

Association of Ferrara Intracorneal Ring Segments with Phakic Intraocular Lens for Improved Visual Acuity in Young Keratoconus Patients: A Case Series

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ABSTRACT

Aim: We present a case series involving five eyes in four young patients with advanced keratoconus who were implanted with Ferrara intrastromal corneal ring segments (ICRS) followed by phakic intraocular lens (PIOLs).

Background: ICRS have been used for the management of keratoconus in order to prevent further keratoconus progression and improve visual performance. Nonetheless, many patients may still suffer from moderate to high myopia after ICRS, requiring refractive error correction, which may not be achieved with glasses, contact lenses, or laser refractive surgery. For such cases, PIOLs have emerged as an alternative to correct residual refractive errors.

Case description: Patients were aged between 13 years and 32 years at ICRS implantation. Around 6 months after ICRS implantation, patients were submitted to a second procedure for the implantation of an implantable collamer lens (ICL), Artisan or Artiflex PIOL to correct residual myopia. After the combined Ferrara ICRS and PIOL implantation, all treated eyes demonstrated a significant improvement in topographic findings and visual acuity, with reduced refraction and keratometric astigmatism.

Conclusion: The combined procedure was successful in reshaping the cornea and improving visual acuity of patients.

Clinical significance: The association of ICRS and PIOL can be an important alternative that should be considered to provide young patients with improved visual acuity in a moment of their lives when they are at their most productive phase.

Keywords: Intracorneal ring segments, Keratoconus, Phakic lens.

International Journal of Keratoconus and Ectatic Corneal Diseases (2019); 10.5005/jp-journals-10025-1175

INTRODUCTION

Keratoconus is a progressive disease that affects the topography of the cornea, resulting in impaired visual acuity and refractive errors.^{1,2} Procedures such as the implantation of intrastromal corneal ring segments (ICRS),^{3,4} and corneal collagen crosslinking⁵⁻⁷ have been recently introduced for the management of keratoconus.

After ICRS implantation, many patients may still suffer from moderate to high myopia, requiring refractive error correction.⁸ In cases correction may not be achieved with glasses, contact lenses, or refractive surgery with laser,^{9,10} phakic intraocular lens (PIOLs) emerge as a possible alternative.^{11,12} Previous studies with keratoconus patients with high myopia have already reported on improved visual acuity after the sequential implantation of Intacs⁸ and Keraring¹³ ICRS and implantable collamer lenses (ICLs) in the posterior chamber, and Intacs¹⁴ ICRS and Artisan in the anterior chamber.

This case series reports on the findings of a group of patients with advanced keratoconus and high myopia who were implanted with Ferrara ICRS followed by the implantation of ICL, Artisan, and Artiflex phakic intraocular lens (PIOL).

CASE DESCRIPTION

This retrospective case series presents the results of the implantation of Ferrara ICRS followed by the implantation of ICL, Artisan, and Artiflex PIOLs in five eyes of four patients (two female and two male) with keratoconus, high myopia, and contact lens intolerance, conducted at Provisão Hospital de Olhos, Maringá,

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How to cite this article: Almodin EM, Almodin F, Almodin J. Association of Ferrara Intracorneal Ring Segments with Phakic Intraocular Lens for Improved Visual Acuity in Young Keratoconus Patients: A Case Series. *Int J Kerat Ect Cor Dis* 2019;8(1):23-28.

Source of support: Nil

Conflict of interest: None

Brazil. All the patients were systemically healthy and presented no other eye conditions.

Before and after the implantation of Ferrara ICRS and PIOL, the patients underwent a thorough eye examination, which involved uncorrected visual acuity (UCVA) and distance-corrected visual acuity (DCVA) with the Snellen chart, cycloplegic refraction, and videokeratoscopy using Tomey (Tomey Corporation, Japan) and Wavelight Oculyzer (Wavelight Allegretto, Alcon, USA).

Ferrara ICRS Implantation

All the five eyes in this case series were implanted in the steepest topographic axis of the cornea with Ferrara ICRS (AJL Ophthalmic, Valladolid, Spain) of various thicknesses and arc lengths. One or two ICRS segments were implanted depending on the topography of the cornea, whereas ICRS thickness was defined according to

the spherical equivalent and corneal thickness. The surgery was conducted under topical anesthesia. The thickness of the cornea was obtained preoperatively using the pachymetry map (Oculyzer). The tunnel for ICRS insertion was created with a femtosecond laser equipment (Ziemer 8, Ziemer Ophthalmic Systems, Germany) at 80% of the corneal thickness at its thinnest point in the 5.0 mm optical zone. After the surgery, patients were instructed to apply antibiotic-steroid eye drops at every 6 hours during two weeks, avoid rubbing their eyes, and use artificial tears as required.

PIOL Implantation

PIOL implantation occurred with a minimum of 6 months after the ICRS surgery. Two of the eyes received a posterior chamber PIOL (Visian ICL; Staar Surgical, Monrovia, California, USA), two eyes were implanted with a foldable anterior chamber iris-fixed Artiflex PIOL (Ophtec, Groningen, the Netherlands), and one eye received a rigid anterior chamber iris-fixed Artisan PIOL (Ophtec, Groningen, the Netherlands). The type of lens was chosen based on the topographic astigmatism of the patient. The size of the PIOLs was defined according to the measurements of corneal white-to-white and anterior chamber depth, conducted with the IoLMaster 500 (Carl Zeiss Meditec AG, Germany). Lens power calculation was performed aiming at emmetropia or slight residual myopia. All PIOLs were implanted under peribulbar anesthesia as previously described in the literature.⁸⁻¹⁵ No complications were observed either intra- or postoperatively.

- Case 1: MBS, a 19-year-old female patient. Six months after the implantation of two Ferrara ICRS (160/300) in OD, UCVA and DCVA improved significantly, and a reduction in the refraction and keratometric astigmatism was also observed. Topography and tomography showed a significant flattening of the cornea. The patient then received the implantation of an Artiflex PIOL (-9.5 D). Six months after the procedure, UCVA, DCVA, and manifest refraction were significantly improved (Fig. 1 and Table 1).
- Case 2: ELLS, 13-year-old male patient. Six months after the implantation of one Ferrara ICRS (210/200) in OD, UCVA was still count fingers but DCVA showed a significant improvement with a reduction in the refraction and keratometric astigmatism. Topography and tomography showed a significant flattening of the cornea. Six months after the implantation of an Artisan lens

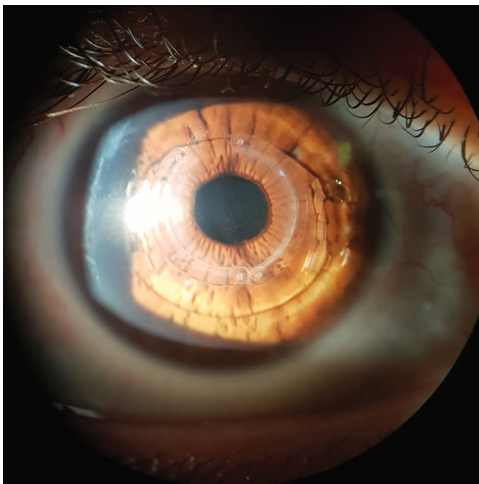


Fig. 1: Patient (MBS) with two Ferrara intracorneal ring segments in association with an Artiflex phakic intraocular lens in OD

Table 1: Patient MBS (OD). Pre- and postoperative ophthalmic parameters

Exam	Topography							Oculyzer—pentacam				ECD (cells/ mm ²)				
	UCVA	DCVA	SPH	CYL	Axis	K1	K2	Axis	Astigm	K1	K2		Axis	Astigm	Pach	Q
Pre-ICR	CF	20/60	-14.75	0.00	—	48.3	53.1	115°	4.80	48.10	52.20	109°	4.10	464	-0.83	3257
Post-ICR	20/60	20/30	-3.50	-2.00	5°	37.00	39.50	173°	2.50	38.40	39.30	60°	0.90	452	0.56	2857
Pre-IOL	20/100	20/50	-8.00	-1.75	95°	37.10	41.70	173°	4.60	39.50	39.50	162°	0.00	442	1.82	2800
Post-IOL	20/100	20/40	1.50	-5.00	105°	37.98	43.73	8°	5.75	38.9	42.60	102°	3.70	452	1.48	2462

(−19.5 D), improved UCVA, DCVA, and manifest refraction were observed (Table 2).

- Case 3: CESP, 27-year-old male patient. Six months after the implantation of two Ferrara ICRS (160/200) in OD, UCVA and DCVA improved significantly, with a reduction in the manifest refraction and keratometric astigmatism. Topography and tomography showed a significant flattening of the cornea. The patient then received an ICL (−23 D), and six months after implantation, improved UCVA, DCVA, and manifest refraction were observed (Table 3).
- Case 4: VFS, a 32-year-old female patient. After the implantation of two Ferrara ICRS (160/200) in AO, topographic findings, UCVA, and BSCVA improved significantly, and reduction in the manifest refraction and keratometric astigmatism was also observed in AO. Six months after Ferrara implantation, an ICL (−13.00 D) and an Artiflex (−14.5 D) PIOL were implanted in OD and OS, respectively. Six months later, a significant improvement in refraction was found in AO, with improved UCVA and DCVA (Table 4—OD; Table 5—OS).

DISCUSSION

This case series illustrates the sequential implantation of Ferrara ICRS for the management of keratoconus followed by the implantation of a PIOL to correct residual refractive error. The results demonstrated that this combined procedure was successful in reshaping the cornea and improving the visual acuity of patients.

Several studies have shown that the implantation of Ferrara ICRS for the management of mild to moderate forms of keratoconus is safe and predictable, resulting in improved visual outcomes in all eyes studied.^{16–18} Tunnel creation with femtosecond laser for the implantation of ICRS has also been shown to be minimally invasive, resulting in improved visual acuity.^{8,13} These findings are in agreement with the results in the present study, which showed a significant flattening of the cornea and improved UCVA and DCVA after ICRS implantation, without any intraoperative or postoperative complications.

Although the corneal shape improved after ICRS implantation, patients still presented a significant degree of ametropia, in agreement with previous reports.^{8,19,20} Because the patients were intolerant to contact lenses and the high residual myopia contraindicated the use of laser refractive surgery,^{9,10} we opted for the implantation of PIOLs. The approach employed in the present study has been previously termed as “therapeutic bioptics”.²¹ It is considered therapeutic because the main goal of the combined procedure is to restore vision, differently from elective refractive surgery, whose aim is to reduce dependence on vision correction (spectacles or contact lenses).

The choice of the PIOL was based on the axis of the corneal astigmatism. When the maximum corneal curvature (K2) was at or near the 180° axis, ICL was selected. When K2 was at or near the 90° axis, Artiflex was chosen if the refractive astigmatism was less than 2.5 D, and Artisan if it was more than 2.5 D. The posterior chamber ICL is considered to be technically less challenging than anterior chamber iris-fixated Artisan and Artiflex.¹¹ Both Artisan and Artiflex follow similar implantation procedures. However, the rigid material of Artisan requires a 5.5 mm posterior corneal incision, which may induce more postoperative astigmatism.¹⁵ Artiflex, on the contrary, is made of a foldable material that can be inserted through a smaller incision (3.2 mm) without the need for sutures, reducing induced

Table 2: Patient ELLS (OD). Pre- and postoperative ophthalmic parameters

Exam	UCVA	DCVA	SPH	CYL	Axis	Topography			Oculyzer—pentacam			ECD (cells/ mm ²)				
						K1	K2	Axis	Astigm	K1	K2		Axis	Astigm	Pach	Q
Pre-ICR	CF	20/400	−18.00	−7.50	100°	55.38	64.28	105°	8.90	63.30	68.10	114°	4.80	415	−2.67	2893
Post-ICR	20/60	20/50	−16.00	−2.00	180°	61.10	64.60	91°	3.50	58.00	61.10	90°	3.10	415	−1.97	2659
Pre-IOL	CF	20/50	−11.00	−1.75	180°	61.14	64.66	91°	3.50	58.00	61.10	90°	3.10	415	−1.97	2659
Post-IOL	20/30	20/20	−0.50	−0.75	180°	57.86	60.73	139°	2.90	58.8	59.70	124°	0.90	415	−2.07	2189

Table 3: Patient CESP (OD). Pre- and postoperative ophthalmic parameters

Exam	UCVA	DCVA	SPH	CYL	Axis	Topography				Oculyzer—pentacam				ECD (cells/ mm ²)		
						K1	K2	Axis	Astigm	K1	K2	Axis	Astigm		Pachy	Q
Pre-ICR	CF	20/30	-24.00	-0.50	135°	47.2	54.2	111°	7.00	45.50	48.80	114°	3.30	517	-0.60	3314
Post-ICR	20/80	20/30	-16.00	-2.50	75°	48.40	50.20	156°	1.80	45.70	47.40	90°	1.70	509	-0.28	3543
Pre-IOL	20/80	20/30	-16.00	-2.50	75°	48.40	50.20	156°	1.80	45.70	47.40	90°	1.70	509	-0.28	3543
Post-IOL	20/20	20/20	0.50	-2.75	30°	45.91	47.84	120°	1.94	45.3	47.60	124°	2.30	491	-0.43	2719

Table 4: Patient VFS (OD). Pre- and postoperative ophthalmic parameters

Exam	UCVA	DCVA	SPH	CYL	Axis	Topography				Oculyzer—pentacam				ECD (cells/ mm ²)		
						K1	K2	Axis	Astigm	K1	K2	Axis	Astigm		Pach	Q
Pre-ICR	CF	20/1000	-15.50	-5.25	130°	53.6	57.2	48°	3.60	54.70	56.80	45°	2.10	402	-0.98	3429
Post-ICR	20/100	20/50	-7.50	-2.25	135°	48.40	52.50	172°	4.10	47.90	50.00	154°	2.10	410	0.03	2914
Pre-IOL	20/70	20/40	-11.00	-2.50	180°	51.36	51.97	15°	0.61	49.30	52.30	2°	3.00	408	-0.33	2516
Post-IOL	20/30	20/20	-1.25	-0.25	95°	52.95	53.78	23°	0.83	51.3	53.20	6°	1.90	432	-0.49	2439

Table 5: Patient VFS (OS). Pre- and postoperative ophthalmic parameters

Exam	UCVA	DCVA	SPH	CYL	Axis	Topography			Oculyzer—pentacam			ECD (cells/ mm ²)				
						K1	K2	Axis	Astigm	K1	K2		Axis	Astigm	Pach	Q
Pre-ICR	CF	20/1000	-24.00	-1.50	165°	50.5	52.9	79°	2.40	52.40	53.30	95°	0.90	429	-0.86	3029
Post-ICR	20/100	20/50	-7.00	-2.50	45°	50.40	52.10	139°	1.70	48.00	50.50	159°	2.50	420	-0.45	2600
Pre-IOL	20/100	20/20	-13.50	-2.50	90°	49.40	51.90	163°	2.50	48.80	51.20	164°	2.40	—	-0.56	2532
Post-IOL	20/20	20/20	-0.05	-0.75	105°	51.39	53.44	18°	2.55	49.6	53.00	179°	3.4	445	-0.68	2240

astigmatism.²² Despite their differences, all the PIOLs used in the present study demonstrated to be effective and predictable in correcting myopia in the phakic keratoconic eyes.

After PIOL implantation, the UCVA improved significantly as a result of decreased visual distortion caused by high myopia and astigmatism, in agreement with previous studies.^{8,13,14} Both UCVA and DCVA showed a significant improvement, while the manifest refraction showed a significant reduction, with minimal residual myopia and astigmatism. Additionally, both refraction and keratometry were stable 6 months after the combined procedure.

The results demonstrated by the present study indicate that PIOLs (anterior or posterior) can be safely used to correct residual refractive error after the implantation of Ferrara ICRS in eyes with keratoconus and high myopia. Nonetheless, this procedure can only be considered successful if both refraction the progression of keratoconus can be stabilized. Because of the young age of the treated patients, regular follow-ups will be required to ensure that refraction and the shape of the cornea remain stable over time. Another important question regards the possible corneal tissue damages, especially to endothelial cells, caused by PIOLs. The implantation of posterior chamber PIOL^{23,24} and iris-fixated IOL (iris-claw lens)^{25,26} have been shown to reduce the endothelial cell density (ECD). Of particular concern with anterior chamber PIOLs is the possible cell loss due to mechanical contact between the PIOL and the endothelium of the cornea.²² However, several studies demonstrated that Artisan/Artiflex do not touch the endothelium, and ECD is stable in the long-term.^{27,28} A recent study demonstrated that the implantation of Artiflex was predictable for the correction of moderate to high myopia, with no statistically significant changes in EDC or polymegathism after 6 months of follow-up.²⁹ Great care must, however, be employed in case selection based on preoperative parameters, such as patient age, iris configuration, and anterior chamber depth of at least 3.2 mm from the epithelium.³⁰

CONCLUSION

The results obtained in this small case series demonstrated that ICRS implantation followed by PIOL implantation provides good results with predictability and efficacy when the case is well selected, the correct surgical technique is employed, and postoperative care is provided in the long-term.

CLINICAL SIGNIFICANCE

The combined procedure presented here is an important alternative that should be considered to provide young patients with improved visual acuity in a moment in their lives when they are at their most productive.

ACKNOWLEDGMENT

The authors would like to thank Mr Antonio Carlos Correa for his assistance in reviewing and translating the text into English.

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