

INTRAOCULAR LENS POWER CALCULATION AFTER CORNEAL PHOTOREFRACTIVE SURGERY; LITERATURE REVIEW

EL CÁLCULO DE LALENTE INTRAOCULAR TRAS CIRUGÍA FOTO-REFRACTIVA CORNEAL. REVISIÓN DE LA LITERATURA

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ABSTRACT

Objective: Revision of methods for estimating corneal power (Kpost) and effective lens position (ELP) for cataract surgery after corneal refractive surgery.

Methods: Review of medical literature.

Results: To calculate the intraocular lens that achieves emetropia after corneal refractive surgery it is necessary to correct the Kpost and to estimate the effective lens position again correcting it. There are different formulae depending on the available information. Ideally, we need pre (Kpre) and post-treatment keratometry record (Kpost) and pre (Rpre) and post (Rpost) refraction. In this way, we can use the Aramberri's double-K method in the formula for calculating intraocular lens power.

Conclusions: Previously to keratorefractive procedure is advisable to have pre-treatment refraction and keratometry (K and method) registered: Kpre value is critical to calculate the ELP (*Arch Soc Esp Ophthalmol 2009; 84: 283-292*).

Key words: Intraocular lens, refractive surgery, corneal refractive power, cataract surgery, doble-K correction, effective lens position.

RESUMEN

Objetivo: Revisión de las distintas fórmulas de corrección del poder refractivo de la córnea (Kpost) y de la estimación de la posición efectiva de la lente (ELP) para la cirugía de cataratas después de cirugía refractiva corneal.

Método: Revisión de la literatura médica.

Resultados: Es necesario realizar una corrección de la Kpost para el cálculo de la lente intraocular tras cirugía refractiva. Existen diferentes vías dependiendo de la información disponible. Para estimar la ELP es necesario realizar una nueva corrección. Es aconsejable disponer de la queratometría previa (Kpre) y posterior (Kpost) a la cirugía y la refracción previa (Rpre) y posterior (Rpost). De esta manera, podremos realizar la corrección doble-K de Aramberri en la fórmula de cálculo.

Conclusiones: Es conveniente registrar la refracción y queratometría (K, y método) previamente a la cirugía refractiva: la Kpre es crítica para el cálculo de la ELP.

Palabras clave: Lente intraocular, cirugía refractiva, potencia dióptrica corneal, cirugía cataratas, corrección doble-K, posición efectiva de la lente.

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INTRODUCTION

It is increasingly frequent to schedule patients who underwent refractive surgery for cataract surgery. There is a difficulty with these patients, which is calculating the right intraocular lens powers to achieve a satisfactory degree of ametropia.

Refractive surprises after lens surgery are quite frequent, with a 100% prevalence if the adequate corrections are not made (1). There are two reasons for this: a faulty calculation of the corneal power and an inadequate estimation of the effective lens position (ELP).

After corneal refractive surgery, the utilization of the measured keratometric value without any correction will produce a faulty calculation of the intra-ocular lens power. Thus, a patient treated for myopia who undergoes cataract surgery will come out hypermetrope and on the contrary, if the patient was previously treated for hypermetropia after cataract surgery will exhibit myopia.

If we only carry out this correction, we will again obtain residual myopia or hypermetropia. The reason for this is faulty estimation of ELP if we only use the Kpost value for the calculation formula.

The purpose of this review is to provide the tools required for correcting the Kpost value to obtain a new, corrected Kpost (Corr-Kpost) to be introduced in the calculation of the formula together with the value prior to corneal laser refractive surgery (Kpre) in order to obtain an adequate estimate of the ELP and accordingly a correct calculation of the power of the IOL.

SUBJECTS, MATERIAL AND METHODS

The search, selection and assessment of results was made by two independent researchers (JCMG and CRL), with the following preestablished consensus.

Search Strategy

Searches were made in the World Wide Web and the MEDLINE database. To obtain reliable IOL after refractive surgery in MEDLINE between January 2001 and December 2008 the scrutiny options recommended by experts were utilized (2-

4). Several keywords were tried out (intra-ocular lens, refractive surgery, corneal refractive power, post-op keratometry, double-K correction and effective lens position), compound descriptors and meta-terms in increasing specificity towards the topic of the study, selecting and crossing those which were more productive and selective (2-4). The summaries of all the work published in English and Spanish was read and all the complete articles included in the study were collected. The search was supplemented with a web search (Firefox-Google) to find reliable scientific publications not included in Medline (4,5).

Selection of articles for analysis

Inclusion criteria

- The main objective of the study is to assess the reliability of the calculation of the IOL for cataract surgery in patients previously operated of photo refractive corneal surgery.
- The study provides necessary data of the ophthalmological history and details the eye problem before the intervention.
- The materials and methods allow the research to be reproduced.
- It specifies when and how the results are observed, providing objective evidence.
- The publication is recognized by a scientific body.

Exclusion criteria

- Papers in meetings, unpublished research experiences, author opinions, etc.

Descriptive grouping statistics

We considered the number of eyes intervened in each study (n) and the degree of emmetropia after cataract surgery. To assess the reliability of the calculation method (CMR) in each article we established the following quantitative scale: Refractive error > -1 dioptries [-1], emmetropia [0], refractive error > +1 dioptries [1]. To score each study, the results of the post-op refraction were taken into account. For each study we recorded the refraction achieved after

cataract surgery as well as the most relevant data in the discussion and conclusions sections.

The CMR scores were previously agreed by both researchers, defining as the pondered calculation method reliability (PCMR) the result of $CMR \times n$, and global or group reliability (CMRG) was defined as the quotient of PCMR/MR, where MR is maximum reliability.

Validation of results

In order to validate the interobserver reliability in the search, selection of articles and reliability scoring in the quantitative scale, the Kappa index (K) was calculated. A valid match was considered when $K > 0,7$. the discrepancies between both researchers were resolved by consensus utilizing the critical and deductive reasoning method (6,7).

After analyzing all the information, we demonstrated several ways to estimate Kpost and proposed the correction in the IOL calculation formula based on whether we have a key data, i.e., the keratometry prior to refractive surgery.

RESULTS

There are several methods for correcting the dioptre power of the cornea after refractive surgery to obtain the corrected Kpost value (Corr-Kpost). Basically, said methods can be classified in those which utilized the spherical equivalent change produced or those which utilize the value given by the corneal topography.

The calculation of the IOL in patients operated on corneal laser refractive surgery is much more complex than in normal cases because, in addition to having extreme axial lengths (which, in and of itself, increases the complexity of the calculation), additional factors come into play due to the surgery which alters the predictability of existing formulae (8,9).

Accordingly, the process for calculating the IOL power must be modified in the case of eyes with corneal photo-refractive surgery. There are two sources of error: the incorrect prediction of ELP by the formula and the erroneous determination of the cornea power by keratometry (10). The correction of these two factors allows for the correct calculation in these eyes, as follows:

1. Prediction of ELP (double-k method): utilize the K prior to corneal surgery in the ELP prediction

algorithm and the Kpost in the vergence calculation as the power of the first system lens.

2. Determination of corneal power after refractive surgery: after ablation surgery, the anterior surface of the cornea flattens while the posterior face does not change. This altered relationship leads to an overestimation of the corneal power by keratometers, leading to a necessary correction of the Kpost.

Several methods have been described to correctly determine the power of the cornea, depending on the data we have at hand (1). In general terms, we can find three possible situations (fig. 1):

1. We know the pre-op keratometry and refraction (Kpre and Rpre).

2. We only know Rpre and the post-op refraction and keratometry (Rpost and Kpost).

3. We have no data prior to surgery.

Kpre will be the measured value before corneal refractive surgery, if available. Otherwise, it can be calculated adding up the corrected dioptres in the cornea to the value we will define as Kpost.

1. We know all the data: Kpre, Kpost, Rpre and Rpost

a) Clinical History Method (CHM) (11,12)

$$\text{Corr-Kpost} = Kpre - EEpre + EEpost$$

EEpre: pre-op spherical equivalent.

EEpost: post-op spherical equivalent.

For example. we have a patient with a Kpre=49.25D. a Rpre (EEpre) in eyeglasses plane of -8 D and a Rpost=-1D.

EEpre (vertex distance 12 mm): -8 D

Rpre in corneal plane: $-8/(1-[0.012 * -8]) = -7.30$ D.

EEpost (vertex distance 12 mm): -1 D

Rpost in corneal plane: $-1/(1-[0.012*-1]) = -0.98$

Rpost - Rpre= $-7.30 - (-0.98) = -6.32$ D

Corrected-Kpost = Kpre-correction= $49.25 - 6.32 = 42.93$ D.

Subsequently we can utilize the Aramberri SRK/T formula (13) with the double-K correction (Kpre and Corrected-Kpost).

b) Modification of topokeratometric K (14)

Corr-Kpost: Kmean (SimK)-15% corrected dioptres.

Example:

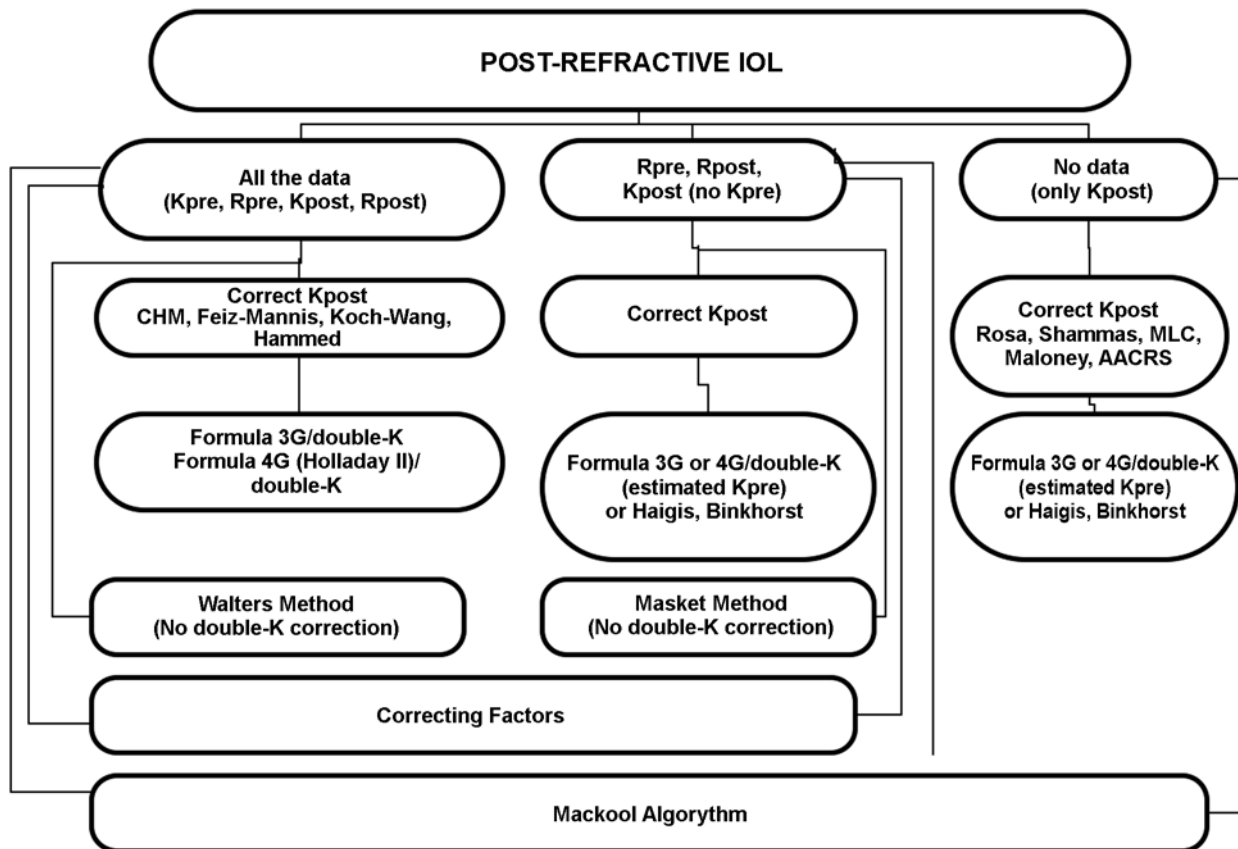


Fig. 1: IOL calculation algorithm.

simK=37D,
10D correction,

Corr-Kpost = 37-1.5 = 35.5D.

We enter the data in any formula with double-K correction.

c) *The Feiz-Mannis Method (15)*

The power of IOL is calculated as if the patient had not submitted to refractive surgery. We add the change induced by LASIK in the refractive error (ΔD) divided by 0.7.

$$LIO_{post} = LIO_{pre} + (\Delta D/0,7)$$

d) *The Koch-Wang Method (16)*

We perform a corneal topography and take the value of EffRp (effective refractive power).

$$Corr-K_{post} = EffRp (\Delta D \times 0.19)$$

e) *The Hammed Method (17,18)*

We also take the EffRp value and calculate the correction as follows:

$$Corr-K_{post} = EffR_{Padj} = EffRp - (\Delta D/0.15)$$

f) *Orbscan and Pentacam Topographic indices (19)*

The maps which calculate the para-axial power are the Mean Total Power in Orbscan and the Net Power in Pentacam. The scanned slit topographs allow the measurement of the anterior and posterior face of the cornea. It is possible to obtain the total cornea power directly by adding the actual values of both surfaces. Accordingly, we will be able to avoid the assumptions on which Placido's keratometers

and topographs are based on ($K=1,3375$). This K is not the actual para-axial power of the central cornea because the refraction index which comes closest to this value is 1.3315. However, 1.3315 is the value utilized by the most widely applied vergence formulae. Therefore, the values obtained by Orbscan and Pentacam converted by the addition of a factor to an equivalent of the standard K keratometric index (1.3375): for Pentacam, Net Power would be +0.95 and +1.1 for the Orbscan Mean Total Power (MTP).

Example: eye operated for 4 myopia dioptres.
 SimK = 40.7 dioptres.
 MTP = 38.86.
 $38.86 + 1,1 = 39.86$

g) Walter's corneal bypass method

We enter the values for K_{pre} and axial length (AXL) in the calculation formula with a target refraction equivalent to the pre-LASIK refraction.

Example:

Pre-LASIK Refraction = -11.75 with $K_{pre} = 43.87$ and AXL = 28.54 mm.

The target refraction we will introduce in the calculation formula will be -11.75.

With this method we will not need K_{post} or its estimation as the double-K correction is not necessary in the calculation formula (20).

2. We only know the R_{pre} , R_{post} and K_{post}

a) Refraction Difference (1)

One more time we must estimate the K_{post} . Continuing with the above example, if $R_{pre} = -8D$ and $R_{post} = -1D$, the correction in the corneal plane will be

$$R_{post} - R_{pre} = -7.30 - (-0.98) = -6.32D$$

Assuming that $K_{post} = 39.25D$, utilizing the correction proposed by Feiz (11) we obtain the following values:

$$\text{Corrected-}K_{post} = K_{post} - 0.23 * \text{correction}$$

$$\text{Corrected-}K_{post} = 39.25 - 0.23 * 6.32$$

$$\text{Corr-}K_{post} = 37.79D.$$

Subsequently, we introduce the data in that calculation formula. As we don't have the value for K_{pre} , we will not be able to calculate the double-K correction and therefore we should utilize the

Holladay-II formula (available only after purchasing the commercial software) or the formula of Haigis (21) or Binkhorst (which do not utilize the K values).

b) Utilization of correcting factors

This is the simplest method but not error-free. We can utilize the Feiz nomogram (Table 1) (22), which calculates the IOL power according to the change introduced in EE or Koch's nomogram (tables II and III) which calculates said power according to the corrected dioptres and the axial length (23).

c) Obviously, for correcting K_{post} we can utilize the method described in the previous section but, as we don't have the K_{pre} , we will not be able to calculate the double-K correction.

Assuming specific values, we could take all the risk of calculating a K_{pre} in order to carry out the double-K correction in the calculation formula. For example, for a patient who affirms that he had been operated 10 years ago with PRK for about eight dioptres, the K_{post} will be 37. We assume a correction in eyeglasses of 8D, translated into 7.30 in the corneal plane. We calculate the K_{post} deducting 15% from 7.30 (i.e., 1.09) from 37:

$$K_{post} = 37 - 1.09 = 35.91.$$

Table I. Feiz Nomogram

Change in EE (eyeglass plane)	Δ IOL Power (D)
1	0.6
1.50	0.66
2	0.96
2.50	1.26
3	1.55
3.50	1.85
4	2.15
4.50	2.45
5	2.74
5.50	3.04
6	3.34
6.50	3.64
7	3.93
7.50	4.23
8	4.53
8.50	4.83
9	5.12
9.50	5.42
10	5.72
10.50	6.02
11	6.31
11.50	6.61
12	6.91

Table II. Nomogram for calculating IOL after myopic refractive surgery. The number must be added to the power calculated utilizing SRK-/T, Hoffer Q and Holladay I

Corrected Dioptres	Axial length (mm)											
	19	20	21	22	23	24	25	26	27	28	29	30
2	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.5	0.4	0.3
	0.5	0.4	0.4	0.3	0.3	0.2	0.2	0.2	0.1	0.1	0	0
	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.3	0.2	0.1
3	1	1	1	1	1.1	1.1	1	1	0.9	0.8	0.7	0.6
	0.7	0.6	0.5	0.5	0.4	0.3	0.3	0.3	0.2	0.2	0.1	0
	0.7	0.7	0.7	0.7	0.7	0.7	0.8	0.7	0.6	0.4	0.3	0.2
4	1.3	1.3	1.3	1.4	1.4	1.4	1.4	1.3	1.2	1.1	0.9	0.8
	1	0.8	0.7	0.6	0.5	0.5	0.4	0.3	0.3	0.2	0.1	0
	0.9	0.9	0.9	1	1	1	1.1	0.9	0.8	0.6	0.5	0.4
5	1.7	1.7	1.7	1.7	1.7	1.8	1.7	1.6	1.5	1.4	1.2	1.1
	1.2	1	0.9	0.8	0.7	0.6	0.5	0.4	0.4	0.3	0.2	0
	1.1	1.2	1.2	1.2	1.2	1.3	1.3	1.2	1	0.8	0.7	0.5
6	2	2	2	2	2.1	2.1	2.1	2	1.8	1.7	1.5	1.4
	1.4	1.2	1	0.9	0.8	0.7	0.6	0.5	0.5	0.4	0.3	0.1
	1.4	1.4	1.4	1.5	1.5	1.6	1.6	1.5	1.2	1	0.8	0.7
7	2.3	2.3	2.3	2.4	2.4	2.5	2.4	2.3	2.2	2	1.8	1.7
	1.6	1.4	1.2	1.1	0.9	0.8	0.7	0.6	0.6	0.5	0.3	0.1
	1.6	1.6	1.7	1.7	1.8	1.8	1.9	1.7	1.5	1.2	1	0.9
8	2.6	2.6	2.6	2.7	2.7	2.8	2.8	2.6	2.5	2.3	2.2	2
	1.8	1.6	1.4	1.2	1.1	1	0.8	0.7	0.7	0.6	0.4	0.2
	1.8	1.9	1.9	2	2	2.1	2.2	2	1.7	1.5	1.2	1
9	2.9	2.9	2.9	3	3.1	3.2	3.1	3	2.8	2.7	2.5	2.3
	2	1.7	1.5	1.3	1.2	1.1	1	0.8	0.8	0.7	0.5	0.2
	2.1	2.1	2.2	2.2	2.3	2.4	2.5	2.3	2	1.7	1.4	1.2
10	3.1	3.2	3.2	3.3	3.4	3.5	3.4	3.3	3.1	3	2.8	2.6
	2.2	1.9	1.7	1.5	1.3	1.2	1.1	1	0.8	0.7	0.6	0.3
	2.3	2.4	2.4	2.5	2.6	2.7	2.8	2.6	2.2	1.9	1.7	1.4

Table III. Nomogram for calculating IOL after hyperemmetrope refractive surgery. The number must be deducted from the power calculated utilizing SRK-/T, Hoffer Q and Holladay I

Corrected Dioptres	Axial length (mm)											
	19	20	21	22	23	24	25	26	27	28	29	30
2	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.5	0.4	0.2	0
	0.5	0.4	0.4	0.3	0.3	0.2	0.2	0.1	0.1	0.1	0	0
	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.4	0.3	0.2	0	0
3	1.1	1.1	1.1	1.1	1.1	1.1	1	0.9	0.7	0.5	0.2	0
	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.5	0.3	0.2	-	-
	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.5	0.3	0.2	-	-
4	1.4	1.4	1.4	1.4	1.4	1.5	1.4	1.2	0.9	-	-	-
	1.1	0.9	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0	0	0
	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.6	0.4	0.4	-	-
5	1.8	1.8	1.8	1.8	1.8	1.9	1.8	1.7	-	-	-	-
	1.4	1.1	0.9	0.7	0.6	0.4	0.3	0.2	0.1	0	0	0
	1.1	1.1	1	1	1	1	1	0.7	0.3	-	-	-
6	2.2	2.2	2.2	2.2	2.2	2.5	-	-	-	-	-	-
	1.7	1.3	1.1	0.9	0.7	0.5	0.3	0.2	0	0	0	0
	1.1	1.1	1.1	1.1	1.1	1.1	1.1	0.7	0.3	-	-	-

The Kpre can be calculated adding 35.91 + 7.30 = 43.21.

In this way we will introduce in the formula of the Kpre value = 43.21 and Kpost = 35.91.

d) *The Masket method*

This method makes an adjustment in the regression formula, adding it in the case of myopic LASIK and deducting it in the hyperemmetrope LASIK.

IOL power adjustment = $EEpre * (-0.326) + 0.101$

Example:

With the SRK/T formula we obtain an IOL = 16 for emmetropia.

$EEpre = -6$

Power Adjustment = $-6 * (-0.326) + 0.101 = +2.057$.

We add 2 to the originally calculated IOL: $16 + 2 = 18D$.

Accordingly, we in plant and IOL of +18 dioptrés (24).

With this method, it is not necessary to utilize the double-K correction.

3. We have no data prior to surgery other than K_{post}

We measure the K value in the usual manner (in the K_{post} example = 39.25). Subsequently, we correct the K_{post} value by means of two regression formulae:

a) *The Rosa formula (25)*

Corrected refraction with the Rosa formula (R_{rosa}) = $R (0.0276 LA + 0.3635)$

AL=axial length; $R=k/337.5$

Therefore, the estimated post-op K value is $[K_{post}(R_{rosa})] = 337.5/R_{rosa}$

Example: $AL = 25.5$

$R = 337.5/39.25 = 8.5987$

$R_{rosa} = 8.5987 * (0.7038 + 0.3635) = 9.17$

Therefore, $K_{post}(Rosa) = 36.80$

The Rosa formula only utilizes the SRK formula (SRK/T if $AL \leq 29.4$ mm or SRK-II if $AL > 29.4$ mm).

b) *The Shammas Formula (26)*

$K_{post}(Shammas) = 1.14 K - 6.8$.

$K_{post}(Shammas) = 1.14 * 44.25 - 6.8 = 50.45 - 6.8$

$K_{shammas} = 43.65D$

The Shammas method only utilizes the Shammas formula.

c) *The contact lens Method (27)*

We perform a subjective refraction, after which we place a rigid PMMA contact lens of a known base curve (power) and perform another refraction. If the refraction does not change, the cornea has the same power as the contact lens. If the refraction is more myopic, the contact lens is more curved (and therefore has more power) than the cornea. The opposite will occur in hypermetropia. Then we calculate the K_{post} .

R_{post} = Refraction in post-op eyeglasses = -1D

R_{lc} = Correction with the contact lens = +1D.

Base Curve = $CB = 40$

DR (Difference in Refraction) = $R_{lc} - R_{post} = +1 - (-1) = +2$

$Corr - K_{post} = CB + DR = 39.25 + 2 = 41.25 D$.

d) *The Maloney Method (24)*

For this method a topography is needed and the K_{post} is calculated on the basis of $EffRp$

$Corr - K_{post} = (EffRp \times 1.114) - 6.1$

e) *The American Society of Cataract and Refractive Surgery Method (19)*

This method allows the calculation of the posterior radius of the cornea on the basis of the corrected dioptrés. The objective is to quantify the anterior/posterior surface ratio before and after surgery. The result is that this ratio remains quite constant throughout the range of non-operated corneae (40.55-47.2): 1.25 (± 0.3) (mean and standard deviation). After surgery, the ratio becomes variable with an increase which is proportional to the correct dioptrés. A linear ratio can be adjusted as follows:

$Ant/Post$ Ratio = $1.257 + 0.032 \times$ Dioptrés corrected in the cornea.

On the basis of an anterior curvature radius obtained with topography or keratometry, by means of this formula we can calculate the radius of the posterior surface and subsequently the total power of the cornea. If the $Simk$ is of 37 D, we obtain the anterior radius:

$n_2 - n_1 / \text{dioptrics}$
 $0.3375 / 37 = 9.12 \text{ mm}$
 If we apply the Ant/Post ratio formula:
 $1.257 + 0.032 \times 10 = 1.58$
 We obtain rpost:
 $9.12 / 1.58 = 5.77 \text{ mm}$
 If we convert to dioptrics:
 $1.336 - 1.376 / 5.77 = -6.93$
 We calculate the power of the anterior surface:
 $0.376 / 9.12 = 41.23$
 We add up the surfaces and the corneal thickness:
 $41.23 + 0.1 - 6.93 = 34.4$
 Which gives the actual para-axial power of the cornea.

We could also estimate the K_{pre} as seen in section 2 in order to endeavor to carry out the double-K correction.

An interesting control measure is provided by the Haigis formula which does not utilize the K_a value as ELP predictor to validate the results. In this formula we will only introduce LA, anterior chamber depth (ACD) and K_{post} . Said formula is not published in a peer review Journal but we can obtain the IOL constants in the Wurzburg University website (21).

f) The Mackool algorithm

Cataract surgery is performed and the patient is left aphakic. We apply Mackool's algorithm:
 Refraction in aphakia (EE) * 1.75 = IOL power.
 In a time slot between the date of the surgery and three weeks later the IOL is implanted (28).

4. Refractive Surprise

If, even though the adequate corrections have been made, the result is a refractive error, it is possible to change the IOL according to table 4 (29).

DISCUSSION

The inexact calculation of the dioptric IOL power to be implanted in cataract surgery after refractive surgery is a problem of growing importance.

The alteration of the relationship between the anterior and posterior face of the cornea after a photo-refractive procedure and the utilization of the

Table IV. Corrections for IOL replacement

Pre-op EE (D)	Residual hypermetropia: IOL power increase (D)	Residual myopia: IOL power decrease (D)
1	0.21	0.68
1.50	1.04	1.26
2	1.87	1.84
2.50	2.70	2.42
3	3.53	3.00
3.50	4.36	3.58
4	5.19	4.16
4.50	6.02	4.74
5	6.85	5.32
5.50	7.68	5.90
6	8.51	6.48

Note: Absolute EE values.

standard keratometric index renders the keratometric reading provided by keratometers or topographs inexact and induces to error in the calculation of the ELP and the intra-ocular lens power (1,10).

The total dioptric power of the cornea is the sum of the power of the anterior side (convex lens) and the posterior side (concave lens). After photo-refractive surgery there is a change in the curvature of the anterior surface (which becomes flatter in myopic photo-refractive surgery and increases its curvature after hypermetropia surgery), while the posterior surface does not change.

Traditional and corneal topography-simulated keratometry estimate the corneal power measuring the 3.2 central millimeters of the anterior surface. For a normal prolate cornea, this assumption is adequate but after refractive surgery the ratio is altered. The instruments which measure the anterior as well as posterior surface such as Orbscan and Pentacam are able to diminish this error in the determination of the overall corneal power.

The alteration of the refraction index after corneal refractive surgery is a further source of error: Standard keratometres are based on a corneal refraction index of 1.3375 for converting the curvature radius to a dioptric power and obtain a mean corneal power by averaging the dioptric powers of the anterior and posterior corneal surface. After refractive surgery, the ratio between the curvature radius of the anterior and posterior surfaces of the cornea is no longer 7.5/6.3 and this gives rise to errors in the calculation of ELP (9,24,25). Thus, after photo-refractive surgery the values of the

various corneal refraction indices are no longer valid (standard refraction index =1.3375; SRK/T=1.3333). However, these values do allow the calculation of the total corneal refractive power on the basis of the curvature radius of the cornea anterior surface in eyes which have not been operated on (1,14,23,24).

Accordingly, measuring the net corneal power is not the best approach because the values utilized by keratometers and topographs are not matched in these eyes. An added problem is that we are unable to quantify the deviation between the change of the refractive power of the measured cornea and the refractive change in order to determine a correction factor. Although mean values have been proposed (14-25% of the refractive change), the dispersion is excessively high, probably as a result of changes in the posterior corneal curvature (10,14,24,25).

In addition, the post-op refractive surprise can be explained by the inefficiency of the calculation formula when utilizing only Kpost. The third-generation formulae (SRK/T, Hoffer/Q, Holladay-I, Haigis) calculate the position of the lens as regards the cornea (ELP) measuring the depth of the anterior chamber in the case of the Haigis formula, or estimating said depth by means of keratometry (SRK/T, Hoffer/Q, Holladay-I). If the keratometry is not exact, any error will be transferred to the ELP calculation. Any third-generation theoretical formula performs two steps: First it utilizes AXL and K for calculating the anterior chamber depth (ACD); secondly, this variable, again together with AXL and K, is utilized for calculating the dioptric power of the IOL. If we consider that in the first step the depth of the anterior chamber is estimated and that this anatomical distance does not change after refractive surgery, it seems obvious that the utilization of a K value smaller than the original (arising out of the refractive surgery) will yield a lower value of ELP and therefore of the IOL power, with the ensuing refractive post-op surprise (10,14,24,25).

Aramberri proposed a modification of the SRK/T formula in which Kpre is utilized to estimate the ELP and Kpost for calculating the IOL dioptric power (double-K formula). Any third-generation formula can be corrected for utilizing Kpre for calculating the ELP and Kpost for calculating the IOL Power (13).

If all the data are available (pre- and post-op keratometry and refraction), the calculation method

which appears to be more reliable is the clinical record (1,9). However, if we do not have the Kpre, we can utilize Koch's nomograms (16). In the worst scenario, when we only have the Kpost, the only option is to perform the correction thereof by means of the Rosa Method which appears to be quite reliable, or the Shammas and contact lens methods which are slightly more complicated because the Shammas method utilizes a proprietary formula and the MLC requires a special set of lenses (23-25). Logically, when we don't have the Kpre value, we cannot perform the double-K correction and a residual error of between 1 and 3 dioptres is to be expected (14,20-34).

One important conclusion is that annotating the Kpre value is critical for calculating the ELP. In fact, we will be able to estimate the ELP only for patients of whom we have the previous refractive history (Kpre and Rpre) by means of a third generation formula with Aramberri's double-K correction (10,13).

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