)	-7.13 ±3.34	-5.74 ±2.84	-2.98 ±2.33
Cylinder	-4.38 ±2.03	-3.94 ±2.30	-2.62 ±1.93
Mean K	52.47 ±4.01	51.59 ±4.01	48.31 ±3.65

TABLE 2. IMPROVEMENTS IN MEAN VISUAL AND REFRACTIVE OUTCOMES (GROUP 2)			
	Preop	Post-ICRS	Post-CXL
UCVA	0.11 ±0.09	0.26 ±0.21	0.32 ±0.21
BCVA	0.22 ±0.16	0.50 ±0.24	0.55 ±0.23
Spherical equivalent (D)	-7.05 ±5.54	-3.74 ±4.25	-2.81 ±4.08
Cylinder	-4.68 ±2.60	-2.63 ±1.57	-2.20 ±1.67
Mean K	52.06 ±4.93	49.12 ±4.61	48.08 ±4.13

transplantation and still achieves excellent visual and refractive outcomes. We believe it is unnecessary to perform ICRS implantation and CXL treatment simultaneously because healing at the incision site is extremely important. After femtosecond channel creation with a 1-mm incision, epithelialization and perfect healing can be achieved by the end of the first postoperative day. We have found that perfect healing can decrease the risk of migration and melting; on the other hand, wide epithelial defects can cause the healing process to lag.

Incomplete tunnel creation is one the most common complications of femtosecond laser channel creation because bridges in the tunnel may cause problems during ICRS implantation. Our advice is to increase the energy level or decrease spot separation, to avoid complications. We have created channels and implanted segments successfully without changing the procedure's parameters.

After ICRS implantation, we examine postoperative results at 1, 3, and 6 months. If the K readings are greater than 1.00 D, we perform CXL to stop the progression and achieve further improvements in visual and refractive outcomes. Certain conditions call for an alteration in the combined treatment, to cater to the patient's situation. If the patient is younger than 20 years, has a corneal thickness less than 400 µm with the risk of superficial migration of the segments, or cannot return for follow-up, we perform CXL treatment on the worse eye 1 month after ICRS implantation and then perform CXL on the second eye 1 month later.

We have found that ICRS implantation is an effective method for the improvement of UCVA and BCVA in keratoconic eyes. The inhibiting effect of ICRS on keratoconus progression is still unclear; however, the addition of CXL to the procedure stops the progression of the disease and provides greater improvements than Keraring implantation alone. ■

TAKE-HOME MESSAGE

- Intrastromal corneal ring segments regularize the front surface of the cornea by building tissue in the mid-periphery.
- ICRS implantation performed before CXL provided greater improvements inUCVA, BCVA, cylinder, and spherical equivalent.

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