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REVIEW

Intracorneal Ring Segments in Keratoconus: A Narrative Literature Review

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Background: Keratoconus is a bilateral, non-inflammatory corneal ectasia characterized by progressive thinning and conical protrusion, leading to irregular astigmatism, usually in association with high myopia. Visual rehabilitation options include corneal collagen cross-linking (CXL), rigid gas permeable contact lenses, intracorneal ring segments (ICRS), phakic intraocular lenses, and corneal transplantation. ICRS are synthetic, biocompatible implants or allogenic corneal tissue, designed to reduce corneal curvature and optimize the refractive profiles. Initially used in 1978 to treat myopia, their role in keratoconus was established in 2000. This review explores ICRS types, surgical techniques, and emerging developments.

Methods: A literature review was conducted using PubMed. A total of 117 peer-reviewed manuscripts, including review articles, randomized controlled trials, case series, and reports, were analysed. Reference lists of publications were also reviewed.

Results: ICRS types include MyoRings, KeraRings, Ferrara Rings, and Intacs, each with unique design characteristics and implantation methods. Corneal allogenic intrastromal ring segments represent the latest innovation in ICRS. Femtosecond laser-assisted tunnel creation offers improved control over stromal depth and uniformity, reducing complications compared to mechanical dissection. Studies indicate slight corneal stiffening post-ICRS implantation, with no significant changes in intraocular pressure. Topographic changes post-ICRS show significant corneal flattening and reduction in astigmatism. Complications include epithelial defects, segment migration, and keratitis, but long-term follow-up reveals low rates of serious adverse events.

Conclusion: ICRS provide an effective option for enhancing vision in select keratoconus patients, ultimately lowering the chances of requiring a corneal transplant. They are of particular use in those intolerant to contact lenses and without central corneal scarring. Future research should focus on long-term outcomes. Combining ICRS with other procedures like CXL may enhance outcomes, though careful patient selection is crucial.

Keywords: Intracorneal ring segments, keratoconus

Introduction

Keratoconus is the most common corneal ectasia characterised by a bilateral non-inflammatory, progressive thinning of the cornea. It results in irregular astigmatism, high myopia and conical protrusion, with consequential effects on visual acuity and function. The options for visual rehabilitation include corneal collagen cross-linking (CXL), rigid gas permeable contact lenses, intracorneal ring segments (ICRS), phakic intraocular lenses, and ultimately penetrating or anterior lamellar keratoplasty.[1]

Intracorneal ring segments (ICRS) are currently either synthetic, biocompatible implants or made from allogenic corneal tissue, designed to reduce corneal curvature in a specific meridian and thereby regularize the refractive profile. ICRS were first implanted in 1978 by Reynolds for the management of myopia,[2] however it was not until 2000 that Colin et al utilised their role for visual rehabilitation in keratoconus.[3] Following this, a range of ICRS devices have been trialled, with both mechanical and femtosecond laser assisted techniques used for implantation. ICRS offer a viable therapeutic option to improve vision, thereby reducing the likelihood of requiring corneal transplantation, in patients who are contact lens intolerant, without central corneal scarring.

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This narrative review summarises the published literature to date, exploring types of rings, surgical techniques and current emerging developments for their role in the management of keratoconus.

Methods

Review of literature was performed using the PubMed database. Primary search terms used included "intracorneal ring segment", "keratoconus", "intrastromal corneal ring segment", "intacs", "keraring", "ferrararing" and "myoring". No date restriction was applied; however, further search filters included human-only studies and articles published in the English language. Articles related to other corneal ectasias were excluded. A total of 117 peer-reviewed manuscripts were analysed which comprised review articles, randomised controlled trials, case series and case reports. To ensure maximal data capture, the reference lists of individual publications were also studied.

Types of Rings

ICRS devices increase the space between corneal collagen fibres. The resulting arc shortening effect causes flattening of the area enclosed by the ring. The corneal flattening ability is directly proportional to the ring thickness and inversely proportional to ring diameter.[4] In the context of keratoconus, with patients having an irregular corneal profile, these laws may be less predictable, making accurate estimation of post-operative refraction challenging.

ICRS that are most commonly used and available are the MyoRings, KeraRings, Ferrara Rings, and Intacs. Each of these possess differing design characteristics and have unique implantation methods and biomechanical effects on the cornea.

The KeraRing (Mediphacos Belo Horizonte, Brazil) is made of polymethyl methacrylate (PMMA)[5] and was specifically designed for use in keratoconus, with a triangular cross-section. It is postulated that the triangular shape induces a prismatic effect directing reflected light away from the visual axis. It has an apical diameter of 5mm and flat base width of 0.6mm. Variations are available for arc length (90, 160, 210 and 355 degrees) and thickness (0.15–0.30 mm).

The Ferrara ring (Mediphacos Belo Horizonte, Brazil) was first implanted into corneas with keratoconus in 2003.[6] They are also made of PMMA with a triangular cross section. They are available in variable thickness (0.15–0.35 mm) and arc lengths (90, 120, 160 or 210 degrees). They have a 5.6mm external diameter and 0.6mm base. They have a 1.5mm radius of curvature and the smallest optical zone diameter of 5mm

Intacs (Addition Technology Inc, Des Plaines, IL, CA) are the most widely used ICRS in the current practice.[7] They are hexagonal in cross section and available in thickness variations ranging from 0.21 to 0.55 mm. They have an optical zone of 7mm with a 6mm variant (Intacs SK) also available. The larger optical zone necessitates implantation in the thicker, peripheral cornea, further from the visual axis, and results in a lower incidence of haloes and glare.

The MyoRing (DIOPTEX GmbH, Linz, Austria) is the only complete 360-degree ring design available.[8] Optical diameter can vary from 5 to 8 mm and thickness varying from 0.2 to 0.32 mm. The mechanical effects imposed by the nature of the 360-degree ring allow it to effectively function as a further (artificial) limbus.

Corneal allogenic intrastromal ring segments represent the latest innovation in ICRS, first described by Jacob et al in 2018.[9] Unlike their synthetic counterparts, they are entirely biological tissue derived from donor corneal buttons. Upon fashioning of two semicircular ring segments from donor tissue, they undergo submersion in riboflavin, followed by insertion into the host cornea and subsequent ultraviolet light exposure to induce crosslinking of the donor segments to the host stroma. Although studies currently indicate they are safe and effective, longer-term outcome data is needed.

Tunnel Creation Techniques

The first ICRS to be placed into keratoconic corneas were done so with mechanical dissector devices provided by the ring manufacturers. Three years later in 2003, the first case series was published for femtosecond laser assisted tunnel creation. It was hypothesised that the laser assisted modification offered greater control over the tunnel's stromal depth and ensured more uniformity between cases. A recent meta-analysis compared mechanical tunnel creation with femtosecond laser assisted insertion for ICRS.[10] Of the 115 studies that were evaluated, there was a considerable improvement in visual outcomes in terms of best corrected visual acuity, refractive profile and mean keratometry readings post ICRS surgery. Interestingly, there were no significant differences in these outcomes between the laser assisted and mechanical tunnel formation groups. It is worth noting, however, post-operative complications were markedly higher when ICRS was inserted with mechanical dissection. These included epithelial defects, anterior/posterior perforation and persistent wound gaping. However, it is important to be cognisant of the cost and accessibility restrictions with respect to femtosecond laser usage. The results of this meta-analysis comparison are somewhat limited by the fact that the included trials varied for patient age, stage of keratoconus, and type of ICRS used.

Corneal Biomechanics

Previous studies have suggested that there is no change to corneal biomechanical properties post ICRS, as measured by the Ocular Response Analyzer (ORA; Reichert Inc, Depew, NY) and Corvis ST (OCULUS, Wetzlar, Germany).[11] These studies, however, did not exclude patients who underwent previous cross linking (CXL). In 2023, Vinciguerra et al[12] published their results of corneal biomechanical analysis in 30 eyes post-ICRS implantation, with no previous surgery or CXL, and mean follow-up of 15 months. In their prospective study, all eyes underwent laser assisted insertion of a Ferrara ring. Biomechanical measurements were obtained using Corvis ST and the Ocular Response Analyzer. The key finding of this study was a slight increased stiffening response measured by stress–strain index (SSI). Mean SSI increased from 0.88 preoperatively to 1.01 postoperatively ($p = 0.03$). Otherwise, there was no significant change in biomechanically corrected intraocular pressure measurements (bIOP) pre- and post-surgery. The authors hypothesised that the favourable stiffness profile was due to the ring exhibiting properties reflective of an artificial limbus by conferring additional support to the central cone and a favourable distribution of stress, rather than any intrinsic change to the corneal tissue's biomechanical properties, as seen with CXL. It is important to highlight the small study sample and that differences noted were small. In addition, all patients received the Ferrara ring and so the data may not be reproducible to other ICRS types. More recently in 2024, Hamon et al[13] performed a larger retrospective review of 112 eyes following Intacs SK. Mean SSI in this subset of patients remained unchanged, and there was no difference in bIOP. Further insights may be gained from larger studies with a wider range of ICRS types.

Topographic Changes

Corneal topography is the cornerstone of ICRS implantation. It is important to measure as a baseline pre-implantation, and it should be re-assessed afterwards to assess the changes made by the ICRS. Berty et al[14] demonstrated that ICRS implantation significantly flattened both the anterior and posterior surfaces of the cornea and that improvement of corneal asphericity led to improved visual outcomes.

A large study of Ferrara Ring and KeraRing ICRS implantation in keratoconus patients showed significant reduction in corneal curvature.[15] There was a significant reduction reported in the spherical equivalent of patients post-operatively, and refractive astigmatism was decreased by over 50%. Overall, the findings showed that the cornea was flatter post-operatively, with significantly more flattening seen in the anterior than the posterior corneal surface. It was found that ICRS combinations increase the volume of the area between them, and that 5mm segments were better at flattening the cornea. Asymmetric implants were effective in regularising the corneal topography. The 6mm segments showed similar reduction in reducing astigmatism as their other counterparts in this study.[15]

Another study also showed that post-ICRS implantation, visual acuity improved significantly along with significant decreases in refractive spherical equivalent and cylinder measurements and mean simulated keratometry readings.[16]

A large retrospective analysis of patients with advanced keratoconus treated with ICRS found that corneas with a preoperative Kmax >57 D experienced a greater and significant reduction in axial curvature post-operatively than corneas with a preoperative Kmax <57 D.[17] They also gained more Snellen lines of corrected visual acuity at 1 year of follow-up. This was all demonstrated without a significantly different incidence of the main common complications that can be seen with ICRS implantation (explantation, extrusion, and infectious keratitis).

In a study of 65 eyes in 45 patients, ICRS implantation caused an improvement in the mean spherical equivalent from -8.82 ± 4.57D to -3.45 ± 4.81D ($p < 0.01$).[18] The average keratometry measurement decreased from 49.23 ± 5.22D preoperatively to 45.63 ± 4.89D postoperatively ($p < 0.01$).

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A study by Hamon et al (2022)[13] assessing specifically corneal topographic changes in femtosecond laser-assisted ICRS implantation found 2 different types of corneal stromal changes, which could occur (diffuse peri-segmental fibrosis and lamellar channel deposits), but found that neither of these affected corneal topography or refraction.

Pre-Operative Planning

Pre-operative planning is of great significance when it comes to ICRS implantation. Complete ophthalmic examination should be performed. The best uncorrected and corrected visual acuity should be measured. The cornea should be assessed for corneal topography, pachymetry and aberrometry. Measurements of biomechanical properties may also be taken, although this is often of research interest at present (with ocular response analyser (ORA) or Corvis ST).[1] In order to obtain accurate corneal measurements, use of soft contact lenses and rigid contact lenses should be discontinued for 1 and 2 weeks, respectively.

Patient selection has a big role in successful outcomes, and the ideal candidate for ICRS implantation would be: an adult over 18 years of age, who has intolerance to contact lens use, with best corrected distance visual acuity (CDVA) <0.6 on the decimal scale. They should have no central corneal scarring present.[1] The minimum corneal thickness required for implantation varies depending on the selected segment thickness and this should be ascertained at the pre-operative visits.[19]

Asymmetric Intracorneal Ring Segments

Implantation of symmetric ICRS is the norm and constitutes standard practice globally. However, asymmetric implantation can be of benefit and should be considered in certain patient populations. In certain phenotypes of ectasia, such as oval ("duck"/type 2, Fernandez-Vega/Alfonso classification) and asymmetric bowtie ("snowman"/type 3, Fernandez-Vega/Alfonso classification) patterns of keratoconus, the employment of asymmetric ICRS implantation has been shown to be of benefit. A head-to-head comparison by Baragel et al[20] in 2021 demonstrated a reduction in vertical asymmetry and a prevention of an increase in corneal aberrations with the implantation of two asymmetric ICRS compared to the implantation of two symmetric ICRS in 68 eyes with "snowman" type keratoconus.

The Keraring Asymmetric ICRS (Mediphacos Belo Horizonte, Brazil), AJL PRO+ (AJL Ophthalmic, S.A.) and the Visumring represent asymmetric ICRS devices that have been investigated in the literature. Baptista et al[21] investigated the use of the Keraring Asymmetric ICRS in 21 eyes with keratoconus ("duck" and "snowman" phenotypes) and noted significant improvements in visual acuity, astigmatism and comatic aberrations, with more pronounced differences noted in "duck" phenotypes. Similarly, Benlarbi et al[22] demonstrated the efficacy of the AJL PRO + implant in 33 eyes with the "duck" phenotype of keratoconus with improvements in refractive, topographic, aberrometric and visual parameters. Successful implantation of the Visumring (353-degree arc length) with improvements in visual acuity and astigmatism was reported in 30 eyes by Vega-Estrada et al in 2019.[23] Unlike the aforementioned devices, however, five cases suffered from severe corneal melt and subsequent explanation was required. All of these cases were eyes with advanced keratoconus (3 with grade IV and 1 with grade plus). Thus, this device is not readily available.

Asymmetric ICRS require substantial further research; however, small studies seem to suggest positive outcomes in subsets of patients with "duck" and "snowball" phenotypes of keratoconus.

Paediatric Populations

Cases of keratoconus in children present a management challenge. They can often have severe disease at presentation and can progress more rapidly. Prompt and effective intervention is therefore of even higher priority. Conservative options such as spectacle or contact lens correction may be poorly tolerated in this population. There is a paucity of evidence published on the outcomes of ICRS in patients under 16 years of age. One retrospective case series reviewed 17 eyes with mild to severe keratoconus who underwent ICRS with CXL performed one month later.[24] The age range of participants was 9–14 years. At 6 months follow-up, statistically significant improvement was seen for CDVA from 0.30 ±0.19logMAR to 0.12±0.1logMAR ($p = 0.001$). Complications were reported in one eye due to corneal vascularisation and overlying thinning requiring ring removal. This patient self-reported excessive eye rubbing emphasising the importance of patient selection in surgical planning.

A later study examined a larger cohort of 118 eyes retrospectively.[25] All patients were <18 years (mean age of 16.1 years) and had no previous documented evidence of progression. Those with prior surgery or advanced disease were excluded (Stage 4, Amsler-Krumeich classification). This cohort did not undergo concurrent CXL. Mean CDVA improved from 0.19 (± 0.15) to 0.10 ±0.12 ($P \leq 0.0001$) at 6 months. Only 23 eyes completed the 60 month follow-up with no patients experiencing significant disease progression. Despite supporting the safety and efficacy of ICRS in CXL naïve paediatric eyes, this study is limited by a large degree of attrition bias. Further research should be directed to prospective study designs with a longer, complete, follow-up period.

Combined Procedures

In patients with known progression of keratoconus, CXL is indicated to stabilise the condition.[26] CXL may, however, also be combined with ICRS or PTK to facilitate quicker visual rehabilitation and less time off work, although again patient selection is paramount. Same-day combined intervention prevents ablation of already cross-linked tissue to reduce the risk of future progression. Furthermore, patients are not subject to repeated epithelial removal that carries the small associated risk of superficial stromal haze. Some authors have also noted regression in the effect of ICRS for eyes that have not been cross linked.[27] In this regard, Rocha et al[28] reviewed 55 eyes undergoing same-day combined treatment of ICRS + PTK + CXL. Their results at 6 month follow-up showed 70% of eyes gained ≥3 lines in UCVA and there were no surgical complications. The results suggested good candidates for CXL combined with ICRS and superficial PTK included those with CDVA ≤ 20/32, corneal thickness >440 m, and maximum keratometry readings of <55 D. With regard to HOAs there was a statistically significant improvement in all measured parameters. Further studies on combined procedures should look to quantify the differential effect of PTK and ICRS as well as longer follow-up to support the excellent safety profile observed thus far.

With regard to the order of intervention, there are differing opinions within the literature. Some researchers have suggested that prior CXL leads to corneal stiffening, making altering the corneal curvature with ICRS less efficacious.[29] They have therefore advocated for same-day treatment with CXL and ICRS in a single sitting.[29] A previous meta-analysis[30] however looked to compare three surgical sequences: CXL followed by ICRS, ICRS followed by CXL and same-day treatment. A total of 6 studies with one year of follow-up data met the inclusion criteria. There was no statistically significant difference between the groups with regard to post operative refractive astigmatism and BCVA.

Another aspect of combined intervention is the use of toric phakic IOL following ICRS implantation. McLinctock et al[31] retrospectively reviewed 14 eyes who underwent toric phakic IOL insertion post Ferrara ring surgery. Ferrara ring segments were offered to patients with contact lens intolerance, previous cross linking, CDVA ≤ 20/40, absence of corneal scarring and corneal thickness > 400 microns in the proposed area of implantation. Six months following ring insertion, phakic IOL was offered to patients with stable refractions, absence of cataract, endothelial cell density >2000 cell/mm^2, anterior chamber depth > 2.8mm and regular astigmatism on topography. At 6 months post phakic IOL surgery, the number of eyes with a CDVA >20/40 increased from 31% to 100% and mean refractive cylindrical power reduced from 4.8D to 1.2D ($p = 0.002$). Similar promising results have also been reported by other authors,[32,33] however it should be noted that only a subset of patients will be suitable for the aforementioned surgery. For example, patients may still have irregular astigmatism following ICRS, and CDVA may not be sufficient for phakic IOL. Ultimately, refractive rehabilitation in keratoconic eyes will be a more challenging process, but ICRS combined procedures offer a viable therapeutic option in patients that historically would have only been offered a corneal transplant.

Advanced Disease

Visual improvement in patients with advanced keratoconus is a topic of contention among experts. Poor pre-operative visual acuity has been deemed a positive prognostic factor for visual improvement[34] however achieving significant visual improvement in advanced disease (stage 4, Amsler–Krumeich classification) with ICRS has been noted to be less likely.[28] Predictability may be limited in advanced disease and preoperative alignment of keratometric and refractive axis angles can be challenging.

Dockery et al[17] compared the implantation of ICRS in 70 eyes of patients with mild/moderate keratoconus (Kmax < 57D) with 71 eyes of patients with advanced keratoconus (Kmax > 57D). They demonstrated a significantly greater reduction in axial curvature and visual acuity with no significant difference in complication rates in patients with advanced disease versus those with mild/moderate disease. Shetty et al[35] have exhibited similarly positive findings and deemed younger age, male sex and central corneal thickness >400 to be associated with better outcomes in this subset of patients with advanced disease (Stage 3, Amsler–Krumeich classification). Kanellopoulos et al[36] have described the possible complications that can afflict this category of patients. Although their study of 20 eyes with moderate to advanced keratoconus (stage 2/3, Amsler–Krumeich classification) showed significant improvements in visual acuity, they also described complications in 30% of their cases, including anterior chamber perforation, exposure secondary to thinning, and infection.

Although ICRS implantation in advanced disease has been shown to be effective, the potential risks must be weighed up with the likelihood of achieving practical visual improvements.

Complications

Despite being less invasive than other forms of visual rehabilitation in keratoconus patients such as corneal transplantation, ICRS are not without their complications. Intraoperative complications include epithelial defects, damage to the segment, depth asymmetry and perforation.[37] These risks have been reduced following the use of femtosecond laser for intrastromal tunnel creation as previously discussed. Other intraoperative risks can result from placing the rings too limbal or too central, which reduces the reliability of achieving the desired postoperative profile. Increasing surgical grade and experience have been shown to reduce intraoperative complications.[38]

Postoperative complications include corneal oedema, corneal melt, corneal haze, neovascularisation at the entry wound, deposits within the tunnel, infectious keratitis and sterile keratitis.[39] Segment migration towards the incision site has also been reported. In cases of recurrent migration, Jarade et al have demonstrated single suture fixation of the ring segment through the channel to be a viable method for management.[40]

It should be noted that post-operative complications can present late and thus long-term follow-up in ICRS patients is paramount. Oatts et al published a case series of three patients who experienced late extrusion and subsequently achieved a best corrected visual acuity (BCVA) of 6/6, with the onset of extrusion presenting as late as 20 years post operatively in one patient.[41] This highlights potential reversibility as a possible advantage of ICRS over corneal ablative interventions. Furthermore, a retrospective case series of 50 eyes reported late segment breaks occurring in three patients between two and six years after implantation, in the absence of preceding trauma or eye rubbing.[42] All three cases were manufactured for a 5.0mm optical zone and arc length between 155 and 160 degrees. There was no statistically significant relationship between optical zone diameter and likelihood for a break to occur. It has been suggested that a 5.0mm diameter associated with a thinner ICRS may contribute to an increased degree of fragility as compared to segments with greater thickness, however no studies investigating this further are present in the published literature. Anterior chamber intrusion has also been reported 7 years post-implantation in a patient with progressive keratoconus and persistent eye rubbing, resulting in corneal hydrops.[41]

Infectious keratitis is a rare complication with ring segments predominantly seen in the early postoperative period. One such case of infectious keratitis in a 40-year-old patient with the Ferrara implant is described in the literature.[43] This patient presented 4 months post-operatively with infiltration at the channel entry point and a 15% hypopyon. Corneal scraping grew *staphylococcus aureus* and the patient underwent surgical removal of the ring segments. Channel irrigation with vancomycin was performed with subsequent topical moxifloxacin being administered post-operatively. Recovery with corneal scarring was reported.

As keratoconus is a disease that affects the topography of the cornea, there might be reason to be wary of tear film instability and the possibility of dry eye disease in these patients. Thus, it was hypothesised that ICRS implantation, through improvement of the corneal topography, might reduce symptoms of dry eye. A case series of 20 patients who had their tear film assessed before and after ICRS implantation showed that the procedure does not result in a significant change in tear film osmolarity or tear film volume, and neither does it improve the tear film stability.[44] Another study of 15 patients also failed to show any significant difference in Schirmer test, tear break-up time or corneal staining, but did report significant improvement in patient-reported symptoms of dry eyes after ICRS implantation.[45] Further research with larger sample sizes is needed to provide further evidence about the tear film stability following ICRS implantation.

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Explantation

Explantation may be indicated following the complications described above. Patient-reported intolerance of glare, halos and foreign body sensation following ICRS implantation have also been reported and may necessitate explantation.[40,46] Many reported ICRS explantations have been performed electively due to subjective refractive symptoms.[40] Explantation remains uncommon overall - a systematic review over a 24-year period showed explantation rates ranged between 0.5% and 83.3% between different reported studies.[46] Centres which had higher ICRS implantation rates demonstrated an explantation rate between 0% and 1.4%.[46]

Regarding the procedure, it has been reported that if the implantation was performed recently and the wound had not fully healed, then the original incision site may be re-opened using a Sinskey hook.[40] Otherwise, a diamond blade may be used to create an incision adjacent to the ICRS at the same corneal depth as the ICRS was inserted at.[40] This depth can be confirmed pre-operatively with anterior segment OCT. Following obtaining access to the ring, a Sinskey hook can be placed anterior to the ICRS and moved down gently to break adhesions of the ring with the stroma. The Sinskey hook can then be used to gently extract the ICRS. A single 10–0 nylon suture can be used if necessary for closure of the entry incision.[40]

Role of Optical Coherence Tomography

OCT imaging has several particular uses in the management and follow-up of patients with keratoconus and ICRS implantation. As mentioned previously, OCT imaging can be used for pre-operative confirmation of ICRS depth before explantation.[47] Spectral-domain OCT has additionally been demonstrated to be useful for measuring ICRS depth and potential migration in follow-up studies of patients with ICRS.[48] Custom-made spectral anterior-segment OCT programs have also been shown to be useful in calculating corneal topography, pachymetry and aberrations.[47]

Conclusion

ICRS offer a viable means to improve vision in keratoconus patients, thereby reducing the likelihood of requiring a corneal transplant. Their primary indication is for patients who are intolerant to contact lenses and do not have central corneal scarring. The published data to date are supportive of a favourable safety profile, however future research should focus on long-term outcomes. Combining ICRS with other procedures like CXL may enhance outcomes, though careful patient selection is crucial. CAIRS represent the latest innovation in ICRS utilising purely biological tissue from donor buttons.

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References

1. Sakellaris D, Balidis M, Gorou O. et al. Intracorneal Ring Segment Implantation n the Management of Keratoconus: an Evidence-Based Approach. *Ophthalmol Ther*. 2019;8:5–14. doi:10.1007/s40123-019-00211-2
2. Burris TE. Intrastromal corneal ring technology: results and indications. *Curr Opin Ophthalmol*. 1998;9:9–14. doi:10.1097/00055735-199808000-00003
3. Colin J, Cochener B, Savary G, et al. Correcting keratoconus with intracorneal rings. *J Cataract Refract Surg*. 2000;26:1117–1122. doi:10.1016/S0886-3350(00)00451-X
4. Burris TE, Baker PC, Ayer CT, et al. Flattening of central corneal curvature with Intrastromal Corneal Rings of increasing thickness: an eye-bank eye study. *J Cataract Refract Surg*. 1993;19:182–187. doi:10.1016/S0886-3350(13)80404-X
5. Coskunseven E, Kymionis GD, Tsiklis NS, et al. One-Year Results of Intrastromal Corneal Ring Segment Implantation (KeraRing) using Femtosecond Laser in Patients with Keratoconus. *Am J Ophthalmol*. 2008;145:775–779.e1. doi:10.1016/j.ajo.2007.12.022
6. Jm L, Lyra D, Ribeiro G, et al. Tomographic Findings After Implantation of Ferrara Intrastromal Corneal Ring Segments in Keratoconus. *J Refract Surg*. 2017;33:110–115. doi:10.3928/1081597X-20161027-02
7. Alió JL, Shabayek MH, Artola A. Intracorneal ring segments for keratoconus correction: long-term follow-up. *J Cataract Refract Surg*. 2006;32:978–985. doi:10.1016/j.jcrs.2006.02.044
8. Izquierdo L, Rodríguez AM, Sarquis RA, et al. Intracorneal circular ring implant with femtosecond laser: pocket versus tunnel. *Eur J Ophthalmol*. 2022;32:176–182. doi:10.1177/1120672121994729
9. Jacob S, Patel SR, Agarwal A, et al. Corneal Allogenic Intrastromal Ring Segments (CAIRS) Combined With Corneal Cross-linking for Keratoconus. *J Refract Surg*. 2018;34:296–303. doi:10.3928/1081597X-20180223-01

10. Struckmeier A-K, Hamon L, Flockerzi E, et al. Femtosecond Laser and Mechanical Dissection for ICRS and MyoRing Implantation: a Meta-Analysis. *Cornea*. 2022;41:518–537. doi:10.1097/ICO.0000000000002937
11. Dauwe C, Touboul D, Roberts CJ, et al. Biomechanical and morphological corneal response to placement of intrastromal corneal ring segments for keratoconus. *J Cataract Refract Surg*. 2009;35:1761–1767. doi:10.1016/j.jcrs.2009.05.033
12. Vinciguerra R, Fernández-Vega-Cueto L, Poo-Lopez A, et al. The Effect of Intracorneal Ring Segments Implantation for Keratoconus on In Vivo Corneal Biomechanics Assessed With the Corvis ST. *J Refract Surg*. 2022;38:264–269. doi:10.3928/1081597X-20220202-01
13. Hamon L, Pfahl LJ, Flockerzi E, et al. Implantation of Intracorneal Ring Segments in Keratectasia: effects on Corneal Biomechanics in 112 Eyes. *Cornea*. 2023. doi:10.1097/ICO.0000000000003419
14. Berty MM, Eliwa TF, Gaafar AAM, et al. Effect of intracorneal ring segments on posterior corneal topography in eyes with keratoconus. *Archivos de la Sociedad Española de Oftalmología*. 2022;97:424–431. doi:10.1016/j.oftale.2022.05.005
15. Alejandre N, Pérez-Merino P, Velarde G, et al. Optical Evaluation of Intracorneal Ring Segment Surgery in Keratoconus. *Transl Vis Sci Technol*. 2022;11:19. doi:10.1167/tvst.11.3.19
16. CA Utine, Z Ayhan, CD Engin. Effect of intracorneal ring segment implantation on corneal asphericity. *Int J Ophthalmol*. 2018. doi:10.18240/ijo.2018.08.09
17. Dockery PW, Parker JS, Massenzio EM, et al. Intracorneal ring segment implantation in advanced Keratoconus. *Eur J Ophthalmol*. 2023;33:1324–1330. doi:10.1177/11206721231155213
18. Nacaroglu SA, Yesilkaya EC, Perk FFNK, et al. Efficacy and safety of intracorneal allogenic ring segment implantation in keratoconus: 1-year results. *Eye*. 2023;37:3807–3812. doi:10.1038/s41433-023-02618-5
19. Vega A, Alió JL. Criteria for patient selection and indication for intracorneal ring segments in keratoconus. *Eye and Vision*. 2024;11:13. doi:10.1186/s40662-024-00379-0
20. Barugel R, David C, Kallel S, et al. Comparative Study of Asymmetric Versus Non-asymmetric Intrastromal Corneal Ring Segments for the Management of Keratoconus. *J Refract Surg*. 2021;37:552–561. doi:10.3928/1081597X-20210526-01
21. Baptista PM, Marques JH, Neves MM, et al. Asymmetric Thickness Intracorneal Ring Segments for Keratoconus. *Clin Ophthalmol*. 2020;14:4415–4421. doi:10.2147/OPTH.S283387
22. Benlarbi A, Kallel S, David C, et al. Asymmetric Intrastromal Corneal Ring Segments with Progressive Base Width and Thickness for Keratoconus: evaluation of Efficacy and Analysis of Epithelial Remodeling. *J Clin Med*. 2023;12:1673. doi:10.3390/jcm12041673
23. Vega-Estrada A, Chorro E, Sewelam A, et al. Clinical Outcomes of a New Asymmetric Intracorneal Ring Segment for the Treatment of Keratoconus. *Cornea*. 2019;38:1228–1232. doi:10.1097/ICO.0000000000002062
24. Abdelmassih Y, el-Khoury S, Dirani A, et al. Safety and Efficacy of Sequential Intracorneal Ring Segment Implantation and Cross-linking in Pediatric Keratoconus. *Am J Ophthalmol*. 2017;178:51–57. doi:10.1016/j.ajo.2017.03.016
25. Alfonso JF, Fernández-Vega-Cueto L, Lisa C, et al. Long-Term Follow-up of Intrastromal Corneal Ring Segment Implantation in Pediatric Keratoconus. *Cornea*. 2019;38:840–846. doi:10.1097/ICO.0000000000001945
26. Sykakis E, Karim R, Evans JR, et al. Corneal collagen cross-linking for treating keratoconus. *Cochrane Database Syst Rev*. 2015;2015:1. doi:10.1002/14651858.CD010621.pub2
27. Piñero DP, Alio JL, Kady B, et al. Refractive and Aberrometric Outcomes of Intracorneal Ring Segments for Keratoconus: mechanical versus Femtosecond-assisted Procedures. *Ophthalmology*. 2009;116:1675–1687. doi:10.1016/j.ophtha.2009.05.016
28. Rocha G, Ibrahim T, Gulliver E, et al. Combined Phototherapeutic Keratectomy, Intracorneal Ring Segment Implantation, and Corneal Collagen Cross-Linking in Keratoconus Management. *Cornea*. 2019;38:1233–1238. doi:10.1097/ICO.0000000000002073
29. Dal A, Canleblebici M, Kutluksaman B, et al. Effects and safety of combined corneal collagen crosslinking and intrastromal corneal ring segment treatment in patients with keratoconus: a retrospective study. *BMC Ophthalmol*. 2024;24:473. doi:10.1186/s12886-024-03745-7
30. Hashemi H, Alvani A, Seyedian MA, et al. Appropriate Sequence of Combined Intracorneal Ring Implantation and Corneal Collagen Cross-Linking in Keratoconus: a Systematic Review and Meta-Analysis. *Cornea*. 2018;37:1601–1607. doi:10.1097/ICO.0000000000001740
31. McLintock CA, McKelvie J, Miraflores Gomez S, et al. Outcomes of sequential intracorneal ring segment and phakic intraocular lens insertion for visual rehabilitation in keratoconus. *Eur J Ophthalmol*. 2021;31:2219–2226. doi:10.1177/1120672120969600
32. Ferreira TB, Güell JL, Manero F. Combined Intracorneal Ring Segments and Iris-Fixated Phakic Intraocular Lens for Keratoconus Refractive and Visual Improvement. *J Refract Surg*. 2014;30:336–341. doi:10.3928/1081597X-20140319-01
33. Alfonso JF, Lisa C, Fernández-Vega L, et al. Intrastromal corneal ring segments and posterior chamber phakic intraocular lens implantation for keratoconus correction. *J Cataract Refract Surg*. 2011;37:706–713. doi:10.1016/j.jcrs.2010.10.060
34. Alió JL, Piñero DP, Alesón A, et al. Keratoconus-integrated characterization considering anterior corneal aberrations, internal astigmatism, and corneal biomechanics. *J Cataract Refract Surg*. 2011;37:552–568. doi:10.1016/j.jcrs.2010.10.046
35. Shetty R, Kurian M, Anand D, et al. Intacs in Advanced Keratoconus. *Cornea*. 2008;27:1022–1029. doi:10.1097/ICO.0b013e318172fc54
36. Kanellopoulos AJ, Lh P, Perry HD, et al. Modified Intracorneal Ring Segment Implantations (INTACS) for the Management of Moderate to Advanced Keratoconus. *Cornea*. 2006;25:29–33. doi:10.1097/01.ico.0000167883.63266.60
37. Mounir A, Radwan G, Mohamed Farouk M, et al. Femtosecond-assisted intracorneal ring segment complications in keratoconus: from novelty to expertise. *Clin Ophthalmol*. 2018;12:957–964. doi:10.2147/OPTH.S166538
38. Torquetti L, Cunha P, Luz A, et al. Clinical Outcomes After Implantation of 320°-Arc Length Intrastromal Corneal Ring Segments in Keratoconus. *Cornea*. 2018;37:1299–1305. doi:10.1097/ICO.0000000000001709
39. Oatts JT, Savar L, Hwang DG. Late extrusion of intrastromal corneal ring segments: a report of two cases. *Am J Ophthalmol Case Rep*. 2017;8:67–70. doi:10.1016/j.ajoc.2017.10.004
40. Nguyen N, Gelles JD, Greenstein SA, et al. Incidence and associations of intracorneal ring segment explantation. *J Cataract Refract Surg*. 2019;45:153–158. doi:10.1016/j.jcrs.2018.09.021
41. Moshirfar M, Bean AE, Desautels JD, et al. Corneal Hydrops Secondary to Intrastromal Corneal Ring Intrusion into the Anterior Chamber 7 Years after Implantation: a Case Report. *Ophthalmol Ther*. 2017;6:373–379. doi:10.1007/s40123-017-0105-7
42. Jarade E, Dirani A, Fadlallah A, et al. New Technique of Intracorneal Ring Segments Suturing After Migration. *J Refract Surg*. 2013;29:855–857. doi:10.3928/1081597X-20130723-01

43. Galvis V, Tello A, Delgado J, et al. Late Bacterial Keratitis After Intracorneal Ring Segments (Ferrara Ring) Insertion for Keratoconus. *Cornea*. 2007;26:1282–1284. doi:10.1097/ICO.0b013e3181506142
44. Vastardis I, Gatzioufas Z, McLintock C, et al. Tear film parameters before and after intracorneal ring segment implantation in keratoconic eyes. *Eur J Ophthalmol*. 2021;31:2213–2218. doi:10.1177/1120672120958301
45. Carracedo G, Recchioni A, Alejandre-Alba N, et al. Signs and Symptoms of Dry Eye in Keratoconus Patients Before and After Intrastromal Corneal Rings Surgery. *Curr Eye Res*. 2017;42:513–519. doi:10.1080/02713683.2016.1200098
46. Bautista-Llamas M-J, Sánchez-González MC, López-Izquierdo I, et al. Complications and Explantation Reasons in Intracorneal Ring Segments (ICRS) Implantation: a Systematic Review. *J Refract Surg*. 2019;35:740–747. doi:10.3928/1081597X-20191010-02
47. Pérez-Merino P, Ortiz S, Alejandre N, et al. Ocular and Optical Coherence Tomography–Based Corneal Aberrometry in Keratoconic Eyes Treated by Intracorneal Ring Segments. *Am J Ophthalmol*. 2014;157:116–127.e1. doi:10.1016/j.ajo.2013.08.017
48. de Sanctis U, Lavia C, Nassisi M, et al. Keraring Intrastromal Segment Depth Measured by Spectral-Domain Optical Coherence Tomography in Eyes with Keratoconus. *J Ophthalmol*. 2017;2017:1–9. doi:10.1155/2017/4313784