

Intraocular Lens Power Determination in 10 Patients with Previous Radial Keratotomy with or without Astigmatic Keratotomy: A Case Series

Seyed-Mohammad-Reza Taheri, MD¹ • Azita Kheiltash, MD, MPH²

Abstract

Purpose: To compare results of different methods for true corneal power determination and intraocular lens (IOL) power calculation formulas in 10 eyes of 7 patients with previous radial keratotomy (RK) with or without astigmatic keratotomy

Methods: In this case series study, we determined the corneal power of 10 eyes of 7 patients who had undergone RK with or without astigmatic keratotomy with two methods: the contact lens method (CLM) and the mean keratometry of the 3 mm zone in topography. In the next step, the IOL power for these eyes was calculated with the 3 formulas of SRK II, SRK T, and Holladay II; the latter was used for the IOL selection. Refractive results were determined 3 month after surgery. According to the rule that 1.5 diopter (D) change in IOL power results in 1.0 D change in a patient's refraction at the spectacle plane, we estimated the manifest refraction of these eyes with other formulas and compared them with the results achieved by Holladay II formula.

Results: Using the CLM and Holladay II formula, the postoperative manifest refraction spherical equivalent in 8 eyes ranged from -3.00 to +2.00 D. Both CLM and the mean keratometry of the 3 mm zone in topography lead to a greater degree of hyperopia after cataract surgery with SRK II formula than SRK T, and with SRK T than Holladay II. The mean spherical equivalent with mean keratometry of the 3 mm zone in topography and Holladay II formula was 0.08 D, and with CLM and Holladay II formula was -0.05 D.

Conclusion: In this study, it seemed that after RK, the mean keratometry of the 3 mm zone in topography gives a better estimate of true corneal power compared with CLM, and that the Holladay II formula brings results closer to emetropia compared with SRK II and SRK T formulas.

Keywords: IOL Calculation, Intraocular Lenses, Holladay II, SRK T, SRK II, Cataract Surgery, Radial Keratotomy

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1. Noor Ophthalmology Research Center, Noor Eye Hospital
2. School of Social Medicine, Tehran University of Medical Sciences
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Correspondence to:
Seyed-Mohammad-Reza Taheri, MD
Noor Ophthalmology Research Center,
Noor Eye Hospital, Tehran
Tel:+98 21 88651515
Email: mtaheri@noorvision.com

Introduction

With the introduction of new theoretic formulas and biometry instruments, the accuracy of intraocular lens (IOL) power calculation for cataract and refractive lens surgery has greatly improved.¹ At present, the standard of care is to have at least 50% of patients within ± 0.50 diopter (D) of the predicted refraction, 90% within ± 1.00 D, and 99.9% within ± 2.00 D.^{2,3} However, IOL power calculation after refractive surgery including radial keratotomy (RK) still remains a challenge.⁴ In fact, the main issue in the IOL power calculation for these eyes is determining the exact true corneal power.⁵⁻⁷ The reason is simple; the conventional instruments for corneal power determination (keratometry, videokeratography and topography) work based on the assumption that astigmatism is regular, which does not apply to cases of irregular astigmatism, like after RK. Also, the assumptions that the center of the cornea is a sphere and the radius of the posterior curvature is 1.2 mm steeper than the anterior curvature are not acceptable for corneas which have undergone keratorefractive surgery.^{8,9} RK induces peripheral elevation and central flattening of the cornea, affecting both the anterior and posterior radius of curvature similarly. In RKs with an optical zone of 3 mm or less, the true corneal power determination accuracy is diminished. It is still not known whether this inaccuracy is due to corneal irregularity in the central area and the small optical zone or an increase in the anterior/posterior ratio of radius of curvature in the cornea.⁸ Another source of error in IOL power calculation in these eyes is the incorrect evaluation of the effective lens position (ELP).¹⁰ For these reasons, after keratorefractive surgery for myopia, keratometry and topography overestimate the power of the central cornea, and this error results in underestimation of calculated IOL power which then leads to hyperopia in these eyes after cataract surgery.^{4,11}

Aramberri et al reported the benefits of the double-K method in IOL power calculation of eyes which have undergone keratorefractive surgery.¹² In 1996, Holladay understood this concept and used this to further develop his IOL calculation formula (Holladay II).¹³ The Holladay II formula (Holladay IOL Consultant) uses the corneal power for a vergence

formula to calculate the refractive power of the eye and also ELP. The formula considers 7 variables to estimate the ELP including keratometry, axial length (AL), horizontal white-to-white diameter of the cornea, anterior chamber depth, lens thickness, age and refraction.¹⁴ The Holladay II software makes it possible to use the effective refractive power (Eff-RP) as an alternative for keratometry (Alt K) in vergence calculations. To determine the ELP, this software uses the original keratometry before keratorefractive surgery or (if not available) 43.86 which is the mean keratometry in the human population.¹⁴ There are also other formulas like SRK II and SRK T for calculating the IOL power.

In this case series we compare the results of the contact lens method with the mean keratometry of 3 mm zone in topography for true corneal power determination and IOL power calculation formulas (SRK II, SRK T and H II) in 10 eyes of 7 patients with previous RK with or without astigmatic keratotomy.

Methods

In this case series, we studied 10 eyes of 7 patients who had undergone a classic 8 incision RK surgery for the correction of myopia, one to ten years before. Six eyes also had astigmatic keratotomy (AK) (Table 1).

Phacoemulsification was performed on all eyes, during which a temporal incision or superior limbal incision with tunnel was made, intraocular gel was injected in the anterior chamber, and then capsulorrhexis was performed. Then hydrodissection, hydrodelamination and phacoemulsification were performed, respectively, before an IOL (SA60AT) was implanted in the bag. All surgeries were done by one surgeon (author) at Noor Vision Correction Center using the Storz or Legacy phacoemulsification units.

The CHM was possible only in cases number 9 and 10, because in the other cases, the prerefractive surgery keratometry and the stable postrefractive surgery manifest refraction data were not available. The CLM was performed in the 8 patients whose cataract condition permitted this method (cases 3 to 10), and in 9 eyes (cases 1 to 7 and 9 and 10) the mean keratometry of the 3 mm zone in topography was used (Table 2).

Table 1. The results of the different true corneal power determination methods

Case No.	Surgery	Manual keratometry	Contact lens Method (CLM) keratometry	Zone 3 mm Keratometry	Mean Sim-K keratometry
1	RK	40.00	-	37.21	-
2	RK	41.75	-	42.38	42.20
3	RK	37.50	38.87	39.34	37.88
4	RK+AK	33.63	36.62	36.55	36.36
5	RK+AK	33.75	38.62	36.82	37.1
6	RK+AK	41.88	39.50	41.76	42.33
7	RK+AK	42.50	41.50	41.61	42.00
8	RK	36.50	35.62	-	-
9	RK+AK	38.88	40.62	40.11	40.35
10	RK+AK	39.75	39.37	41.64	41.90

Table 2. The results of the different true corneal power methods and IOL power calculation formulas after 3 months

Case No.	Postcat-SEQ							
	CLM-HOLII	CLM-SRK II	CLM-SRKT	Zone 3mm-HOLII	Zone 3mm-SRK II	Zone 3mm-SRKT	CHM-HOL II	CHM-SRK II
1	-	-	-	-0.83	+0.50	-0.16	-	-
2	-	-	-	+0.16	-0.50	+0.16	-	-
3	+0.50	+1.53	+1.53	-0.46	+0.87	+0.87	-	-
4	+2.00	+3.33	+3.00	+2.00	+4.00	+3.33	-	-
5	+0.60	+1.60	+1.60	-0.75	+1.00	+0.60	-	-
6	-3.00	-2.67	-2.67	-1.00	-0.37	-0.37	-	-
7	-0.38	-0.05	-0.05	-0.38	-0.05	-0.05	-	-
8	-0.50	+1.83	+1.16	-	-	-	-	-
9	+1.33	+1.67	+1.67	+0.67	+1.33	+1.33	+2.33	+2.33
10	-1.00	0.00	-0.33	+1.33	+1.33	+1.33	+2.00	+2.00
Mean	-0.05	+0.91	+0.74	0.08	+0.90	+0.78	+2.17	+2.17
SD	1.55	1.80	1.73	1.05	1.35	+1.14	0.23	0.23
Range	-3.00 to +2.0	-2.67 to +3.33	-2.67 to +3.0	-1.10 to +2.0	-0.5 to +4.0	-0.37 to +3.3	+2.0 to +2.3	+2.0 to +2.3

In seven eyes (cases 3 to 7 and 9 and 10), we used both CLM and the mean keratometry of the 3 mm zone in topography, but we select the IOL calculated with CLM and Holladay II for implantation during phacoemulsification surgery [in the cases 3 to 10 (8 eyes)] and in the cases 1 and 2 we used the IOL calculated with the mean keratometry of the 3 mm zone in topography and Holladay II for implantation.

We used all three Holladay II, SRK II and SRK T formula to calculate the IOL power in these eyes.

In the Clinical History Method (CHM),^{4,15} the corrected refractive error at the corneal plane is subtracted from the preoperative mean keratometry and this is used as the true corneal power (keratometry) in the IOL calculation formulas. Therefore, in this method

the pre- and post- refractive surgery data (before cataract formation) is necessary.

In the hard contact lens over refraction Method (CLM),^{16,17} a manifest refraction (MR) is performed for the patient. Then, a plano hard contact lens (PHCL) with a certain base curve is fitted and over refraction (OR) is performed on the PHCL for the patient. In the next step, the MR without PHCL is subtracted from the MR with PHCL, and the result with its sign is added to the dioptric equivalent of the PHCL base curve:

True Keratometry (K) = base curve of PHCL (dioptric equivalent) + [OR (CL) – MR]

This true keratometry is then used in the IOL calculation formulas.

The computerized video keratography (EyeSys Corneal Analysis System) (CVK)⁹ method is an equivalent to the mean keratometry of the 3 mm zone in topography [Tomey TMS- 1(computed Anatomy Inc)].⁵ In this method, the mean keratometry of the 3 mm zone is used as the true keratometry after keratorefractive surgery.^{5,9}

MR was performed for all patients, 3 month after phacoemulsification with PCIOL implantation. This was considered the stable refraction and used as a criterion for the accuracy of true keratometry determination methods and IOL calculation formulas.

The target refraction for all patients was plano. We used the 118.4 as A-constant for SA60AT that was printed at the IOL package, in the IOL calculations.

According to the rule that every 1.50 D change in the IOL power results in 1.00 D change in a patient's refraction at the spectacle plane,^{18,19} we calculated the patient's expected refraction using the keratometry derived from CHM, CLM, and the mean keratometry of the 3 mm zone in topography and the SRK II, SRK T and Holladay II formulas and The results were then compared with each other.

Results

In this case series, we studied 10 eyes of 7 patients including 2 male and 5 female. The mean age of these patients at the time of

phacoemulsification surgery was 45.7±6 years (range 33–52 years). The mean time between RK and phacoemulsification in these patients was 5.8±2.8 years (range 1 to 10 years). The mean myopia of these patients before RK surgery was -5.88±1.99 D (range -3.75 to -9.25). The results of different methods of true keratometry and IOL calculation formula are shown in Table 2. The mean axial length in all 10 eyes was 25.94±1.6 mm (range 24.29 to 29.88 mm).

Contact Lens Method

Three months after phacoemulsification, the manifest refraction spherical equivalent (MRSE) with CLM derived keratometry and Holladay II formula (N=8) was in the range of ±0.50 D in 3 eyes (28%), ±1.00 D in 5 eyes (63%), and ±2.00 D in 7 eyes (87.5%) (Figure 1). Four eyes (50%) were on the myopic side (-0.38 to -3.00 D), and 4 eyes (50%) on the hyperopic side (+0.50 to +2.00 D). The MRSE after cataract surgery with CLM and Holladay II formula in these 8 eyes was -0.05±1.55 D (range -3.00 to +2.00 D) (Figure 2).

The calculated MRSE after phacoemulsification, achievable with CLM derived keratometry and SRK II formula, (N=8) was in the range of ±0.50 D in 2 eyes (25%), ±1.00 D in 2 eyes (25%), and ±2.00 D in 6 eyes (75%) (Figure 1). Two eyes (25%) were on the myopic side (-0.05 to -2.67 D), 5 eyes (62.5%) on the hyperopic side (+1.53 to +3.33 D), and 1 eye (12.5%) was plano. The MRSE after cataract surgery with CLM and SRK II formula in these 8 eyes was +0.91±1.80 D (range -2.67 to +3.33 D) (Figure 2).

The calculated MRSE after phacoemulsification, achievable with CLM derived keratometry and SRK T formula (N=8) was in the range of ±0.50 D in 2 eyes (25%), ±1.00 D in 2 eyes (25%), and ±2.00 D in 6 eyes (75%) (Figure 1). Three eyes (37.5%) were on the myopic side (-0.05 to -2.67 D), and 5 eyes (62.5%) were on the hyperopic side (+1.16 to +3.00 D). The MRSE after cataract surgery with CLM and SRK T formula in these 8 eyes was +0.74±1.73 D (range -2.67 to +3.00 D) (Figure 2).

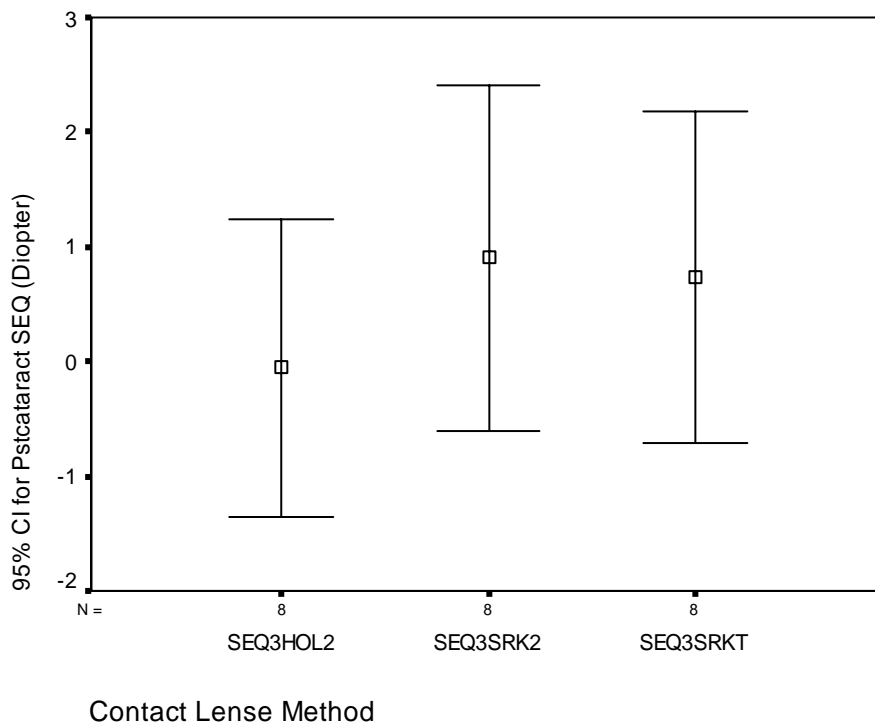


Figure 1. Comparison of the results of different IOL calculation formula with contact lens method (CLM) and their ranges

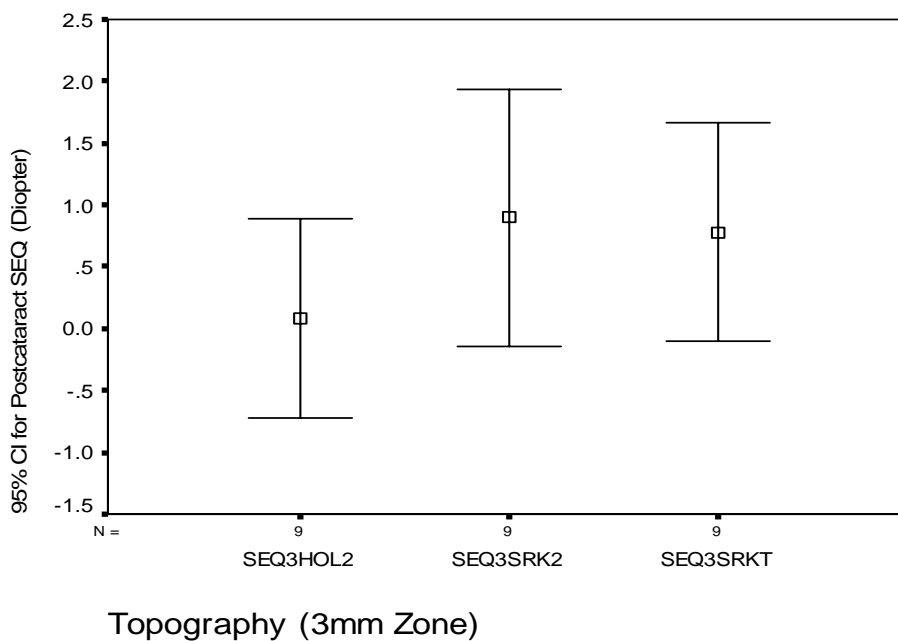


Figure 2. Comparison of the results of the different IOL calculation formula with mean keratometry of 3 mm zone in topography and their ranges

The mean keratometry in the 3 mm zone

The MRSE after phacoemulsification with the mean keratometry of the 3 mm zone in topography as keratometry and Holladay II formula, 3 months after cataract surgery, (N=9) was in the range of ± 0.50 D in 3 eyes (33.3%), ± 1.00 D in 7 eyes (78.0%), and ± 2.00 D in 9 eyes (100%). Five eyes (56.0%) were on the myopic side (-0.38 to -1.00 D), and 4 eyes were (44.0%) on the hyperopic side ($+0.16$ to $+2.00$ D). The MRSE after cataract surgery with the mean keratometry of the 3 mm zone in topography as keratometry and Holladay II formula in these 9 eyes was -0.08 ± 1.07 D (range -1.00 to $+2.00$ D) (Figure 3).

The MRSE after phacoemulsification with the mean keratometry of the 3 mm zone in topography as keratometry and SRK II formula, 3 months after cataract surgery, was in the range of ± 0.50 D in 4 eyes (44%), ± 1.00 D in 6 eyes (66.6%) and ± 2.00 D in 8 eyes (89%) (Figure 4). Three eyes (33.3%) were on the myopic side (-0.05 to -0.50 D), and 6 eyes (66.6%) on the hyperopic side ($+0.50$ to $+4.00$ D). The mean MRSE after cataract surgery with the mean keratometry of the 3 mm zone in topography as keratometry and SRK II formula in these 9 eyes was $+0.90 \pm 1.35$ D (range -0.50 to $+4.00$ D) (Figure 3).

The MRSE 3 months after phacoemulsification with the mean keratometry of the 3 mm zone in topography as keratometry and SRK T formula was in the range of ± 0.50 D in 4 eyes (44%), ± 1.00 D in 6 eyes (66.6%), and ± 2.00 D in 8 eyes (89%) (Figure 4). Three eyes (33.3%) were on the myopic side (-0.05 to -0.37 D), and 6 eyes (66.6%) were on the hyperopic side ($+0.16$ to $+3.33$ D). The mean MRSE after cataract surgery with the mean keratometry of the 3 mm zone in topography as keratometry and SRK T formula in these 9 eyes was $+0.78 \pm 1.17$ D (range -0.50 to $+3.33$ D) (Figure 3).

Table 1 shows the keratometry values derived from different methods. In the 7 eyes for which we used all 4 methods to estimate the keratometry, the mean keratometry with manual keratometry, CLM, mean keratometry of the 3 mm zone in topography, and mean simK in topography were 38.27 ± 3.56 , 39.30 ± 1.55 D, 39.69 ± 2.24 and 39.70 ± 2.54 D, respectively.

The MRSE 3 months after cataract surgery, with the mean keratometry of the 3 mm zone in topography and CLM, as keratometry and Holladay formula, is shown in figure 5, which represent that the accuracy of the mean keratometry of the 3 mm zone in topography is comparable to CLM.

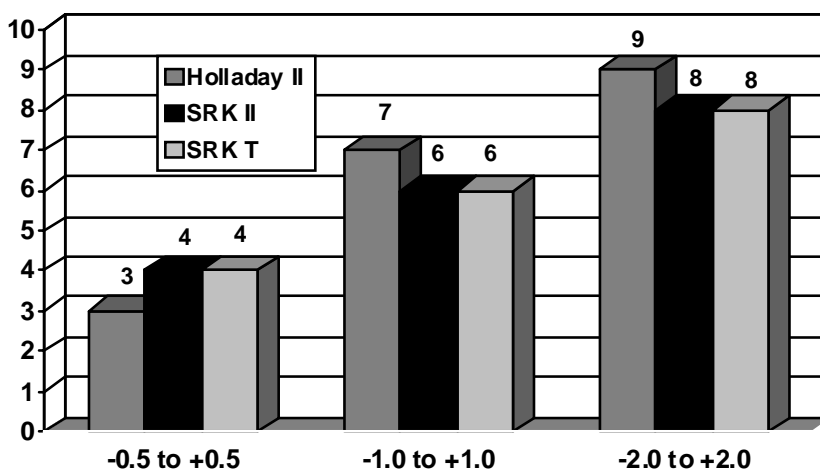


Figure 3. Comparison of the results of the different IOL calculation formula with mean keratometry of 3 mm zone in topography

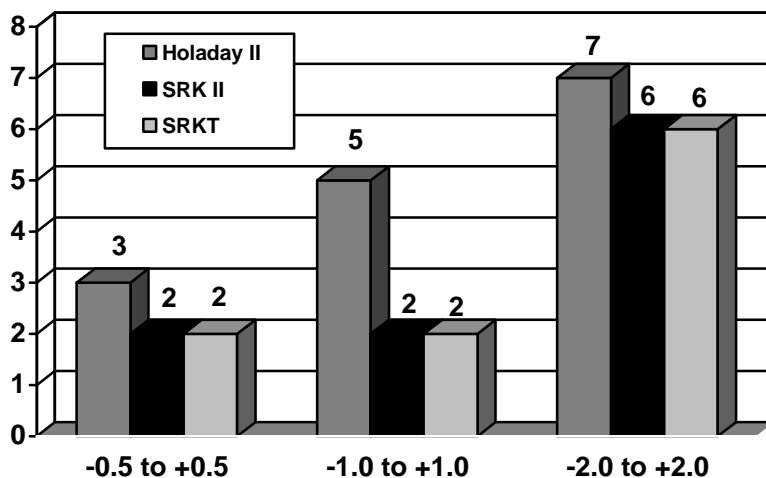


Figure 4. Comparison of the results of the different IOL calculation formula with contact lens method (CLM)

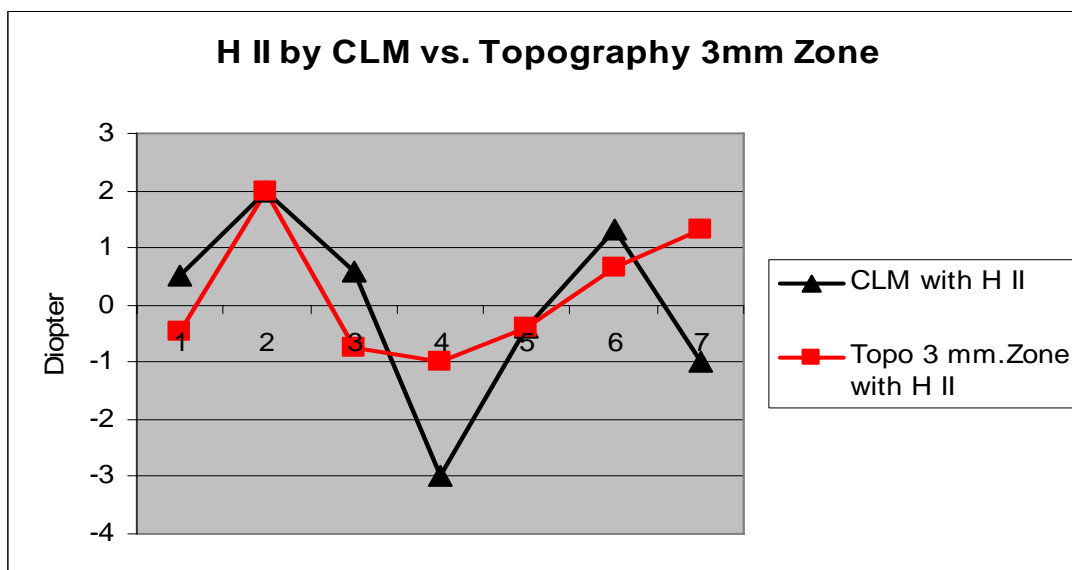


Figure 5. Comparison of the results of the contact lens method (CLM) with mean keratometry of 3 mm zone in topography using Holladay II IOL calculation formula

Discussion

An increasing number of patients who have had RK surgery will need subsequent cataract extraction with IOL implantation. As mentioned before, the main concern in these patients is true corneal power determination. Previous studies showed that after RK surgery, a knee is produced between the directly treated portion of the cornea and the indirectly altered effective optical zones. This causes the keratometer to overestimate the

anterior corneal power in the peripheral steeper areas more than the flat central area.⁸

Conventionally, there are 5 methods to determine the true corneal power in these eyes:

1. Clinical History Method (CHM)^{4,15}
2. Hard Contact Lens OR Method (CLM)^{16,17}
3. Computerized Video Keratography (EyeSys Corneal Analysis System) (CVK)⁹

This is an equivalent to the mean keratometry of the 3 mm zone in topography [Tomey TMS-1 (computed Anatomy Inc)].⁵

4. Mean keratometry of 4 mm zone at Holladay view in Pentacam (Holladay view)²⁰
5. BESSt formula²¹

The limitation of CHM is unavailability of the original refractive and keratometric data before keratorefractive surgery.^{4,15} On the other hand, in eyes with severe visual loss due to progressed cataract and poor red reflex, the CLM cannot be performed, because the on axis refraction with 0.25 to 0.50 D accuracy is only possible with a visual acuity (VA) of $20/80$ or more. Indeed, the cataract must be in the stage that, the axis of refraction is free. It is important to know that an off-axis refraction may result in remarkable errors in keratometry and IOL power calculation in these patients.^{4,9,17}

As mentioned before, use of keratometry or simulated keratometry (Sim-K) as the true corneal power results in hyperopic refractive error after cataract surgery in almost all cases.⁴ On the other hand, cataract surgery per se can aggravate hyperopia in the early postoperative stage by flattening the RK incisions.^{6,16,22} Many reports showed that in RK and PRK patients, conventional keratometry and mean keratometry of the 3 mm zone in topography or automated keratometry are more accurate than CHM.²²⁻²⁴ However, the most acceptable method for estimating the true corneal power is CHM, which is used with third and fourth generation formulas (like Holladay II) to calculate the IOL power.²⁵

Effective refractive power (Eff RP) (Holladay Diagnostic Summary, EyeSys Topography) estimates the refractive power of the corneal surface at the central 3 mm zone of the pupil using the Stiles-Crawford effect. This parameter is known as equivalent sphere power of the central 3 mm zone in the pupillary area and is almost equal to the mean keratometry in the 3 mm zone in topography. This parameter is different from Sim-K in topography. In standard topography, Sim-K is the estimate of two points on the 3 mm zone, not all points on the entire zone. Like standard keratometry, these two points are on two

meridians 90 degrees apart. The greater the difference between the mean Sim-K and Eff RP (and mean keratometry of the 3 mm zone in topography), the greater the error in IOL calculation results.^{7,14}

As you can see in table 2, in cases 9 and 10, the MRSE after cataract surgery with CHM compared with other methods (CLM and the mean keratometry of the 3 mm zone in topography) is more hyperopic. This finding concurs with previous studies, but more studies with more cases are needed to further confirm this.

It is important to know that in the CHM, it is not possible to use the precataract surgery refraction data as the postrefractive surgery stable refraction, because nuclear sclerosis can produce myopic shift. The unavailability of prerefractive surgery MR and keratometry data and stable postrefractive surgery MR is the main problem with CHM use in these patients. On the other hand, CHM is greatly dependant on refraction accuracy. Therefore, other methods including CLM and mean keratometry of the 3 mm zone in topography may be needed. The refraction accuracy, and whether cataract density permits on axis refraction with 0.25 to 0.50 D accuracy, is important in the CLM as well.⁸

In cases where postrefractive surgery stable refraction is not available, regardless of the method, the least estimated keratometry must be used for IOL power calculation.⁵ Chen et al used the flattest keratometry without double-K method and selected -1.50 D as target refraction and saw that only 29% of eyes was in the range of ± 0.50 D and 42% of eyes have more than +0.50 D refractive error.⁴ When the target refraction was changed to the plano, 83% of eyes have postcataract surgery refraction more than +0.50 D. This finding shows the importance of the double-K method use along with central corneal power measurement in prevention of postcataract surgery hyperopia in these patients. The idea of using mean keratometry of the 3 mm zone in topography as the keratometry was first suggested by Maeda et al at 1997.²⁶ Argento et al reported that the mean keratometry of the 3 mm zone in topography is more accurate than manual keratometry and CLM.⁵ Awwad et al used mean keratometry of 3 mm zone in topography with Holladay I formula and double-K method for IOL calculation and

could achieve ± 0.50 D of emetropia in 87.50% and ± 1.00 D of emetropia in 100.00% of patients.¹⁸

In our case series, 10 eyes were studied. Figure 1 shows that with the CLM and Holladay II formula more patients are closer to emetropia, and SRK T and SRK II formulas come next in accuracy, respectively. Figure 2 demonstrates that with the mean keratometry of the 3 mm zone in topography, the Holladay II formula is again more accurate than the other two formulas. Figures 3 and 4 show that the refractive results after cataract surgery with CLM and Holladay II compared with SRK II and SRK T are closer to emetropia and the eyes are rather on the myopic side. With the CLM and SRK T, the patients became more hyperopic than with Holladay II, and with SRK II more hyperopic than SRK T. This is also true with the mean keratometry of the 3 mm zone in topography. Figure 5 reveals that with the Holladay II formula, the accuracy of the mean keratometry of the 3 mm zone in topography is comparable to or even more accurate than CLM, and the patients are closer to emetropia. This is in accordance with the findings in Argento's study.

Tables 1 and 2 show that in cases 1, 2, 3 and 8, who underwent only RK surgery, the accuracy of the corneal power determination and IOL power calculation was higher than in cases who underwent RK+AK. This could be due to more corneal irregularity with performing these two procedures

simultaneously. Tables 1 and 2 reveal that the mean keratometry of the 3 mm zone in topography with Holladay II has the accuracy comparable to CLM with Holladay II or even better; the SRK T and SRK II make patients more hyperopic, in an increasing order. In case 6, the CLM error leaves the patient with severe myopia, while the mean keratometry of the 3 mm zone in topography helps the patient approach emetropia. The results in our study were acceptable, but not as accurate as some other studies in which 94% of patients were in the ± 1.00 D range of the intended refraction.²⁷ This can be attributable to the wider range of refractive errors in our study, and the variety of refractive procedures performed on them. It is also because of the dependency of CLM to accuracy of refraction and its being on axis. There was no significant relationship between AL and postcataract surgery MRSE in these eyes (Pearson correlation = 0.38). The most important limitation of our study was the small number of cases.

Conclusion

In conclusion, the mean keratometry of the 3 mm zone in topography is a more accurate method for patients who have undergone RK with or without AK, compared with CLM. The Holladay II is the most accurate formula followed by SRK T, and SRK II, respectively. More studies with more cases are needed to confirm these findings.

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