

# Comparison of Refractive Outcomes of Different Intraocular Lens Power Calculation Formulas in Keratoconic Patients Undergoing Phacoemulsification

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## Abstract

**Purpose:** In the present study we have tried to find the most reliable intraocular lens (IOL) power calculation formula in patients with keratoconus (KCN) and cataract.

**Methods:** In a prospective case series between October 2010 and March 2012, eligible patients with cataract and KCN underwent phacoemulsification with IOL implantation. Preoperatively, based on IOL master keratometric data IOL power calculation was subsequently performed by means of six well-known formulas: Haigis, Holladay 1 and 2, Hoffer Q, SRKII, and SRKT. Postoperatively the “desired IOL power” was back-calculated in order to determine the most accurate formula for IOL power calculation.

**Results:** Fourteen patients (20 eyes) with nuclear sclerosis and KCN were cumulatively enrolled. The mean age was 56.7 years $\pm$ 13.8 (SD) (range, 23 to 70 years). Nine patients (64%) were males. In mild KCN subgroup, SRK II and SRK-T represent as the “matched formulas” within defocus range of less than 1 D in 66.6% of cases. In moderate KCN subgroup, Hoffer Q, Holladay 1, Holladay 2, SRK II and SRK-T II represent as the “matched formulas” within defocus range of less than 1 D in 75% of cases. Finally in severe KCN subgroup, SRK II represents as the “matched formula” in 50% of cases.

**Conclusion:** Findings of the present study suggest that irrespective of axial length classification, the SRK II formula can be considered as “the ideal formula”; the one with the most reliable outcome in all stages of KCN.

**Keywords:** Keratoconus, Intraocular Lens Power Calculation Formula, Cataract Surgery

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## Introduction

Similar to normal population, keratoconic patients are at risk of cataract development as a consequence of aging processes considering that cataract formation maybe more prevalent in keratoconic patients due to its association with atopia and use of some medications.<sup>1</sup> However, intraocular lens (IOL) power calculation in patients with keratoconus (KCN) is challenging, due to corneal irregularities, high astigmatism and relatively increased axial length.<sup>2</sup> Few reports have evaluated the accuracy of IOL power calculation formulas or K-reading methods in keratoconic patients who undergo cataract surgery. In the present study we have tried to find the most reliable IOL power calculation formula in patients with KCN and cataract.

## Methods

In a prospective case series between October 2010 and March 2012, eligible patients with cataract and KCN underwent phacoemulsification with IOL implantation. All surgeries were performed by two surgeons (M. Z. & H. H.) on an outpatient basis.

KCN was diagnosed by a combination of classic clinical (slit-lamp examination & red reflex evaluation) and abnormal corneal topographic imaging (orbiscan or pentacam) findings. Subsequently KCN severity was evaluated according to maximum keratometric reading by IOL master keratometer (Carl Zeiss Meditec AG). This staging method was first introduced by Thebpatiphat et al who classified KCN severity as mild (max k-reading less than 48 diopters), moderate (max k-reading equal to or more than 48 D but less than 52 D); and severe (max k-reading equal to or more than 52D).<sup>1</sup>

Inclusion criteria were measurable and reproducible preoperative subjective refraction, patient's reluctance to perform penetrating keratoplasty (in advanced stages of KCN), stability of refraction for at least two years ( $\pm 1$  D), and minimum follow-up of three months. Exclusion criteria were, privilege for other interventional options, presence of pterygium or history of pterygium excision, previous refractive surgery or intraocular surgery, endothelial cell density less than 1,500 cells/mm<sup>2</sup>, complicated cataract surgery or cataract surgery with any method other than phacoemulsification (clear corneal

incision, temporal approach) with in-the-bag IOL implantation, corneal opacity or severe red reflex distortion and any other ocular comorbidities affecting preoperative best corrected visual acuity (BCVA).

Patients were instructed to discontinue contact lens use for two months before keratometric assessment.

Preoperatively, BCVA, manifest and subjective refractive error, were recorded. Additionally slit lamp biomicroscopy of anterior segment and funduscopy examination were also performed.

Axial length and ACD were measured using the IOLmaster device (Carl Zeiss Meditec AG). According to axial length, the patients were categorized to four subgroups; group I (less than 22 mm), group II (equal or more than 22 mm but less than 24.5 mm), group III (equal or more than 24.5 mm but less than 26 mm) and group IV (equal or more than 26 mm). Based on IOLmaster keratometric data IOL power calculation was subsequently performed by means of six well-known formulas: Haigis, Holladay 1 and 2, Hoffer Q, SRKII, and SRKT. Holladay 2 calculations were performed by Holladay IOL consultant software. Other formulas were applied by utilizing IOLmaster software (Carl Zeiss Meditec AG - ver. 3.02).

Preoperatively the best IOL power for implantation was mostly determined by SRKII, as concluded in a previous study. Although in some cases the final calculated power was modified according to the surgeon's experience, targeting a minimal residual myopic refractive error (-0.5 D max).

The study was approved by the Ethics Committee of Tehran University of Medical Sciences and all patients who expressed consent for entering this study were clearly informed about the prognosis of the intervention.

Specifically it was emphasized that only the spherical component of refractive error may be corrected, that spectacles would be needed after the operation to correct residual errors, and that further enhancement by refractive surgery (excimer laser) might not be possible. Considering the fact that different types of IOL were implanted, adjusted Lens Constants were imported to IOLmaster calculator software.

Patients were invited for examination on 1 & 7 days and 1 & 3 months postoperatively. Evaluation included uncorrected visual acuity (UCVA), BSCVA, standard manual keratometry & slit-lamp evaluation. Postoperatively the “desired IOL power” was back-calculated in order to determine the most accurate formula for IOL power calculation. It was calculated by subtracting “corrected” residual spherical equivalent (SE) from “implanted IOL power”; in which “corrected” residual SE is calculated by a refractive vergence formula to consider vertex distance effect (Refractive Vergence Formula for Pseudophakic and Aphakic Eyes, IOL Power Calculations From Refractive Data (v. 02.8 Warren E. Hill, East Valley Ophthalmology, Ltd. Mesa, Arizona USA). Afterwards “matched IOL power formulas” for each subgroup were determined among various IOL power calculations (six formulas) considering “desired IOL power” with an acceptable defocus range of  $\pm 1D$  (or  $\pm 0.5 D$ ). In these calculations, surgically induced astigmatism was not evaluated.

## Results

Fifteen patients with nuclear sclerosis and KCN were cumulatively enrolled, one of whom was excluded from analysis due to pseudophakic retinal detachment. Others (14 patients - 20 eyes) underwent uneventful, clear-cornea (3.2 mm  $\times$  3.0 mm tunnel) phacoemulsification with implantation of a foldable IOL in the posterior capsular bag. The mean age was 56.7 years  $\pm$  13.8 (SD) (range, 23 to 70 years). Nine patients (64%) were male. Only one of the patients was on rigid gas permeable contact lens.

Mild, moderate and severe KCN was identified in six (30%), four (20%) and ten eyes (50%), respectively. Distribution of measured axial lengths is demonstrated in table 1. None of the eyes in the study had an axial length of less than 22 mm. The distribution of KCN severity and axial length among the studied patients is summarized in table 2. Mean follow-up time was 4.3 months (range, 3 to 12 months).

Assuming residual myopic error of less than -0.5 D to be negligible, 10 eyes (50%) were spherically emmetropic postoperatively. Sixteen eyes (80%) were within  $\pm 1 D$  spherical emmetropia.

Postoperative mean SE in both mild and moderate KCN groups were +0.25 D, while in severe KCN group this figure turned out to be -0.91 D (Table 3). P-values could not be evaluated because the sample size was too small. Apart from one case, postoperative cylinder were within  $\pm 0.5 D$  of preoperative data and no significant change in cylinder component was observed postoperatively.

Assuming a defocus range of 1 D as acceptable, we found SRK II, SRK T, Holladay I and II and Haigis as the matched formulas for all four eyes with mild to moderate KCN in group II of axial length. Although among the two eyes with severe KCN, only one was within the 1 D defocus range by SRK T and Haigis formula.

In group III of axial length, the single case with moderate KCN did not match the 1 D defocus range while five eyes (71%) out of seven with mild and severe KCN, matched the range by SRK II formula. In group IV of axial length, all three eyes with mild KCN lied within the 1 D focus range by SRK II formula while SRK T and Haigis were the ideal formula only in two eyes. In this axial length subgroup, no eye had moderate KCN and none of the three eyes with severe KCN lied in the 1 D defocus range (Table 4).

Finally, seven eyes (35%) out of 20 gained no satisfactory result within 1 D of defocus range with any formula (i.e. No “matched formula”). Although by assuming a narrower range of defocus as acceptable ( $\pm 0.5 D$ ) the number of cases within the defocus range decreases but the overall pattern of ideal formula seems to remain unchanged (Table 5).

To summarize the main outcome of the study, in mild KCN subgroup, SRK II and SRK-T, in moderate KCN subgroup, Hoffer Q, Holladay 1, Holladay 2, SRK II and SRK-T, and finally in severe KCN subgroup, SRK II represent as the “matched formulas” within defocus range of less than 1 D in 66.6%, 75% and 50% of cases, respectively.

**Table 1.** Patients distribution base on axial length subgroups

Keratoconus stage	Cases	%
I	3	15
II	5	25
III	3	15
IV	9	45

**Table 2.** Distribution of patients base on axial length and keratoconus severity

Axial length	Keratoconus		
	Mild	Moderate	Severe
22-24.5 mm Group II	1	3	2
24.5-26 mm Group III	2	1	5
26< mm Group IV	3	-	3

**Table 3.** Mean spherical component of refractive

Mean spherical error	Keratoconus	Mild
Preop*		-6
Postop**		0.25

\* Preoperative mean spherical error  
\*\* Postoperative mean spherical error

**Table 4.** Ideal intraocular lens calculation formula within  $\pm 1$  D defocus range according to the keratoconus severity and axial length subgroups. In the parentheses, number of patients within defocus range and total number of patient within that subgroup is shown as numerator and denominator, respectively.

Axial length	Keratoconus		
	Mild	Moderate	Severe
22-24.5 mm Group II	(1/1) SRKII, SRK/T Hoffer Q Holladay 1, 2	(3/3) SRKII, SRK/T Hoffer Q Holladay 1, 2	(1/2) SRKII Haigis
24.5-26 mm Group III	(1/2) SRKII, SRK/T	(0/1) Negative	(4/5) SRKII
26 $\leq$ mm Group IV	(3/3) SRKII (2/2) SRK/T, Haigis	-	(0/3) Negative

**Table 5.** Ideal intraocular lens calculation formula within  $\pm 0.5$  D defocus range. In the parentheses, number of patients within defocus range and total number of patient within that subgroup is shown as numerator and denominator, respectively.

Axial length	Keratoconus		
	Mild	Moderate	Severe
22-24.5 mm Group II	(1/1) SRKII, SRK/T Hoffer Q Holladay 1	(3/3) Hoffer Q Holladay 1, 2 (2/3) SRKII, SRK/T	(1/2) SRKII, Haigis
24.5-26 mm Group III	(1/2) SRKII	(0/1) Negative	(2/5) SRKII
26 $\leq$ mm Group IV	(1/3) SRKII SRKII, SRK/T	-	(0/3) Negative

## Discussion

Since various etiologies may contribute to secondary deterioration of vision in keratoconic patients, a judicious work up should be performed to determine the cause in such cases. As KCN patients get older, cataract formation becomes a more probable etiology for secondary decreased vision.

A previous study reported that cataract formation may occur at a younger age in patients with KCN.<sup>1</sup> Results of the present study are compatible with that report (mean age of 56.7±13.8 years). Mean age of visually significant cataracts in the general population has been found to be 69.6 (±10.9) years.<sup>2</sup>

Technically, cataract surgery remains a safe procedure in keratoconic patients with cataract although unique refractive properties of these patients make it optically challenging. Besides unreliable keratometric reading, elongated axial length (with associated axial myopia) makes IOL power calculation even more challenging.<sup>2</sup>

Most common IOL power calculation formulas basically have been developed either on normal population data or at least on normal eye optics. Therefore in keratoconic patients these formulas cannot be regarded as reliable and in fact are misleading in severe cases. Keratometric data is one of the major sources of error in IOL power calculation. Obviously the prominence of this factor is magnified in keratoconic patients. Even by a thorough literature review few reports about the best method of keratometry or the most accurate IOL power formula in KCN patients can be found. One case report suggested that topography-derived keratometry may be more accurate than standard keratometric readings in keratoconic patients.<sup>3</sup> On the contrary, in a case series conducted by Thebpatiphat et al, no difference between standard keratometry and topography-derived keratometry results was observed in mild KCN patients who underwent cataract surgery.<sup>1</sup>

Leccisotti et al, have utilized axial topographic maps for keratometric readings in keratoconic patients who underwent refractive lens exchange.<sup>4</sup> In the present study keratometric data was primarily intended to be evaluated by various methods but ultimately only IOLmaster-derived keratometric readings were incorporated due to issues of small sample size and missing data.

KCN can be associated with axial myopia. Elongated axial length in combination with unreliable keratometric readings made IOL power calculation more challenging.<sup>2</sup> studies also showed that myopia is a risk factor for cataract formation.<sup>5,6</sup> Some authors tend to incorporate the factor of axial length in decision making to choose the best IOL calculation formula. Although SRK-T and Holladay 1 might be considered as more accurate for higher axial lengths in normal cases, published studies to date have evaluated different IOL calculation formulas and no consensus has been reached.

In the present study, irrespective of KCN staging, SRK-T led to reliable outcomes in just 3 (21.4%) out of 14 eyes with axial lengths larger than 24.5 mm. SRK II led to reliable outcomes in eight (57%) out of 14 eyes with high axial length. Thebpatiphat et al have compared results of SRK, SRK/T, SRK II formulas. The present study was designed to bring more formulas under evaluation.<sup>1</sup> In this limited case series, SRK II was found to be the most reliable formula for IOL power calculation in patients with various stages of KCN, although the reliability decreases in severe stages. It was also shown that cases with mild and moderate KCN and normal axial length (22-24.5 mm) have the highest rate of “matched formulas”. Conversely, in advanced cases of KCN, “matched formula” could hardly be found (Table 4).

Despite the fact that modern IOL power formulas incorporate more variables to enhance the accuracy of IOL power calculations, simple regression formulas based on normal population data interestingly still lead to the most acceptable results. Failure of sophisticated formulas may indicate the need for incorporating different sets of variables or considering different approaches. Modern corneal imaging devices may be the key to solve this problem.

The main limitation in this study may be the small sample size of patients in the subgroups. Our results may be confounded by this problem. Also, perhaps newer methods of evaluating corneal power will improve the accuracy of IOL calculation in the future. Although in our study, we did not use, toric IOL Implantation in these patients may be better option.

## Conclusion

Findings of the present study suggest that irrespective of axial length classification, the SRK II formula can be considered as “the ideal formula”; the one with the most reliable outcome in all stages of KCN.

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