Abstract

Cataract surgery after corneal refractive surgery can be challenging due to the difficulty with accurate IOL power determination. An increasing number of methods designed to measure IOL power to achieve emmetropia. This article includes a brief on the most important and popular methods and the significant problems occurring after refractive surgery.

Key words: IOL Calculation, refractive surgery, cataract.

Introduction

Six decades have passed since the first implantation of an artificial Intraocular Lens (IOL) into human eye. Since then, cataract surgery has evolved and most patients expect unaided vision following this procedure.

Another procedure which has gained tremendous popularity in recent years is excimer laser corneal refractive surgery and it is the second most commonly performed ocular surgical procedure after cataract surgery.

The number of patients presenting with cataract after corneal refractive surgery has been continuously increasing over the years and the main problem for the surgeon is IOL calculation.

The challenge is bigger because these patients have high expectations for their vision.

The two most important measurements that aid accurate IOL power calculation are the axial length of the eye and the corneal curvature. An error of 1.0D in keratometry would result in an equivalent error in IOL which is the same after a 0.33 mm error in axial length determination.
Axial length measurements have been the source of the most refractive surprises but with refinements in biometry techniques and instruments (optical biometry) these errors have decreased.\textsuperscript{1,2} Studies that analyzing axial length before and after corneal refractive surgery found no significant differences.\textsuperscript{3,4}

### Error sources for intraocular lens calculation

#### Corneal Curvature

Corneal curvature after corneal refractive surgery is very difficult to measured. There is no instrument to directly measure corneal power in diopters. Keratometry or topography derive corneal power from the radius of corneal curvature. Corneal power calculations rely on determining the radius of curvature of the anterior cornea in meters (r), which is converted into a diopteric power (P) using an index of refraction (n) utilizing the following paraxial equation:

\[
P = \frac{(n-1)}{r}
\]

Two assumptions regarding topography or keratometry are that:

1) the cornea is a true spherical surface
2) the power of the cornea's paracentral 3-4 mm is not significantly different from the central cornea.

After corneal refractive surgery the anterior corneal curvature modified. After myopic correction the optical zone of cornea become flatter. Usually, inside the pupillary area the central cornea becomes flatter than the portion of cornea that lies over the marginal zone of pupil, so its prolate shape becomes oblate with reverse asphericity. In hyperopic correction the cornea become steeper, more prolate and aspericity increases. This phenomenon increases with the amount of surgical correction and is more evident in laser ablative surgery with small optical zone.\textsuperscript{5-7} Unfortunately, there is no instrument to take measurements at the optical axis but rather a little peripherically. Keratometers measure a portion of cornea that does not include the pupillary central area. It is constituted by a circular crown with diameter that varies between 2 and 4 mm and a width that varies between 0.1 and 0.4 mm according to the constructive characteristics of the keratometer and the measured surface curvature\textsuperscript{8} depending on the optical zone of the ablation, in the periphery there is a good change of measuring a steeper radius than is actually at the center at myopic correction. Therefore, the corneal power will be overestimate.\textsuperscript{9,15} the IOL power underestimated and the patient left hyperopic. In hyperopic correction the corneal power will be underestimate, the IOL overestimated and the patient left myopic.

### Refractive Index

For historical reasons, most Placido topographers and keratometers use the refractive index of 1.3375 for the refractive power of the cornea. This refractive index assumes a constant ratio between the anterior and posterior curvature of the cornea. After excimer laser the anterior corneal surface changes but not the posterior. Changing the anterior-posterior power alters the refractive index in the direct relation to the amount of keratectomy, for every 9% change in ratio, the effective corneal power changed by 0.5 D.\textsuperscript{16}

The other factor that lead to alter the refractive index is the variation in corneal refractive index of the different layers of cornea.\textsuperscript{17} At corneal refractive surgery excimer laser selectively removes anterior stromal layers and leaves the posterior stroma intact. Due to this procedure the total refractive index changes. This is supported by the observed correlation between depth of ablation and error in IOL power after myopic refractive surgery.\textsuperscript{15,18}

### Effective Lens Position

Another factor that has been recognized as important is the postoperative position of the IOL within the eye, the effective lens position (ELP). Standard IOL power formulas use the axial length and corneal power to predict the ELP. Flat keratometers are usually associated with smaller anterior segment and steep with larger. After refractive surgery, the anterior corneal surface is flattened for myopic correction, or steepened for hyperopic surgery but the ELP is unaltered. The problem is bigger as much as is the corneal curvature's change.\textsuperscript{19,20} This end result is that without a special correction formulas will recommend less IOL power after myopic surgery and more IOL power after hyperopic surgery than is actually required.\textsuperscript{10,11,21} The Aramberri Double-K method\textsuperscript{22} was established specifically to correct this problem. In this method the prerfractive surgery keratometry is used to determine the ELP and with this ELP to calculate the IOL power.

### Methods to calculate the true cornea power after refractive surgery

Severe methods have been proposed for calculation corneal refractive power in patients who have undergone corneal refractive surgery. Below some of these methods will be presented.

#### Clinical history

This method, first published by Holladay\textsuperscript{23} and later by Hoffer\textsuperscript{24} consists of subtracting the changes in spherical equivalent refraction induced by the refractive procedure from the keratometric diopters measured before refractive surgery.
\[ K = K_{\text{pre}} + (R_{\text{pre}} - P_{\text{post}}) \]

where \( K \) is the actual value to be used, \( K_{\text{pre}} \) is the prerefractive keratometry, \( R_{\text{pre}} \) is the prerefractive spherical equivalent refraction and \( R_{\text{post}} \) is the postoperative spherical equivalent refraction.

This method theoretically refers to actual corneal power and is easy to calculate if the relevant data are available. This method requires postoperative refraction data unaffected by change in lens power due to cataract and no change in axial length.

**Contact lens over-refraction method**

The contact lens method was first described by Ridley in 1948. This method determines the difference between the manifest refraction with and without a hard contact lens of known base curve and subtracts the difference from that base curve plus the power of the lens:

\[ K = BC_{\text{cl}} + P_{\text{cl}} + OR_{\text{x}} - R_{\text{x}} \]

where \( K \) is the actual value to be used, \( BC_{\text{cl}} \) is the contact lens base curve in diopters, \( P_{\text{cl}} \) is the lens dioptric power, \( OR_{\text{x}} \) is the spherical equivalent of the over refraction over the contact lens and \( R_{\text{x}} \) the spherical equivalent of the refraction without the contact lens.

The advantage of this method is that the necessary equipment is inexpensive and readily available. The only additional step is to place the contact lens on the eye and repeat the refraction. From a theoretical point of view this method is correct, however in practice, it is a difficult application due to the inevitable difficulties of performing accurate refractions with and without contact lenses in eyes affected by cataract.

**Refraction-derived Method**

Shammas et al described a simple method to calculate a corrected keratometric value after myopic Lasik:

\[ K_{\text{cd}} = K_{\text{post}} - 0.23 \times CR_{\text{c}} \]

where \( K_{\text{post}} \) represents the post Lasik \( K \) value and \( CR_{\text{c}} \) is the amount of correction obtained by the refractive surgery. This method used when the pre-Lasik \( K \) readings are not available but the amount of refractive correction is known.

**Net corneal power measurement**

The ideal solution to obtaining accurate corneal power after corneal refractive surgery is to directly measure both anterior and posterior corneal curvature and calculate the net corneal power. Several instruments can directly measure-
Factor, or ACD does for the SRK/T, Holladay and Hoffer Q formulas.

- a1 constant is tied to the measured anterior chamber depth. This changes the shape of the outcomes curve.
- a2 constant is tied to the measured axial length. This also changes the shape of the outcomes curve.

By using three adjustable constants, the surgeon can not only raise or lower the prediction curve, but also adjust its shape. This allows for optimization over a larger range of axial length.

Finally the Haigis-L formula is a formula that can used after myopic-Lasik correction. Using an IOLMaster corneal radius measured in mm, the Haigis-L algorithm generates a corrected corneal radius, which is then used by the regular Haigis formula to calculate the IOL power.32

Conclusion

IOL power calculation after refractive surgery is one of the present challenges in ophthalmology. All the current methods and formulas described in this article have the advantages and disadvantages. None of them is the ideal method. Patients who are candidates for cataract extraction after refractive surgery must be informed that IOL calculation is still inaccurate.

In dealing with these patients it is important to have access to as much of the available prerefractive surgery data as possible, perform a careful preoperative examination of the eye, use as many methods as possible, choose the best keratometry value obtained and calculate the IOL power required using the third and the fourth generation formulas.

References

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