

# Intraocular Lens Power Calculation after Myopic Lasik with no Previous Data: A Review of Available Methods

Juan Carlos Mesa-Gutiérrez\*, Antonio Rouras-López, José Porta-Monnet, Vicente Amías-Lamana, Isabel Cabiró-Badimón and Laura Solanas-García

Hospital Esperit Sant, Barcelona, Spain

## Introduction

Intraocular lens (IOL) power calculation after keratorefractive surgery has been a major challenge for the ophthalmic community and has generated numerous scholarly works and efforts trying to optimize current formulas and tailor new methods to better predict the correct intraocular lens (IOL) power [1-8]. Aramberri's work on the double-K adjustment of third-generation IOL formulas significantly improved the hyperopic results stemming from inaccurate estimation of the effective lens position by those formulas [9].

IOL power calculation can lead to unexpected refractive outcomes for 2 primary reasons. The first is that the surgically induced corneal power change, as measured by keratometry or corneal topography, is underestimated because the standard keratometric refractive index (usually 1.3375) is not valid once the laser modifies the anterior to posterior corneal curvature ratio [10-13]. The second reason is that the IOL position is erroneously predicted by third-generation theoretical formulas (eg, Hoffer Q, Holladay 1, SRK/T) that derive the prediction from the corneal curvature [13-17]. A third reason may be partially responsible for the inaccuracy of IOL power calculation for eyes with a small optical zone and large correction; in this case, the difference between the paracentral corneal area (where keratometry [K] and simulated K readings are taken) and the central cornea area (where the visual axis passes) can be clinically relevant [11,18-20].

When no previous data are available the calculations are more misleading as no double-K adjustment can be done, unless an average value (eg, 43.13 D) is presumed to be the preoperative corneal power. Various formulas have been described, and surgeons can now choose from many methods. This can easily generate confusion rather than accuracy. The aim of the present study was to provide with various methods of calculating IOL power in patients with no pre-refractive surgery data available.

We address two possible scenarios with no preoperative corneal power known. When neither preoperative corneal power nor refractive changes are available the lowest mean absolute error is achieved with the methods of Masket, Seitz/Speicher/Savini, Shammas, and Camellin/Calossi. When preoperative corneal power is unknown but the surgically induced refractive change is known the lowest mean absolute error is achieved with the Masket method followed by the Savini method, Speicher/Seitz method modified by Savini, and Shammas no-history method. Good results can also be obtained with the Awwad and Camellin/Calossi methods when the calculated corneal power is entered into the double-K Holladay 1 formula instead of the double-K SRK/T [21].

## Preoperative corneal power and refractive change unknown

According to a recent paper these are the most reliable methods [21].

### Shammas no-history method + Shammas-PL formula

$$K_{\text{Shammas}} = 1.14 \times K - 6.8$$

The main advantage of this method is that the corrected corneal

power is used in the Shammas post-LASIK (Shammas-PL) formula and in this formula the effective lens position (ELP) does not vary with the corneal curvature, which has been altered by the LASIK procedure [22].

### Seitz/Speicher/Savini + Double-K SRK/T formula

The method of separately considering the anterior corneal curvature and posterior corneal curvature, first described by Seitz and Langenbucher and later reviewed by Speicher, could be considered the most accurate, at least when coupled with the double-K SRK/T formula [2,23]. If the preoperative corneal power is unknown, the Seitz/Speicher method can be modified according to Savini et al., who suggest using a mean value of -4.98 D for posterior corneal curvature [21,24]. The Seitz/Speicher/Savini method:

$$K = \text{simulated } K \times 1.114 - 4.98$$

is similar to other methods like the one proposed by Maloney [25]:

$$K = \text{central corneal power} \times 1.114 - 4.9$$

and the modified version developed by Wang (4):

$$K = \text{central corneal power} \times 1.114 - 6.1$$

equation 6 of Awwad (11, 26).

$$\text{SimKadj no history} = 1.114 \times \text{SimK} - 6.062$$

and, to a lesser extent, the Shammas et al. no-history method [22]:

$$K_{\text{Shammas}} = \text{simulated } K \times 1.14 - 6.8$$

Ho et al. found that the Seitz/Speicher method modified according to Savini et al. is highly accurate [27, 28]. Obviously, this method (developed for eyes for which the preoperative corneal power is not known) must be used in conjunction with double-K formulas, which require entry of the preoperative corneal power. There are 3 possibilities to solve this contradiction: (1) calculate the preoperative corneal power by adding the refractive change to the postoperative corneal power, (2) use a mean value such as 43.13 or (3) estimate the effective lens position (ELP), as suggested by Ho (27-29). The good results obtained with the Seitz/Speicher method (with or without the Savini modification) could be related to its total independence of the surgically induced refractive change (a likely source of errors) [27].

### Rosa method + Single-K SRK/T formula

$$\text{Refraction with Rosa method (Rrosa)} = R \times (0.0276 \text{ AL} + 0.3635)$$

\*Corresponding author: Juan Carlos Mesa-Gutierrez, Servicio de Oftalmología, Hospital Esperit Sant Avda Mossèn Pons i Rabadà, s/n 08923 Santa Coloma de Gramenet, Barcelona, Spain, Tel: 34 93 3864241; Fax: 34932607981; E-mail: [juancarlosmesa@excite.co.uk](mailto:juancarlosmesa@excite.co.uk)

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$K(Rosa) = 337.5/Rosa$

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

Another method proposed by Rosa is as follows [30]

$K_{Rosa} = (1.3375-1)/((K \times RCF)/1000)$ .

RCF: Rosa Correction Factor based on axial length (mm)

22 - <23: 1.01

23 - <24: 1.05

24 - <25: 1.04

25 - <26: 1.06

26 - <27: 1.09

27 - <28: 1.12

28 - <29: 1.15

29:1.22

### Ferrara method [31]

$K = ((-0.0006 \times AL^2 + 0.0213 \times AL + 1.1572) - 1) / (Kr/1000)$ .

AL: Axial length.

Kr: Keratometry (radius of curvature in mm).

Rosa and Ferrara method may easily lead to postoperative myopia [32].

### BESSt method + Double-K formula

The formula takes into account anterior and posterior corneal radii and pachymetry (Pentacam, Oculus) and does not require pre-keratorefractive surgery information [33].

Input Variables

rF: Front corneal radius (mm)

rB: Back corneal radius (mm)

CCT: central corneal thickness (microns)

Formula

$n_{air} = 1$

$n_{vc} = 1.3265$

$n_{CCT} = n_{vc} + (CCT \times 0.000022)$

$K_{conv} = 337.5/rF$

$n_{adj}$ :

if  $K_{conv} < 37.5$   $n_{adj} = n_{CCT} + 0.017$

if  $K_{conv} < 41.44$   $n_{adj} = n_{CCT}$

if  $K_{conv} < 45$   $n_{adj} = n_{CCT} - 0.015$

ELSE;  $n_{adj} = n_{CCT}$

$n_{acq} = 1.336$

$d = d_{cct} / n_{vc}$

$d_{cct} = CCT / 1000000$

$F_{ant} = 1/rF \times (n_{vc} - n_{air})$

$F_{post} = 1/rB \times (n_{acq} - n_{vc})$

Using the BESSt formula, 46% of eyes were within +/-0.50 D of the intended refraction and 100% were within +/-1.00 D.

Output

KBESSt (corneal power after keratorefractive surgery, D) =

$\{ [1/rF \times (n_{adj} - n_{air})] + [1/rB \times (n_{acq} - n_{adj})] - [d \times 1/r \times (n_{adj} - n_{air}) \times 1/rB \times (n_{acq} - n_{adj})] \} \times 1000$ .

BESSt formula has been replaced by the BESSt2 algorithm. Corneal power is still estimated with gaussian optic formula as with BESSt1 but some improvements can be found:

- prediction of preoperative anterior radius from postoperative posterior radius measurements.
- automatic application of double-K adjustment to the predicted preoperative anterior radius.
- It uses a modified 3rd generation formula for IOL power calculation,

preventing the cusp phenomenon which may happen using SRK/T formula.

- Automatic adjustments for extreme axial lengths.
- Contribution of corneal wavefront (spherical aberration) from Pentacam.
- It has two separate algorithms: one for myopia and other one for hyperopia.

According to his author BESSt2 is more accurate than BESSt1 in hyperopia and more accurate than Haigis-L in myopia (34, 35).

### Awwad method + Double-K Holladay I

In the absence of information about the change (D) in spherical equivalent ( $\Delta SE$ ), a regression based solely on average corneal central power (ACCP) in the central 3.0 mm area (ACCP3mm) should be used (26):

$ACCP_{adj} \text{ no history} = 1.151 \times ACCP3mm - 6.799$

In the absence of topographic data a regression based on SimK is to be used:

$SimK_{adj} \text{ no history} = 1.114 \times SimK - 6.062$

### Quantitative area topography (Orbscan II) and Total corneal power (Galilei)

In 2004, Sónego-Krone et al reported that the refractive change at the corneal plane after myopic LASIK had a difference of -0.08/+0.53 D with the corneal power change determined by quantitative area topography in a 4-mm-diameter central zone of Orbscan II total-mean postoperative maps (36).

Quantitative area topography is distinct from quantitative point topography, which assesses the average of only two single steeper and flatter values. The total-mean power maps represent the spherical equivalent refraction of both corneal curvatures with regard to the corneal thickness and are comparable to the equivalent power of the cornea assessed by the thick lens formula. The total-optical power maps represent the ray tracing of light through the whole cornea. The advantage of this method is that the final total corneal powers to be used in IOL calculation may be obtained directly from the topographic maps, as measured after the previous corneal refractive surgery without depending on regression formulas, artificial refraction indices, contact lens over-refraction, aphakic intraoperative refraction, previous refractive or topographic data, algorithms, or correction factors [36,37].

It has been applied in a multicenter study using the total mean power (equivalent power) and the total optical power [38,39]. Total optical power maps by the Orbscan Topography System appear to be relatively accurate in detecting the changes in corneal power measured by refraction after LASIK. The correlation is highest when averaging within the central 4.0 mm zone. The corneal power change derived from axial power maps correlates less well than that derived from the TOP maps, as expected. Total optical power maps appear to provide an accurate measure of corneal power change in LASIK [37-39].

This same method has been applied with success using the Galilei's total corneal power (TCP) by ray tracing from a central zone of 0 to 4 mm diameter. Similar to the Orbscan II total-optical power, the Galilei uses a 4-mm diameter central zone for the TCP derived from ray tracing. Galilei TCP represents the average total corneal power for the central 4 mm diameter of the cornea. This TCP is calculated using the ray tracing method, which takes the actual refractive indices of the cornea into account. The post-LASIK corneal power is estimated using the following formula [40,41]:

post-lasik adjusted corneal power =  $1.057 \times tcp - 1.8348$

## Preoperative Corneal Power Unknown and refractive change known

### Masket method

The equation was determined to be as follows:

$$\text{IOL Power Adjustment} = \text{LSE} \times (-0.0.326) + 0.101$$

Where LSE is the total prior laser treatment, adjusted for vertex distance, in spherical equivalent (SE).

Clinical example is as follows:

Previously myopic eye:

- SRK/T formula suggests 14.0 D for emmetropia after cataract surgery
- Prior laser correction (SE) = - 4.0 D
- Adjustment calculation:  $-4.0 \text{ D} \times (-0.326) + 0.101 = + 1.405 \text{ D}$
- IOL power adjusted by adding +1.4 D to the original + 14 D = +14.5 D for emmetropia

The Masket method had a great advantage in that it omits the double-K step required by the Savini and Seitz/Speicher/Savini methods. The latter methods can be significantly influenced by the choice of the preoperative corneal power to be entered into the double-K formulas. In contrast, the Masket method (like the Shammas no-history method) does not have this drawback [5].

### Savini + Double-K SRK/T

$$K_{\text{Savini}} = ((1.338 + 0.0009856 \times \Delta \text{SEsp}) - 1) / (Kr/1000)$$

$\Delta \text{SEsp}$ : Change in spherical equivalent at spectacle plane

Kr: Keratometry (radius of curvature in mm). [20,21,24]

### Camellin + Double-K Holladay 1

$$K_{\text{Camellin}} = ((1.3319 + 0.00113 \times \Delta \text{SEsp}) - 1) / (Kr/1000)$$

$\Delta \text{SEsp}$ : Change in SE at spectacle plane.

Kr: Keratometry (radius of curvature in mm).

When entered into the double-K SRK/T formula, the corneal power calculated with the Camellin/Calossi method results in a positive arithmetic error in IOL power prediction, with a subsequent myopic outcome. The suboptimal results are probably due to the fact that this method was developed to be used with the Camellin/ Calossi formula for IOL power calculation, which is a modified Binkhorst II formula, and not with the double-K SRK/T formula. The Camellin/ Calossi formula calculates the ELP from the preoperative anterior chamber depth. Considerably better results can be obtained by entering the calculated corneal power into the double-K Holladay 1 formula [8,42].

### Awwad method + Double-K Holladay 1

Two variables, ACCP3mm and  $\Delta \text{SE}$ , were shown to be vital and sufficient for accurate refractive power prediction. The multiple regressions based on these 2 independent variables successfully predicted corneal refractive power (26):

$$\text{ACCP}_{\text{adj}} = \text{ACCP}_{3\text{mm}} - 0.16 \times (\text{SE}_{\text{postLASIK}} - \text{SE}_{\text{preLASIK}})$$

Adjusting for the fact that the measured ACCP3mm overestimates the true value by about 0.16 D for every diopter of myopic laser correction [26].

In ACCP is not available, SimK and  $\Delta \text{SE}$  are to be used:

$$\text{SimK}_{\text{adj}} = \text{SimK} - 0.23 \times (\text{SE}_{\text{postLASIK}} - \text{SE}_{\text{preLASIK}})$$

As the measured SimK overestimates the true value by about 0.23 D for every diopter of laser correction [26].

### Hamed-Wang-Koch method + double-k formula

This method requires knowledge of the refractive change from the surgery and the postoperative Sim-K from the topography unit. This group modifies the effective refractive power (EffRP) of the EyeSys:

$$K = \text{EffRP} - (0.15 \times \Delta \text{SE}) - 0.05$$

They also offered a second method to calculate true corneal power by substituting 0.15 by 0.19 [43,44].

### Jarade method + double-k formula

Requires knowing the surgically induced refractive change at the corneal plane ( $\Delta \text{SEcp}$ ) and the average radius of curvature of the cornea now (Kr) [45]:

$$K_{\text{Jarade}} = ((1.3375 + 0.0014 \times \Delta \text{SEcp}) - 1) / (Kr/1000)$$

### Haigis-L method

$$K_{\text{Haigis}} = -5.1625 \times Kr + 82.2603 - 0.35$$

This method requires only the postoperative K reading from the Zeiss IOLMaster in radius of curvature (or converted to diopters using the index of refraction setting in the IOLMaster) [46].

### Maloney Central Topography method + double-k formula

$$\text{Central power} = (\text{central topographic power} \times [376/337.5]) - 4.9$$

Koch and Wang obtained the best results using the Maloney method using -6.1 instead of -4.9.

[4].

They also offered a second method to calculate true corneal power if  $\Delta \text{SE}$  is known [44]. The formula is:

$$K = \text{EffRp} - (0.19 \times \Delta \text{SE})$$

### Feiz-Mannis method

This method utilizes the change in refractive error to offset the calculated target IOL power [47].

$$P = \text{PTARG} - 0.595 \times \Delta \text{SEcp} + 0.231$$

$$P = \text{IOL Power}$$

PTARG = the target IOL power to produce the postoperative desired refractive error.

The historical K method, although theoretically considered the gold standard, is misleading in practice because myopic or hyperopic errors in post-LASIK refractions can easily translate into errors of the same magnitude in the final post-cataract surgery refraction. In addition, early occult cataractous stage can produce myopic shift and potentially lead to a falsely over-minused post-LASIK refraction result, introducing an error in corneal power estimation. We recommend against using the historical K method [48].

This method is based on the fact that the final change in refractive error the eye obtains from surgery was due only to a change in the effective corneal power. If this refractive change the patient experienced is algebraically added to the presurgical corneal power, we will obtain the effective corneal power the eye has now. Obviously this requires knowledge of the K reading and refractive error prior to refractive surgery (48).

$$K = \text{KPRE} + \text{RPRE} - \text{RPO} \text{ or } [K = \text{KPRE} + \text{RCC}]$$

KPRE = refractive surgery preoperative corneal power  
RPO = refractive surgery PO refractive error (spherical equivalent)  
RPRE = refractive surgery preoperative refractive error (spherical equivalent)  
RCC = surgical change in refractive error (SE) vertexed to Corneal Plane

Our concerns about the clinical history method are in good agreement with several previous studies in which the clinical history method obtained less accurate results than other methods, even when the calculated corneal power was entered into double-K formulas. Hence, we recommend extreme caution when using the corneal power generated by the clinical history method in any double-K formula and agree with Awwad that this method should no longer be considered the gold standard for IOL power calculation after refractive surgery [48,51].

### Important Things to Keep In Mind

What should the clinician do when faced with the daunting problem of post-refractive-surgery IOL power calculation? It is wise to use several approaches. Ideally, it would be optimal to have a spreadsheet that allows the clinician to insert all values available. The various formulas would then be calculated automatically [48]. There is one spreadsheet available at the ASCRS website: [www.ascrs.org](http://www.ascrs.org).

When faced with a range of values for the IOL power, it is wise to look for values that are consistent with at least one other reading. Values that select higher IOL powers are preferable, leaving the patient slightly myopic rather than hyperopic [48].

IOL power calculation is a real problem in eyes that have had refractive surgery. Because it has yet to be proven which proposed method works best in all eyes, it behooves the surgeon to use as many methods as data is available and carefully evaluate the results [48].

### How to Handle Problems and Errors

The major problem is an unacceptable postoperative refractive error. The sooner it is discovered, the sooner it can be corrected and the patient made happy. Therefore, it is wise to perform K readings and a manifest refraction on the first postoperative day in these demanding patients. Immediate surgical correction (24 to 48 hours) will allow easy access to the incision and the capsular bag, a single postoperative period, and excellent uncorrected vision. The majority of medico-legal cases today are due to a delay in diagnosis and treatment of this iatrogenic problem [48].

Up to now, we could only correct this problem by lens exchange, which creates the dilemma of determining which factor created the IOL power error; axial length, corneal power, or mislabeled IOL or a combination of the above. Today, with the advent of low-powered IOLs, the best remedy may be a piggyback IOL. Using a piggyback IOL, it is not necessary to determine what caused the error or to remeasure the axial length of the freshly operated pseudophakic eye [48].

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