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Research Article

A Research on the Efficiency of the Refined Method for Determining the Optical Power of Intraocular Lenses in Patients After Radial Keratotomy

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Abstract

Introduction: The relevance of the issue under consideration is explained by the continuously increasing number of patients after keratotomy who require cataract surgery. Cataract remains a relevant and significant problem in modern ophthalmic surgery. In the last decade, the number of patients undergoing cataract surgery after keratorefractive surgery has increased. Specifically, senile cataracts are increasingly becoming an indication for surgery in eyes that have undergone radial keratotomy.

Purpose of the Study: To evaluate the effectiveness of an optimized approach to calculating the optical power of intraocular lenses in patients after radial keratotomy, independent of clinical and anamnestic refractive data.

Materials and Methods of Research: The studies were carried out based on the results of clinical observations of 39 patients (61 eyes) who had previously undergone radial keratotomy (RK) for myopia and myopic astigmatism along with varying degrees of cataract maturity. The age of the patients ranged from 42 to 62 years, with an average age of 45.2 ± 6.4 years for the subjects.

Results of Our Own Research: As a result of clinical and diagnostic studies, an analysis was conducted of the data concerning the mathematical calculation of the preoperative corneal curvature value after RK, along with the clinical outcomes of predicted refractive outcomes of intraocular lenses in cataract patients.

Discussion: The clinical analysis of the 3rd generation formulas revealed that the calculated value of the effective lens position (ELP) is dependent on the radius of curvature of the cornea. This radius determines the depth of the anterior chamber and the distance of the optical part of the IOL from the posterior surface of the cornea.

Conclusions: 1. The method of mathematical modeling of the optical parameters of the cornea after radial keratotomy can be used as an effective way to calculate the preoperative curvature of the cornea using keratotopographic data of its periphery, providing optimal accuracy in determining the optical power of the IOL. 2. Based on mathematical modeling data, there is a substantiated need to determine the effective position of the lens. 3. A comparative analysis of the refractive results of FEC in patients who underwent RK demonstrated the effectiveness of the double keratometry method. This approach enabled achieving maximum refractive accuracy within 1.15 diopters in 53.4% of cases.

Keywords: Double Keratometry Method; Radial Keratotomy (RK); Effective Lens Position (ELP)

Introduction

Cataract continues to be a relevant and important issue in modern ophthalmic surgery. A particular feature of cataract surgery in the last decade is the increased number of patients who have undergone keratorefractive surgery. Specifically, senile cataract is now more frequently becoming an indication for surgery in patients with a history of radial keratotomy [1,2]. In the age group of over 60 years, the percentage of occurrence and need for surgery exceeds 40% [3,4]. In addition to several technical challenges associated with the heightened risk of intra- and postoperative complications due to scarred corneas, one of the pivotal issues is the accurate calculation of the intraocular lens.

According to several authors, achieving the predicted refraction accuracy is notably lower in patients with scarred corneas compared to those with routine senile cataracts [5-7]. This is primarily due to pronounced irregularities in the keratotopographic map of the cornea, especially in its central regions. The alteration of tear film refraction also plays a significant role. Research from various authors underscores the importance of evaluating not only the anterior topography but also incorporating data from the posterior corneal topography.

In modern approaches to intraocular lens calculation, emphasis is placed on selecting the appropriate formula for calculating the intraocular lens, taking into account not only pure refractive optical parameters, but also the effectiveness of the lens position in the eye cavity in the postoperative period [8-11]. Literature provides data on conducting a comparative analysis of refraction results for calculating the intraocular lens power using the double keratometry method obtained by keratotopography and when using known corneal optical power data with average corneal curvature values [12-14].

Studies on cataract patients after radial keratotomy have justified the theoretical necessity of calculating the effective lens position based on corneal refraction data preceding radial keratotomy as the main criterion for correct intraocular lens optical power calculation in cataract surgery [15-17]. Planning cataract surgery after radial keratotomy involves calculating the intraocular lens optical power using the double keratometry method, regardless of the availability of pre-radial keratotomy refraction data.

Research goal

To evaluate the effectiveness of an optimized approach to calculating the optical power of intraocular lenses in patients after radial keratotomy (RK), independent of clinical and anamnestic refractive data.

Materials and Methods

The study was conducted based on the clinical observations of 39 patients (61 eyes) who had previously undergone LASIK for myopia and myopic astigmatism and were diagnosed with cataracts of varying degrees of maturity, for which phacoemulsification (Phaco) with intraocular lens (IOL) implantation was planned. The postoperative period from the time of LASIK to cataract surgery varied from 17 to25 years. The age of the patients ranged from 42 to 62 years. The average age of the participants was 45.2 ± 6.4 years. All cases were diagnosed with age-related cataracts of varying degrees of maturity. In both groups of participants, no signs of accompanying dystrophic or inflammatory conditions were observed.

Among them, in the first group, 14 patients (18 eyes) had preoperative corneal power values. For the remaining 25 patients (43 eyes) in the second group, there were no preoperative examination data before keratorefractive surgery.

In the first group, all patients underwent a mathematical calculation of the preoperative central corneal curvature value based on the calculated difference between pre- and postoperative topographic corneal examinations.

In group 2, patients did not have preoperative keratometry data, and the calculation of IOL optical power was performed using a modified method of double keratometry with mathematical modeling of the preoperative value of the central corneal curvature.

A comparative retrospective analysis was conducted to assessthe accuracy of IOL optical power calculation using different values of corneal curvature preceding RK: with existing keratometric values versus modeled corneal optical power values with comparable corneal curvature values. A comparative retrospective analysis was conducted to assess the accuracy of intraocular lens (IOL) optical power calculation using different values of corneal curvature preceding radial keratotomy (RK): utilizing existing keratometric values versus modeled corneal optical power values with comparable corneal curvature values.

At the time of cataract removal, various forms of refractive error were present: myopia, hyperopia, and both groups were characterized by a combination with predominantly high astigmatism values. Corneal astigmatism exceeding 1.5 D was detected in 87.9% (53 eyes). Some patients did not have their refractive status of the eye identified due to mature cataracts. The main parameters of the patients' eyes are presented in Table 1.

	Myopic refraction	Hypermetropic refraction	Indeterminate refraction
1 group	61,1% (11 eyes)	27,7% (5 eyes)	11,1% (2 eyes)
2 group	72,09% (31 eyes)	20,9% (9 eyes)	6,9% (3 eyes)

Table 1: Indicators of preoperative clinical refraction in patients with cataracts, in eyes after radial keratotomy.

All patients underwent a complete clinical examination, including visual acuity measurement, refraction testing, ultrasound biometry, pneumotonometry, slit-lamp examination, and fundoscopy. Optical coherence tomography was performed to exclude pathology of the macular region of the retina. Patients with identified fundus pathology were excluded from the study to avoid refractive errors in calculating intraocular lens power. Keratometric analysis was conducted on all patients using corneal topography with the TMS-5 device (Tomey), and IOL power calculations were done using basic formulae from optical biometers Alladin (Topcon) and Verion (Alcon). All surgeries were performed in one clinic, by one surgeon, between 2017 and 2022. Phacoemulsification procedures were carried out using standard techniques on Whitestar Signature (J&J Vision) and Centurion (Alcon) machines. Surgical access was planned based on the location and distance between keratotomized incisions; scleral access was planned for distances less than 2 mm between incisions, while corneal access was used when a sufficient distance was present to prevent trauma to the incisions. A 2.0-2.2 mm wide blade was used for creating the surgical incision. Posterior chamber IOLs (Tecnis Toric ZCT100, ZCT150, ZCT225, CT300, ZCT 375, AKREOS Adapt -8, Acrysof IQ Toric SN6AT2, T3, T4, T5, T6) were implanted.

To calculate the optical power of the IOL in Microsoft Excel, formulas of the double keratometry method were inputted, utilising keratometric values of the cornea before and after refractive surgery. Data of anterior and posterior chamber depth, White-to-White values were entered to determine the effective lens position (ELP), alongside the radius of curvature of the cornea after refractive surgery to determine the optical power of the IOL. A paraxial formula based on the standard keratometric index $r = 337.5/K$ was employed to convert the corneal radius of curvature to refractive power and vice versa. Methods not requiring preoperative keratometry data described in the literature and widely used in cataract surgery post refractive surgery for myopia were applied for retrospective analysis and calculation (Koch-Malony) (Koch D., Wang L., 2003); Rosa Rosa (Rosa N., Capasso L., Lanza M., *et al*. 2005); Shammas (Shammas H.J., Shammas M.C., 2007). Data was recalculated using the average SRK/T formula for comparative evaluation (Retzlaff, Sanders, Kraff, 1990). Clinical refraction calculation after surgery was compared with predicted refraction one month after phacoemulsification, after stabilization of postoperative refraction values. Subjective refraction of the eye was evaluated using sphere equivalent (SE) and compared with functional visual acuity indicators.

To compute the value of preoperative corneal curvature, a mathematical calculation of the standard ratio for calculating keratometric data was conducted. This ratio represents the coefficient of difference between the keratometric value of pre-keratometric data and the obtained value. The Pearson correlation coefficient was calculated during the study. Statistical values such as mean (M) and standard deviation (SD) were provided for the samples, and one-way analysis of variance was used to compare the means.

The results of the original research

The original research results indicated that the mathematical calculation of preoperative corneal curvature values post-PRK and the clinical outcomes of predicted clinical refraction of intraocular lenses in cataract patients were analyzed. The method of mathematical calculation based on topographic analysis of the preoperative central corneal curvature was based on the following criteria:

- The corneal mean values correspond to an ellipsoidal shape with an eccentricity of 0.5 (Cuaycong M.J., Gay C.A., Emery J., *et al*. 1993; Koch D.D., Haft E.A., 1995; Preussner P.R., Olsen T., Hoffmann P., *et al.* 2008).
- After PRK, a standard decrease in refractive indices is typically observed in the central zone of the cornea (Sawusch M.R., Lee Wan W., McDonnell P.J., 1991; Hjortdal J.O., Ehlers N., 1996). It is known that by using postoperative corneal curvature radius values in the periphery and the eccentricity of a normal cornea, the original radius of curvature at the center of the cornea can be computed. The standard mathematical equation of Baker was utilized for modeling the basic corneal profiles (Bennett A.G., 1988; Burek H., Douthwaite W.A., 1993; Lam A., Douthwaite W., 1994).

Dc = 337,5 (1/Rh – 1/Rk)

Where Dc is the radius of curvature of the central point of the cornea corresponding to the projection of the visual axis (mm),

1/Rh is the average radius of curvature of the anterior surface of the cornea (mm),

1/Rk is the average radius of curvature after flattening as a result of RK (mm).

The optimistic use of the modified double keratometry method in calculating intraocular lens power successfully predicted the magnitude of ELP. The value of the refraction of the cornea, altered by keratotomy, was determined as the average value in the central zone with a diameter of 3.0 mm during topographic measurement [18-20].

In both groups, the surgery and postoperative period proceeded without complications. A notable feature of the postoperative period was a more pronounced manifestation of tear film disturbance due to the disruption of the topographic surface of the eye, which affected the recovery of visual functions. Scar formation of the postoperative wound occurred within standard time frames with complete epithelialization in 1-2 days.

The placement of the IOL was standard intracapsularly in 100% of cases, with the optical part positioned centrally relative to the optical axis of the eye. In 8.1% (5 eyes) of cases, there was an observed increase in intraocular pressure in the postoperative period, interpreted as postoperative hypertension and managed pharmacologically. Moderate corneal edema was observed in 11.4% (7 eyes), primarily in eyes with mature cataracts, necessitating increased ultrasound parameters for nucleus fragmentation due to its high density.

Uncorrected visual acuity improved from 0.1 ± 0.11 to 0.65 ± 0.25 in Group 1, and from 0.15 ± 0.12 to 0.68 ± 0.25 in Group 2. Maximum corrected visual acuity improved from 0.25 ± 0.24 to 0.80 ± 0.20, and from 0.4 ± 0.27 to 0.9 ± 0.16, respectively (M ± m - mean and standard deviation).

The analysis of the predictability of IOL calculation in both groups revealed that the highest number of cases of IOL power matching ±1.15 D was observed in the second group when using the modified method of double keratometry in 53.4% of cases (23 eyes), a lower result was noted when calculating the optical power of IOL using the standard SRK/T method, in 33.3% (6 eyes). The frequency of cases of calculation accuracy ±1.0 D was also determined: in 83.7% of cases (36 eyes) by the modified method of double keratometry, in 74.4% (32 eyes) - Shammas, in 51.1% (22 eyes) - Koch-Malony, in 25.6% (11 eyes) - SRK/T.

	1 Group	2 Group	Statistical deviation	Range
Axial length, mm	25,78	26,27	12,5	24,7-30,12
Keratometry, Dioptres	41,75	43,55	3,75	36,7-47,5
Anterior chamber depth, mm	2,68	2,85	0,32	2,42-3,27
Lens thickness, mm	3,43	3,76	0,43	3,32-4,87
IOL optical power, diopters	19,5	18,5	7,75	12-23,5
Sphere equivalent of the refraction before the surgery	8,75	9,55	3,95	(+)3,75 – (-)7,5
Sphere equivalent of the refraction After the surgery	1,57	1,15	2,25	(-)1,75 - (+2,25)

Table 2: Characterizing clinical data in predicting IOL optical power and postoperative refraction.

Conclusion

The conducted clinical analysis of the 3rd generation formulas has shown that the calculated value of effective lens position (ELP) is contingent upon the radius of curvature of the cornea, which determines the anterior chamber depth and the distance of the IOL's optical part from the posterior surface of the cornea. However, due to the flattening of the cornea at the center after RK, the depth of the anterior chamber of the eye also changes, leading to a discrepancy between the predicted and the actual value of the depth of the anterior chamber of the eye. The fact that the flattening of the central part of the cornea affects the relationship of eye chamber parameters requires further study and mathematical refinement, possibly by incorporating other anatomical landmarks into the calculation parameters.

Findings

- The method of mathematical modeling of optical parameters of the cornea after radial keratotomy proves to be an effective approach to calculate the preoperative curvature of the cornea. By utilizing keratotopographic data from its periphery, this method ensures optimal accuracy in determining the optical power of the IOL.
- Based on the data of mathematical modeling and analysis of clinical results of IOL implantation in post-RK eyes, the necessity of determining the effective position of the lens in the eye for the correct calculation of the optical power of the IOL has been justified.
- A comparative analysis of refractive outcomes of phacoemulsification with IOL implantation in patients who underwent RK, in the absence of keratotometric data, demonstrates the effectiveness of using the double keratometry method in lens power calculation, allowing to achieve maximum refractive accuracy within 1.15D in 53.4% of cases.

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