

Comparison of Corneal Power and Intraocular Lens Power Calculation Methods after LASIK for Myopia

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Abstract

Purpose: To evaluate the accuracy of the two methods; the clinical history method (CHM), and the contact lens method (CLM), in refractive corneal power determination and comparing the accuracy of SRK II, SRK T and Holladay II (H II) formulas for intraocular lens (IOL) power calculation in patients who had laser in situ keratomileusis (LASIK) surgery for myopia with or without astigmatism

Methods: In this interventional prospective study, we evaluated 46 eyes of 32 patients who had undergone LASIK for myopia with or without astigmatism and were visited at Noor Eye Clinic during September 2001 to September 2006, for cataract surgery. The corneal power was determined with two methods; CHM and CLM. Then, IOL power was calculated with three formulas; SRK II, SRK T and H II. We used the results of CHM+H II formula for IOL power selection. The manifest refraction (MR) one month after cataract surgery was regarded as the postoperative refraction. 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 calculated the expected refractive results with IOL powers based on other corneal power calculation methods and formulas, and compared them to results with CHM+H II formula.

Results: The mean difference between keratometry values by CLM with CHM methods was 2.53 ± 2.68 D (Pearson correlation, 0.6; $P < 0.0001$). The mean manifest spherical equivalent (SEQ) was -10.44 ± 3.92 D, before refractive surgery, -0.84 ± 1.33 D (range; 1.00 to -5.00 D) before cataract formation, and -0.46 ± 1.04 D (range; 1.87 to -2.62 D) after phacoemulsification and IOL implantation with CHM+H II. The mean expected post-cataract surgery manifest SEQ using the CHM with SRK II and SRK T, were 1.39 ± 1.15 D and 0.56 ± 0.94 D, respectively. The mean expected post-cataract surgery manifest SEQ, using CLM with H II, SRK II and SRK T, were calculated as 1.91 ± 2.37 D, 2.97 ± 2.17 D, and 2.59 ± 2.07 D, respectively.

Conclusion: CHM appears to be more accurate than CLM for true corneal power determination after LASIK surgery for myopia with or without astigmatism. In this series of patients, the most accurate formulas for IOL power calculation were H II, SRK T and SRK II, respectively.

Keywords: Intraocular Lens, Clinical History Method, Contact Lens Method, Refractive Corneal Power Determination, SRK II, SRK T, Holladay II formulas, Photorefractive Keratectomy, Laser in Situ Keratomileusis

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Introduction

An increasing number of patients who have had corneal refractive surgery in the past two decades present with cataract as they grow older and develop age-related lens changes, and make corneal power determination and the subsequent intraocular lens (IOL) power calculation a serious issue in ophthalmology. Theoretically, the best method in corneal power determination is using the anterior and posterior corneal curvature and corneal thickness estimation. Then, with these parameters, we can calculate the true corneal power, using the Gaussian optic formula.¹ However, other methods are used in clinical practice.

Conventional keratometry is not an accurate method in patients with previous corneal refractive surgery.²⁻⁴ Keratometers estimate only 4 points on the cornea in the paracentral area, and ignore the more central areas that are flatter.⁵ Furthermore, after ablative procedures, such as photorefractive keratectomy (PRK) or laser in situ keratomileusis (LASIK), using the standardized refractive index may result in more errors in corneal power determination.^{2,6} Keratometers and computer videokeratographs measure the anterior corneal radius and use the keratometric index of 1.3375 to estimate the total corneal power (anterior and posterior surface) from the anterior corneal radius. Once we change the anterior and posterior corneal curvature ratio through procedures such as LASIK and PRK, the assumptions made by keratometers and videokeratographs to estimate the corneal power are no longer valid.⁵ There are several methods to determine the corneal refractive power after refractive surgery:

- 1- Clinical history method (CHM), in which pre-refractive surgery keratometry and manifest refraction (MR) and post-refractive surgery MR are required³
- 2- Plano hard contact lens (PHCL) over-refraction method (CLM)^{2,7}
- 3- Mean 3 mm zone keratometry in topography⁸
- 4- Mean keratometry of 4 mm zone (Pentacam, Holladay view)⁹
- 5- The BESSt formula¹⁰
- 6- Corneal power bypassing method¹¹
- 7- No-history method¹²

There are also different IOL calculation formulas in which the estimated corneal power is used. The purpose of this study was to compare the accuracy of CHM and CLM in true corneal power determination in patients with previous LASIK surgery for myopia with or without astigmatism. Another goal was comparing the accuracy and predictability of Sanders-Retzlaff-Kraff (SRK) II, SRK T and Holladay II (H II) formulas in IOL power calculation based on refractive results 1 month after cataract surgery.

Methods

In this non-controlled trial, we evaluated 46 eyes of 32 patients who had LASIK for myopia with or without myopic astigmatism. In all eyes LASIK had been done with the Nidek EC-5000 or the Technolas Keracor 217c excimer laser, and we used the two methods of CHM and CLM to determine the corneal power.

Clinical history method (CHM)^{3,13}

In this method, first we calculated the pre-refractive surgery manifest refractive spherical equivalent (SEQ_(R)):

$$\text{SEQ}_{(R)} = \text{Sphere} + \frac{\text{Cylinder}}{2}$$

and estimated the pre-refractive surgery manifest refractive spherical equivalent at the corneal plane (SEQ_(C)):

$$\text{SEQ}_{(C)} = \frac{1000}{\frac{1000}{\text{SEQ}_{(R)}} - 14}$$

In the next step, the SEQ_(R) and SEQ_(C) were calculated for post-refractive surgery MR. Then, using the following formula, we calculated the true corneal power (K_(post)):

K (Post) = pre-RSK + (pre-RS SEQ_(C) - post-RS SEQ_(C))

K (Post) = Post-refractive surgery keratometry (true corneal power)

Pre-RSK = Pre-refractive surgery keratometry
Pre-RS SEQ_(C) = Pre-refractive surgery spherical equivalent at the corneal plane

Post-RS SEQ_(C) = Post-refractive surgery spherical equivalent at the corneal plane

Contact lens method (CLM)^{2,7}

This method can be performed in patients whose on-axis refraction is possible with an accuracy of 0.25 to 0.50 D; that is, the visual axis must be free of cataract. It is important to know that off-axis refraction may result in considerable errors in true keratometry and consequently IOL power calculation.

In this method, all patients had their MR tested. Then, a PHCL with a certain base curve was fitted, and over-refraction (OR) was performed on the PHCL. In the next step, the MR without PHCL was subtracted from the MR with PHCL, and the result with its sign was added to the dioptric equivalent of the PHCL base curve:

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

The calculated keratometry readings with the two above methods were used to calculate the IOL power with SRK II, SRK T, and H II formulas. An SA60AT (Acrysof, Alcon Inc) was selected for each eye based on the results of CHM+ H II formula, A constant of 118.4, and a target refraction of plano.

All patients underwent phacoemulsification. In this procedure, first a 3.2 mm limbal incision was made, the anterior segment was formed with intraocular methylcellulose gel, and then a circumferential curvilinear capsulorrhexis was performed. In the next steps, hydrodissection and hydrodelamination and phacoemulsification were done, and the IOL was implanted in the bag. All cataract surgeries were performed by two surgeons (authors) using the Bausch & Lomb Millennium™ or Alcon Legacy 20000 phacoemulsification units at Noor Eye Clinic.

One month after phacoemulsification with IOL implantation, MR was tested in all patients. This was considered the stable refraction and used as a criterion for the accuracy of true keratometry determination methods and IOL calculation formulas. 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,¹⁴ we calculated the MR with other formulas and compared them with the results achieved with CHM+ H II formula.

Results

The mean age of these 32 patients at the time of phacoemulsification surgery was 48.88±7.27 years (range 37-63 years), and 63% of them were male. The mean time between LASIK and phacoemulsification in these patients was 5.05±2.25 years (range 2 to 10 years). The mean manifest SEQ of these patients before LASIK surgery was -10.44±3.92 D (range -1.75 to -18.75). The mean axial length in these patients was 27.90±2.04 mm (range 23.52 to 32.78 mm). The mean manifest SEQ in these 46 eyes after LASIK surgery and before the beginning of cataract was -0.84±1.33 D (range -5.00 to +1.00). After phacoemulsification, the mean manifest SEQ with CHM derived keratometry and H II formula was -0.54±1.04 D (range -2.38 to +2.63) (Table 1). There was no significant relation between the ages of the patients at the time of cataract surgery and the manifest SEQ before LASIK surgery.

The mean difference between the calculated keratometry with CLM and CHM was -2.53±2.68 D (range -9.09 to +2.33), and the Pearson correlation between them was 0.51 (P<0.0001) (Figure 1). The correlation between manual keratometry and CHM method was 0.75 (P<0.0001) (Figure 2). Mean calculated keratometry with CHM and CLM, and mean manual keratometry values before cataract surgery are summarized in table 2.

In all patients, the implanted IOL was selected according to the power calculated with CHM+ H II formula. As demonstrated in figure 3, there was an acceptable correlation between the IOL powers calculated with CHM+ H II and those calculated with CLM+ H II (Pearson correlation=0.8, P<0.0001). Calculating the expected refraction using the keratometry derived from CHM, and the SRK II and SRK T formulas gave a mean manifest SEQ of 1.39±1.15 D and 0.56±0.94 D, respectively.

Using the keratometry derived from CLM, the mean manifest SEQ after cataract surgery were 1.91±2.37 D with H II, 2.97±2.17 D with SRK II, and 2.59±2.07 D with SRK T. The mean manifest SEQ in these patients with regard to keratometry determination methods and different IOL calculation formulas are shown in table 3 and figures 4 and 5.

Table 1. Patients' refractive data

| Spherical equivalent | Min | Max | Mean | SD |
|-------------------------|--------|-------|--------|------|
| Pre-refractive surgery | -18.75 | -1.75 | -10.44 | 3.92 |
| Post-refractive surgery | -5.00 | 1.00 | -0.84 | 1.33 |
| Post-cataract surgery | -2.38 | 2.63 | -0.54 | 1.04 |

Table 2. Mean keratometry values before cataract surgery, calculated with clinical history method, contact lens method, and manual keratometry

| | Mean | SD | Min | Max |
|----------------------------|-------|------|-------|-------|
| Keratometry post-ref-surg | 37.57 | 2.58 | 30.63 | 43.36 |
| Keratometry history method | 35.53 | 2.87 | 28.91 | 43.29 |
| Keratometry CL method | 38.06 | 2.51 | 30.75 | 42.50 |

Table 3. Expected post-cataract surgery refractive results with 3 formula and CLM and CHM

| | | ±0.50 D | ±1.00 D | ±2.00 D | Myopia | Hyperopia |
|-----|--------|----------|----------|----------|------------|------------|
| CHM | H II | 17 (37%) | 27 (59%) | 45 (98%) | 31 (67.4%) | 15 (32.6%) |
| | SRKT | 19 (41%) | 32 (65%) | 43 (93%) | 12 (26.1%) | 34 (73.9%) |
| | SRK II | 11 (24%) | 20 (43%) | 30 (65%) | 4 (8.7%) | 42 (91.3%) |
| CLM | H II | 6 (13%) | 16 (35%) | 26 (57%) | 7 (15.2%) | 39 (84.8%) |
| | SRKT | 4 (9%) | 6 (13%) | 26 (57%) | 3 (6.5%) | 43 (93.5%) |
| | SRK II | 2 (4%) | 4 (9%) | 16 (35%) | 2 (4.3%) | 44 (95.7%) |

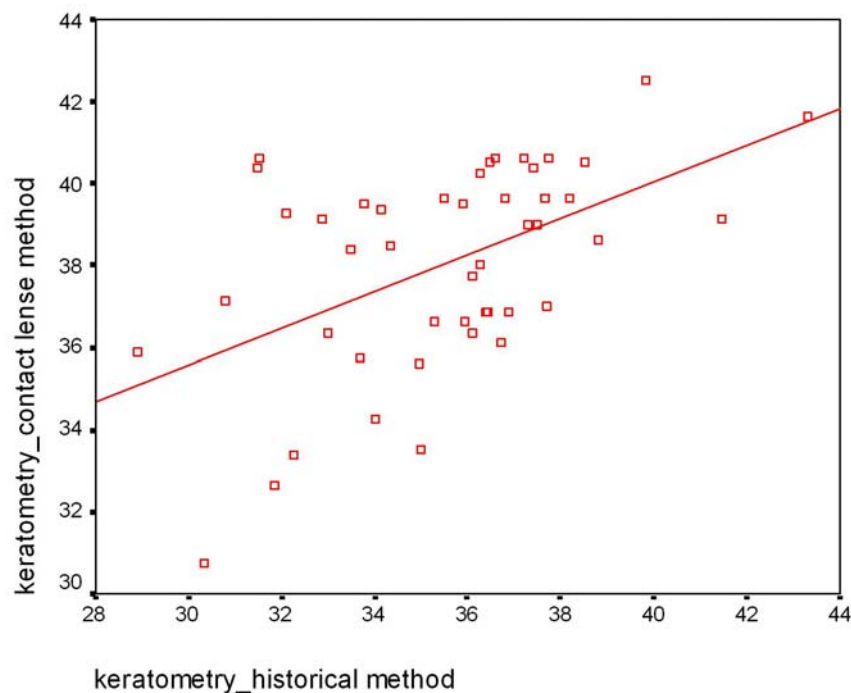


Figure 1. Correlation between calculated keratometry by two methods of CLM and CHM

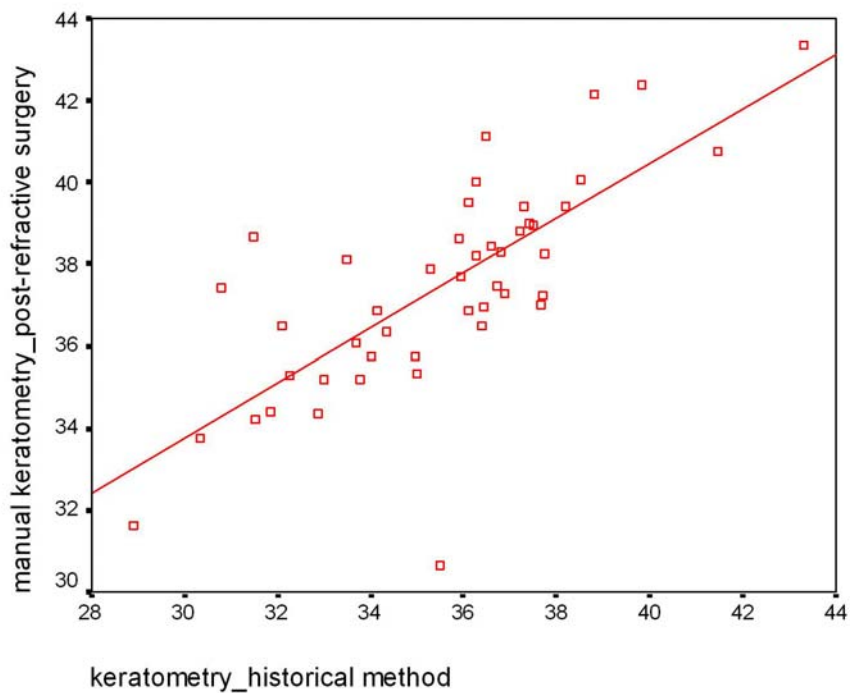


Figure 2. Correlation between calculated keratometry by two methods of manual keratometry and CHM

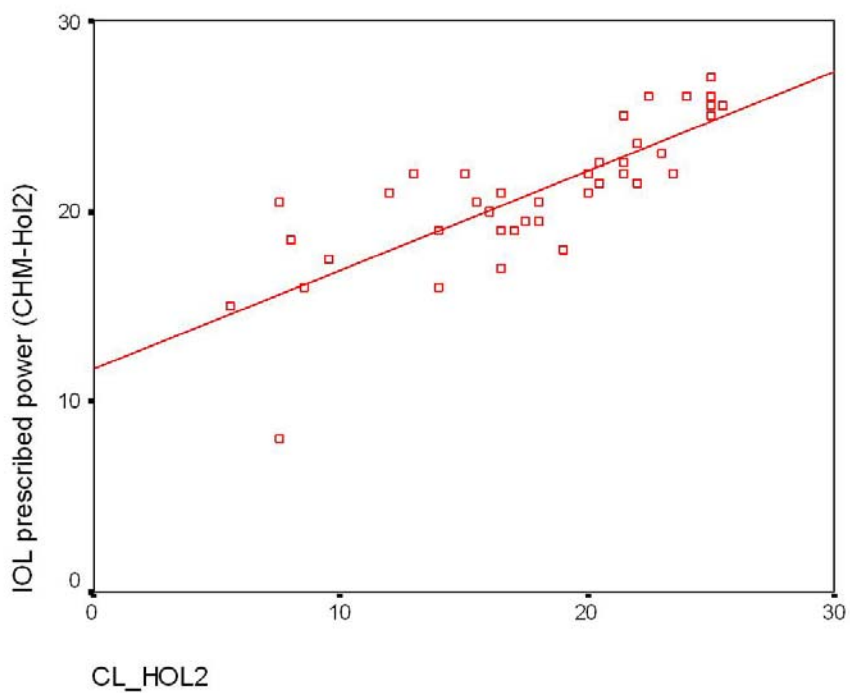


Figure 3. Comparison of intraocular lens power calculated with Holladay II formula and two methods of CHM and CLM

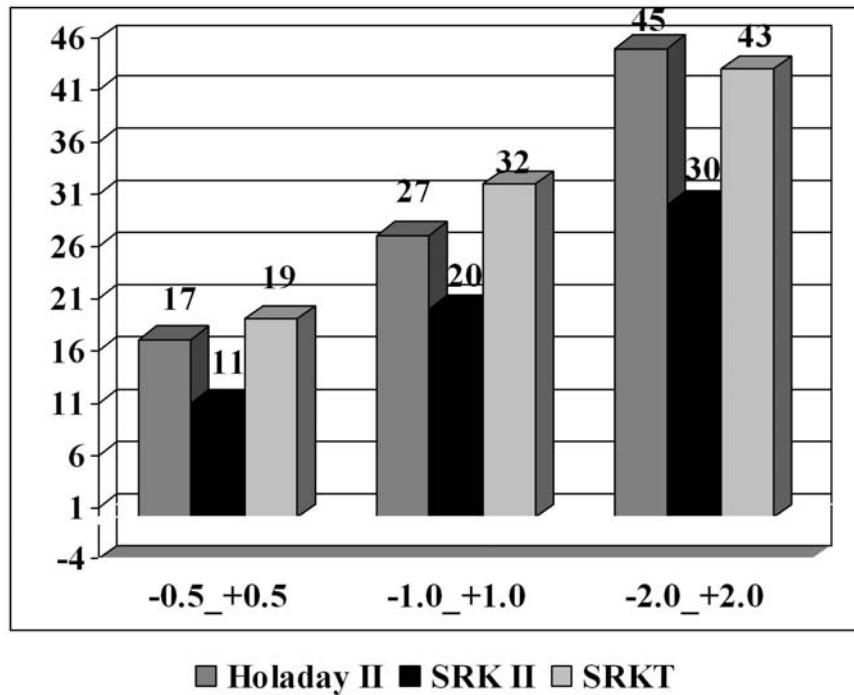


Figure 4. Comparison of the results of different intraocular lens calculation formulas with clinical history method

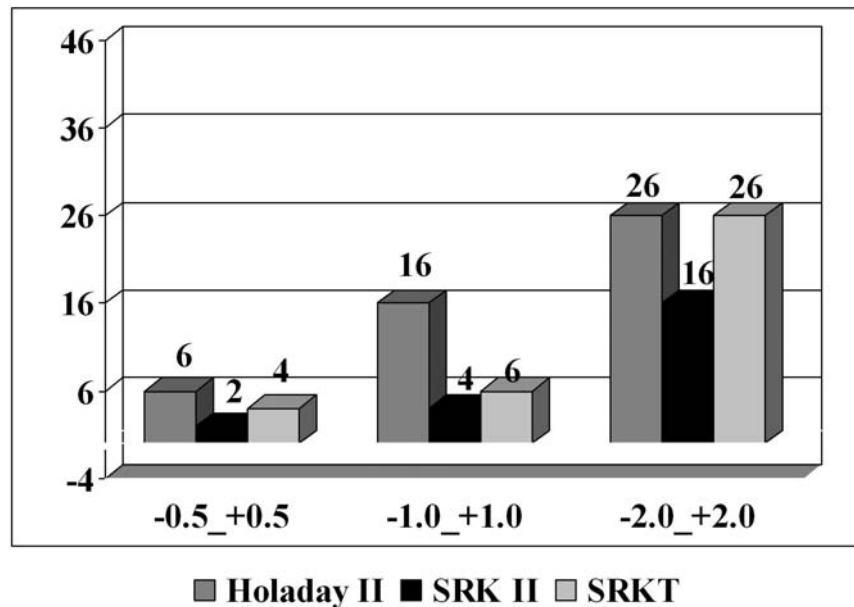


Figure 5. Comparison of the results of different intraocular lens calculation formulas with contact lens method

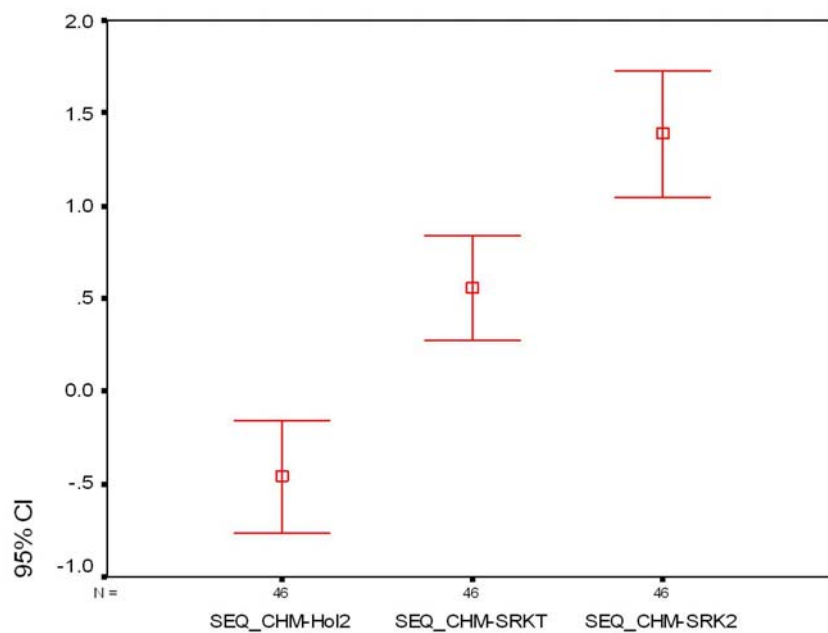


Figure 6. Comparison of the manifest SEQ derived from clinical history method and different intraocular lens calculation formulas

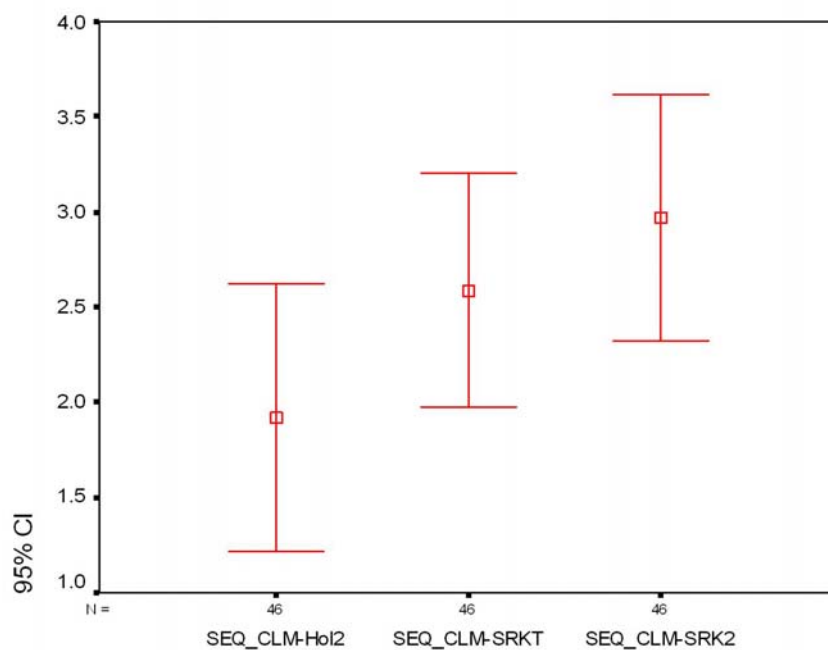


Figure 7. Comparison of the manifest SEQ derived from different intraocular lens calculation formulas with the contact lens method

Discussion

Many patients who have LASIK surgery will eventually need cataract extraction with IOL implantation. This has created a big challenge for ophthalmologists throughout the world. As mentioned before, the main concern in these patients is true corneal power determination. The keratometer overestimates the central corneal power in these eyes, and this results in underestimation of the calculated IOL power, which in turn leads to a hyperopic shift in postcataract refraction in these patients.⁸ Depending on the type of refractive surgery, this overestimation has different causes. After radial keratotomy (RK), the central cornea becomes flatter than the paracentral area, and the midperipheral area may become steeper due to the mechanical instability.² Consequently, the radius of the anterior curvature obtained by the keratometer is no longer an indicator of the central curvature of the cornea, because the keratometer shows the corneal anterior curvature steeper than the flat central area, due to the knee created in RK.¹⁵ Shortly after phacoemulsification, the central corneal power is reduced due to edema of RK incisions, and this results in an unreal transient hyperopic error in these patients.^{2,8} In PRK and LASIK the photoablation profiles are more even and there is no knee. However, after PRK and LASIK, the keratometer is even less accurate in corneal power and as a result in IOL power determination, compared to RK. This is because of the extreme change in the anterior corneal surface with PRK and LASIK, so that it would not be spherical any longer^{15,16}; changes that may be correlated with the ablation depth and so the keratometer error after LASIK can be more prominent than with PRK. Some reports have stated that manual and automated keratometry can be more accurate than CHM in patients who underwent RK and PRK surgery.¹⁷⁻¹⁹ As we mentioned in the introduction, CHM seems the most accurate method in corneal power determination.^{2,3,5,20} However, the accuracy of CHM must be confirmed through well designed clinical trials. In CHM, nuclear sclerosis can result in a myopic shift, and for this reason the precataract surgery MR can not be used as stable postrefractive surgery MR in these patients. In fact, the problem is that the pre and postrefractive surgery MR

and prerefractive surgery keratometry are needed in CHM and these data may not be available in some patient files, and therefore CHM cannot be used in these patients. Also, CHM is highly related to the accuracy of the refraction, so other methods including CLM and Pentacam may be needed in some patients. Also there is regression formulas for calculating the cornea power after myopic LASIK.²⁰

In CLM, the accuracy of refraction and whether the cataract permits on-axis refraction with 0.25 D accuracy are very important. In cases where stable postrefractive surgery MR is not available, regardless of the method used, the least obtained keratometry must be used as true keratometry in IOL power calculation formulas.¹⁹ It is noteworthy that CHM is usually used with forth generation IOL calculation formulas like H II.¹⁵

As the result of this study indicates, the mean difference between the determined corneal power with CLM and CHM was -2.53 ± 2.68 D, and the Pearson correlation (0.51, $P < 0.0001$) was agreeable. The Pearson correlation between the CHM and manual keratometry (0.75, $P < 0.0001$) was stronger correlation. The mean keratometry with manual keratometry was closer to CHM than to CLM (Table 2). The reason could be that advanced cataract in these patients does not permit on-axis refraction with ± 0.25 D accuracy and this results in erroneous CLM results. As mentioned before, in many cases, the needed data for CHM are not available and advanced cataract makes performing CLM impossible. Therefore, in this study with regression method, we tried to obtain formulas to calculate the true keratometry using postrefractive surgery keratometry (K_{post}), axial length, with or without prerefractive surgery manifest SEQ (Pre-SEQ):

$$K_{\text{His}} = 0.42 K_{\text{Post}} - 0.54 \text{ Ax-Length} + 39.03$$

$$K_{\text{His}} = 0.35 K_{\text{Post}} - 0.27 \text{ Ax-Length} + 0.46 \text{ Pre-SEQ} + 35.07$$

Diagram 3 shows a good correlation between the calculated IOL power with two methods; CHM and CLM with H II formula (Pearson correlation=0.8, $P < 0.0001$).

Table 3 demonstrates that CHM with H II formula, with which the mean manifest SEQ

after cataract was -0.54 ± 1.04 D (range -2.62 to 1.87), was the most accurate method and a greater percentage of eyes was closer to emmetropia. This is while with CHM and SRK T, the mean manifest SEQ after cataract was 0.56 ± 0.94 D and with CHM and SRK II, it was 1.39 ± 1.15 D. Indeed, with CHM, the H II and SRK T had a similar function in respect to patients' emmetropia, but H II formula kept patients on the myopic side, while SRK T led them to hyperopia (Figure 6). For this reason, in this study, we calculated the average IOL power with H II and SRK T for each eye, and then determined the expected manifest SEQ. By applying the average results from the two formulas, 43% of eyes were within ± 0.50 D, 73% were within ± 1.00 D, and 96% were within ± 2.00 D of emmetropia. These results suggest that the use of average IOL power,

calculated from CHM with H II and SRK T, brings these eyes closer to emmetropia. Table 3 and figure 5 also show that with CLM, the H II formula was the most accurate formula followed by SRK T and SRK II, respectively. However, CLM+ H II are less accurate than CHM+ H II.

Conclusion

In conclusion, it seems that the most accurate method in our study was CHM+ H II and the least accurate one was CLM+SRK II. The average IOL power derived from H II and SRK T formulas with CHM was also an accurate method. More studies with larger study populations are needed to confirm these findings.

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