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Research Article

Intraocular Lens Power Calculation after Intracorneal Ring Segment Surgery for the Treatment of Post-LASIK Ectasia

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Abstract

Objective: To describe the method of Intraocular lens (IOL) power calculation in eyes after Intracorneal Ring Segment (ICRS) surgery for the treatment of post-LASIK ectasia.

Design: Retrospective observational case-series.

Participants: Three eyes of 2 patients were included in this study.

Methods: Corneal curvature in the central effective optical zone was averaged using corneal topography and k-reading (Kr) was calculated using Jarade IR method for Kr after LASIK. The calculated Kr was used in SRK-T formula for IOL calculation. Accuracy of this IOL calculation method was judged using the manifest refraction outcome after cataract surgery. All eyes were targeted for emmetropia after cataract.

Results: In our series, one eye developed cataract after ICRS surgery for the treatment of ectasia after hyperopic LASIK (+4 D) and 2 eyes developed cataract after ICRS surgery for the treatment of ectasia after myoic LASIK (-10 D). The spherical equivalent of manifest refraction after cataract surgery was within 1.25 D in all eyes.

Conclusion: Using the average corneal curvature in the central effective optical zone to calculate Kr "by Jarade IR" method was found to be accurate in calculating IOL power in ectatic eyes treated by ICRS surgery.

Introduction

As the number of patients undergoing corneal refractive surgery is constantly increasing, an increasing volume of cataract surgery after corneal refractive surgery is anticipated with an expectation of perfect vision without correction [1].

The standard methods for measuring keratometry (manual keratometer, automated keratometry or corneal topography) have been shown to underestimate the corneal flattening after Radial Keratotomy (RK) [2, 3], Photorefractive Keratectomy (PRK) [4-8], and laser in situ keratomileusis (LASIK) [7, 9-11] with an overestimation of the K-reading. As a result, there is a hyperopic shift after cataract surgery in eyes that underwent corneal refractive surgery.

Several methods to obtain K-reading for accurate IOL power calculation after photorefractive surgery have been adopted [6, 8-26]. The calculation or clinical history method [12] is accurate and perhaps the most reliable after RK and photorefractive procedures. However, it has limitations because it requires post-refractive surgery refraction. Jarade et al. [25-27] are the first who proposed a new method for accurate K-reading after corneal refractive surgery based on a new corneal effective index of refraction (IR method). This method allows for an accurate derivation of K-reading from the anterior radius of curvature after corneal refractive surgeries (LASIK and PRK) with no need for the preoperative K-reading. This formula has been proved to be accurate, simple, objective, and does not require preoperative data such preoperative K-reading. The only prerequisite of this formula is the amount of ablation performed (myopia and hyperopia).

Corneal ectasia is a thinning disorder causing irregular corneal astigmatism with progressive loss of best corrected visual acuity (BCVA). It is encountered in keratoconus, pellucid marginal degeneration and as a late complication in refractive surgery. Recently, Intrcorneal Ring Segment (ICRS) implantation has been approved for the visual rehabilitation of patients with ectasia [28]. As such, an increasing number of cataract surgeries are expected in eyes that underwent ICRS implantation for corneal ectasia. Based on our clinical observation, K-reading after ICRS is not accurate and does not reflect the amount of corneal flattening induced by ICRS implantation, subsequently, the amount of flattening in K-reading induced by ICRS insertion and measured by automated keratometer does not accurately reflect the amount of hyperopic shift that is measured

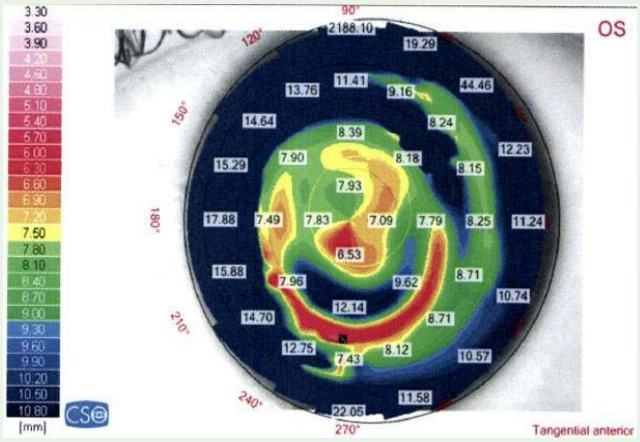

Figure 1: Anterior curvature map (in mm) of the cornea of left eye in patient n1.
On the topography, we can easily identify three consecutive zones (fig): a peripheral bulged zone overlying the implanted segment, an intermediate flat zone just interior to it. This zone attenuates gradually and gives place to the central regular zone which represents the central effective optical zone.

by manifest refraction. Such over estimation of K-reading after ICRS insertion may lead to underestimation of IOL power calculation and hyperopic shift after cataract surgeries in eyes that underwent ICRS implantation for corneal ectasia. To the best of our knowledge there is no work addressing the corneal power and IOL calculation after ICRS surgeries mainly in eyes that developed ectasia after LASIK surgeries. . Here with, we report our approach and its result for such complicated clinical scenario of eyes that developed ectasia after LASIK surgery and that were treated by ICRS surgery and then they developed cataract which necessitates IOL power calculation before the cataract surgery.

Material and methods

Between the years of 2010 and 2011, three eyes of 2 consecutive patients who underwent cataract surgery after ICRS insertion post LASIK ectasia (2 eyes after myopic LASIK and one eye after hyperopic LASIK) were included in this study.

First patient was 40 years old when he was first seen. He had a history of hyperopic LASIK (+4 D in each eye) about 5 years earlier. Patient was complaining of progressive drop of vision in his left eye after the hyperopic LASIK. The eye exam at the time of his first presentation to our eye center revealed the presence of ectasia in his left eye with poor BCVA. Intracorneal ring segment surgery was performed in his left eye with insertion of one segment of Keraring SI5 (Keraring, Mediphacos Ltda, Belo Horizonte, Brazil) followed by corneal collagen cross linking (CXL) 4 weeks after. UCVA post ICRS insertion and CXL improved to 0.7 with almost near plano refraction. Three years later the patient was complaining of recent deterioration of his vision in his left eye which was attributed to cataract formation in the same eye. K-reading was performed using our new approach and IOL power was calculated using SRKT formula. Clear cornel incision Phacoemulsification with posterior chamber IOL implantation was performed in the same aye.

The second patient was 53 years old when he was first seen. He had a history of bilateral high myopic LASIK about 10 year earlier (10 diopters in each eye) with history of bilateral ectasia after LASIK. At the time of his first presentation to our eye center, patient was found to have ectasia and cataract formation in both eyes with very poor BCVA in both eyes. ICRS insertion was performed in order to normalize and regulate the surface of the corneas in both eyes with no CXL performed. More than six months later, K-reading was performed using our new approach and IOL power was calculated using SRKT formula. Clear corneal incision phacoemulsification was performed with posterior chamber IOL.

ICRS insertion work-up and technique

Pre-ICRS insertion screening consisted of a complete ophthalmic workup including: Uncorrected Distance Visual Acuity (UCVA), best Corrected Distance Visual Acuity (BCVA), manifest and cycloplegic refractions, and anterior and posterior segment evaluations with dilated fundus examinations. All patients also had a Placido-Scheimpflug topography using the Pentacam device (Oculus, Optikgerfate GmbH, Wetzlar, Germany) with maping of corneal thickness centrally. All operations were performed by one surgeon (EJ). All surgery was performed using femtosecond laser (IntraLase FS60, Abbot, IL, USA) to create the tunnel at the designed depth and the incision site was chosen to insert the thickest ICRS under the steep corneal zone and the thinnest segment oppositely (in case of 2 segments insertion). In case of one segment insertion, the segment was inserted under the steep area.

K-reading technique and IOL calculation

Placido-Scheimpflug topography using the Pentacam (Oculus, Optikgerfate GmbH, Wetzlar, Germany) was performed in all eyes at the time of K-reading. The average corneal power was mapped inside the clinically determined central effective optical zone (CEOZ). Central effective optical zone was subjectively determined according to the diameter of the ring segment inserted, pupil size, and the regularity of the central cornea. Mapping of the corneal power was performed by measuring the corneal curvature (in meter) at 12 different circumferential corneal points at the 2.7 to 3 mm diameter zone (Figure 1). Average corneal curvature was calculated as a mean of these 12 corneal points and K-reading was measured using Jarade IR method for accurate K-reading after LASIK surgery [25]. The new relative index of refraction (rN) was determined according to the amount of LASIK correction using the linear regression formula:

rN = 0.0014*D + 1.3375 where "D" is the amount of LASIK ablation.

K-reading was derived using the paraxial formula

(K-reading = (rN-1)/R_a (m).

Where Ra refers to the anterior radius of curvature expressed in meters (m).

The calculated K-reading in the CEOZ was entered into the SRK-T formula to calculate the IOL power for each patient after axial length measurement with a target refraction of plano.

Cataract extraction work-up and surgery

All patients underwent cataract extraction (same surgeon, EJ) by phacoemulsification through a clear cornea incision (2.8 mm) in the 90-degree meridian regardless of the steepest axis of astigmatism.

Table 1: Age, amount of LASIK ablation in diopters, time from LASIK to ectasia, time from ICRS insertion to cataract, type of ICRS used, Post ICRS simulated K-reading (SK) measured by corneal topography, Post ICRS calculated k-reading using Jarade IR formula, refraction after cataract surgeries ,UCVA and BCVA in the three eyes.

	Age at the time of cataract surgery (years)	Amount of LASIK correction in diopters	Time from LASIk to the time of ectasia diagnosis (years)	Time from ICRS insertion to cataract surgery (years)	ICRS used	Post ICRS automated K-reading	Post ICRS calcukated K-reading using Jarade IR formula	Refraction after Cataract surgery (SE)	UCVA after cataract surgery	BCVA after catarct surgery
Patient nb.1-LE	43	+4	5	3	Keraring SI5 (160 degrees-300 µm)	Range from 44.0 to 45.5 D	45.8	-0.35	0.65	0.7
Patient nb. 2-RE	46	-10	1	1	Intacs SK 450 µm inferiorly	54.5	47	+1.0	0.6	0.8
Patient nb. 2-LE	46	-10	1	1	Keraring SI6 (210 degrees-300 µm) inferiorly	62.25	50	-1.25	0.2	0.6

SE: spherical equivalence, UCVA: uncorrected visual acuity, BCVA: best corrected visual acuity, ICRS: intracorneal ring segment, RE: right eye, LE: left eye.

All posterior chamber intraocular lenses were implanted within the capsular bag.

Postoperative data including refraction and K-reading were obtained at 6 months post cataract surgeries in all 3 eyes.

Results

Table 1 shows clinical, refractive and topographic pre/post operative parameters of the 2 patients undergoing cataract surgery.

Patient Nb. 1

Ectasia was treated with insertion of Keraring SI5; (160 degrees, 300 microns) followed by CXL 4 weeks after. In this patient, ectasia was previously treated with insertion of Keraring SI5; (160 degrees, 300 microns) followed by CXL 4 weeks after. Before cataract surgery, topography was done using Pentacam device (figure 1), and the calculated K-reading using Jarade IR formula was 45.8 D vs. variable and non consistent Sim K-reading measurements using same automated K-reading (range from 44.0 to 45.5 D). After uneventful cataract surgery targeting plano refraction UCVA improved to 0.7 with a near plano manifest refraction (-035 D of SE). Post ICRS insertion topography in left eye of the first patient is shown in figure 1.

Patient Nb. 2

At the time of his presentation for cataract surgery, UCVA was 0.01 in both eyes with BCVA of 0.3 in the right eye and uncorrectable in the left eye.

Patient was scheduled for ICRS surgery in both eyes in order to decrease corneal irregularities before cataract surgeries. One ring segment of INTACS SK 450 microns was inserted inferiorly in the right eye and one ring of Keraring SI6 210 degrees- 300 microns was inserted inferiorly in the left eye. Post ICRS insertion BCVA improved to 0.4 in the right eye and 0.05 in the left eye. Cataract surgeries were performed almost one year after ICRS insertion, Calculated K-reading was 47D in the right eye and 50 D in the left eye vs. automated K-reading of 54.5 D in the right eye and 62.25D in the left eye. One year after cataract surgeries, UCVA improved to 0.6 in the right eye and 0.2 in the left eye. Spherical equivalent was +1.0 D in the right eye and -1.25 in the left eye with BCVA of 0.8 in the right eye and 0.6 in the left eye (high cylinder refraction in the left eye).

The figure 2 represents a time-line chart of spherical equivalence, UCVA and BCVA of the eyes presented in this case series.

Discussion

Corneal power assessment after corneal refractive surgeries has been proven to be inaccurate with overestimation of K-reading after myopic corneal ablation and underestimation of K-reading after hyperopic ablation [4-11]. The IR method that was published first by Jarade [25, 27] who proposed a new corneal effective index of refraction which takes into consideration the amount of ablated corneal surface induced by refractive surgery. This new index allows for an accurate derivation of K-reading from the anterior radius of curvature. This method was proven to measure K-reading accurately after corneal refractive surgeries. The prerequisites of this method are the amount of correction performed by the refractive procedure and the Ra measured in meter at the time of K-reading after LASIK or PRK [25, 27].

Corneal ectasia is a progressive, non-inflammatory, thinning disorder causing irregular corneal astigmatism and is commonly encountered either as primary corneal keratoconus or after corneal refractive surgery. Corneal actasia is often associated with poor BCVA due to corneal irregularities [29]. ICRS implantation is a tissue-saving technique that is used to reshape the abnormal cornea

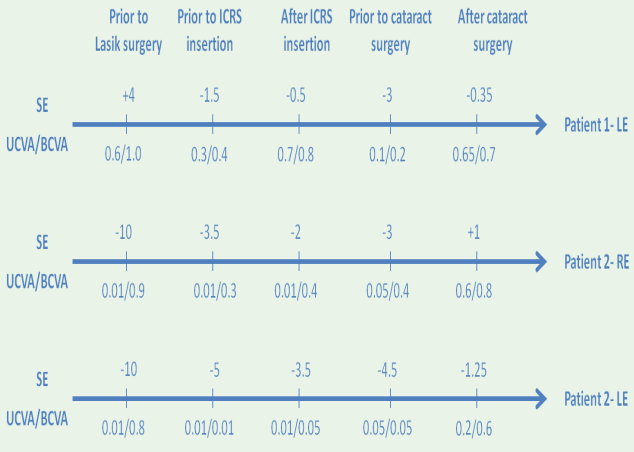

Figure 2: Time-line chart presenting the spherical equivalence, UCVA and BCVA of eyes undergoing cataract surgery.
SE: spherical equivalence, UCVA: uncorrected visual acuity,BCVA: best corrected visual acuity, ICRS: intracorneal ring segment, RE: right eye, LE: left eye.

and improve the topographic abnormalities and visual acuity [28], As per our clinical observation, K-reading measurement is considered as inaccurate after ICRS insertion and does not reflect the amount of corneal flattening induced by ICRS insertion. After ICRS insertion, K-reading measurement using automated K-reading is not accurate and usually it over estimates the actual corneal power. The same phenomena is observed when taking auto refractometer , the refraction measured is always shifted toward myopia relative to the manifest refraction which is considered as a useful and trustful tool to measure the flattening effect after ICRS insertion [30].

The inaccuracy of k-reading provided by current instruments after ICRS implantation is directly related to the inherent properties of those instruments that measure the corneal curvature at a zone close to the inner edge of the ICRS mainly in case of small diameter ring segments (e.g. Kearring SI5 which has an inner diameter of 4.8 mm). We observed that the corneal area adjacent to the inner zone of the ring segment is affected by the volume "mass" effect of the ring which induce a "hump" zone interior to the inner edge which smoothen out progressively toward the central optical zone. Also, this zone adjacent to the inner edge of the ring segment is much affected by the epithelial hyperplasia that is occurring just interior to the inner edge of the ring. This creates a transitional optical zone from the inner edge of the ring segment toward the center of the cornea similar to the transitional optical zone observed after incisional corneal surgeries "knee zone" [31]. That for, the measured K-reading using the current instruments is significantly affected by the presence of the ring segment and usually leads to false high K-reading after ring insertion. Corneal topography after ICRS insertion may demonstrate clearly the presence of this transitional optical zone and we can assume that the Central Effective Optical Zone (CEOZ) used for light focusing is not measured by the current automated methods of K-reading. In contradiction to the excimer refractive surgery, ICRS produce a transitional optical zone which leads to false high K-reading but keeps a normal relation between the anterior and posterior corneal curvatures with normal ratio of dioptric power.

Therefore, it is crucial to accurately delineate the Central Effective Optical Zone (CEOZ). The CEOZ will vary with the ICRS implanted (OZ, thickness, and arc length) and the pupil diameter. In the case of corneal ectasia following LASIK or PRK, 2 major sources of errors of K-reading are present: 1) the disturbance of normal optical ratio between the anterior and posterior corneal curvatures induced by the LASIK or PRK and 2) the presence of ring segment which induces the previously described source of errors in K-reading due to the anatomical and optical distortion created by ICRS.

With the increasing number of ICRS implanted for corneal ectasia after corneal refractive surgeries or for primary keratoconus and as the keratoconus patient population are aging, we are expecting an increasing number of cataract surgeries in eyes that have corneal ectasia (or primary keratoconus) with or without treatment with ICRS. Accurate K-reading and ultimate accurate IOL power calculation in those eyes will be the ultimate challenge of the cataract surgeon. Cataract surgeon can face this challenge in four different scenarios:

a. Catarct surgery in corneal ectasia after refractive surgery that was treated with ICRS insertion (first eye of the patient number one): In this case the mean Ra is calculated by the same way as previously, a new corrected index of refraction is determined using Jarade IR method according to the amount of dioptric correction and the corneal power is derived using the new effective index of refraction and the mean Ra in the paraxial formula.

b. Catarct surgery in corneal ectasia after refractive surgery that is not treated by ICRS insertion (second and third eyes of the patient number 2): ICRS insertion is performed first to normalize the corneal curvature and enhance the BCVA. Then, we calculate the corneal power as indicated in the first scenario.

c. Cataract surgery in primary keratoconus that was treated with ICRS insertion: in this case the ratio between the anterior and posterior corneal curvature is not disrupted. Ra is determined as the average of the Ra within the CEOZ that is determined clinically (as described previously) and the K-reading is derived directly using the relative index of refraction of the normal cornea.

d. Cataract surgery in primary corneal keratoconus that is not treated with ICRS insertion: ICRS insertion is needed in order to enhance the BCVA and should be inserted before cataract surgery in order to avoid the hyperopic shift if ever ICRS insertion is performed after cataract surgery. K-reading after ICRS insertion is described in paragraph (c).

In our small case series, we treated a case of ectasia after hyperopic LASIK with ICRS insertion and 2 cases of severe ectasia after high myopic LASIK. In the 3 cases, the achieved SE of refraction after catarct surgeries were very close to the targeted emmetropia. Manifest refraction is considered as the only reliable way to determine the achieved refraction after cataract surgeries in those cases. To the best of our knowledge, this is the first work in this topic dealing with K-reading and IOL power calculation after ICRS insertion in eyes with corneal ectasia after LASIK. Despite the very encouraging preliminary results of our small case series, this described method has some limitation, because it does not take into consideration the effect of corneal collagen cross linking in K-reading which is not determined yet. Also, determining the CEOZ is affected by the subjective clinical judgment of the treating physician. Another limitation is the assumption that the normal ratio between the anterior and posterior corneal curvature is not affected after ICRS insertion. Such assumption can hypothetically be argued though there is no clinical evidence opposing it.

In conclusion, our small case series is considered as the first work addressing the problem of calculating IOL power after ICRS implantation in ectatic cornea after LASIK with encouraging preliminary results. A larger case series is needed to validate and refine our proposed method of calculating K-reading after ICRS insertion in ectatic corneas.

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