IOL Calculation after Corneal Refractive Surgery

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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.

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Introduction

Six decades have passed since the first implantation of an artificial Intraocular Lens (IOL) into human eye. Sinse 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 presending 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.[1,2] Studies that analyzing axial length before and after corneal refractive surgery found no significant differences.[3,4]

Error sources for intraocular lens calculation

Corneal Curvature

Corneal curvature after corneal refractive surgery is very diffucult 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:

$$P=(n-1)/r$$

Two assumpions 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 aspericity. 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.[5-7] Unfortunately, there is no instrument to take measurments 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[8] depending on the optical zone of the ablation, in the periphery there is a good change of measuring a stepper radius than is actually at the center at myopic correction. Therefore, the corneal power will be overstimate,[9-15] the IOL power understimated and the patient left hyperopic. In hyperopic correction the corneal power will be understimate, the IOL overstimated 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.[16]

The other factor that leed to alter the refractive index is the variation in corneal refractive index of the different layers of cornea.[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 ablatation and error in IOL power after myopic refractive surgery.[15,18]

Effective Lens Position

Another factor that has been recognized as important is the postoperative position of the IOLwithin the eye, the effective lens position (ELP). Standard IOL power formulas use the axial length and corneal power to predict the ELP. Flat keratometrics 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 carvuture's change.[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.[10,11,21] The Aramberri Double-K method[22] was established specifically to correct this problem. In this method the prerefractive 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[23] and later by Hoffer[24] consists of subtracting the changes in spherical equivalent refraction induced by the refractive procedure from the keratometric diopters measured before refractive surgery

$$K=Kpre+(Rxpre-Pxpost)$$

where K is the actual value to be used, Kpre is the preorerative keratometry, Rxpre is the preorerative spherical equivalent refraction and Rxpost 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[25] 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:

$$K=BCcl+Pcl+ORx-Rx$$

where K is the actual value to be used, BCcl is the contact lens base curve in diopters, Pcl is the lens dioptric power, ORx is the sperical equivalent of the over refraction over the contact lens and Rx the sperical 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[19] described a simble method to calculate a corrected keratometric value after myopic Lasik:

$$Kc.cd=Kpost-0,23*CRc$$

where Kpost represets the post Lasik K value and CRc 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 measurment

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 measurement of both corneal surfaces. These methods include slit-scanning tomography (Orbscan II), scheimpflug photography (Pentacam) and optical coherence tomography(OCT). Orbscan II measures elevation and curvature of both corneal surfaces[26]. Pentacam generates a True Net Power Map as well as calculates an equivalent K (at the recommended 4.5 mm zone) called Hollladay Report which has been proposed as an accurate measure of the true corneal power.[27] OCT measurements have good repeatability and accuracy when using to measure total corneal power[28] and IOL power calculation.[29-30]

IOL Power Formulae for Post Refractive surgery Eyes

All available formulas aim to calculate the exact power of a IOL that will placed inside the eye after cataract extraction and that will produce postoperative emmetropia. The best known formulas that we use are the modern theoretical third and forth generations formulas SRK/T, Hoffer Q, Holladay II and Haigis. In these formulas the ELP varies with the axial length and the corneal curvature. The ELP appeared in each of the four formulas with differents name:

SRK/T	A-constant
Hoffer Q	ACD
Holladay II	pACD
Haigis	a0,a1,a2

The Hoffer Q formula and SRK/T formula (third generation formulas) predict the ELP based on axial length and keratometry. In general, these formulas assume that short eyes will produce a shallower ELP, a longer eye will have a deeper ELP, that flat Ks will result in a more shallow ELP and steeper Ks will result in a deeper ELP. For this reason these formulas must be used in conjunction with what has been termed above an Aramberri "Double K" method correction.[22,31]

The Holladay II formula, derived in 1998 (fourth-generation formula). Holladay II uses several additional variables to adjust the recommended IOL power, such as:White to white, Lens thickness, Preop Refraction, Corneal diameter, ACD, Patient's age and Axial length.

The Haigis formula deviced in 1991(fourth-generation formula). The Haigis formula does not depend on assumptions for the ACD and requires real measurement of it. It have three constants (a0, a1, a2) derived by multi-variable regression analysis:

- a0 constant moves the power prediction curve up, or down, in much the same way that the A-constant, Surgeon

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.

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