Accuracy of biometry using automated and manual keratometry for intraocular lens power calculation

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Abstract:
INTRODUCTION: A comparison of precision of intraocular implant power calculation by computing keratometry values by two different methods, namely, the automated and manual keratometry (MK), was done. For checking this accuracy, the parameter taken into consideration was the absolute refractive error which was ascertained postoperatively.

SUBJECTS AND METHODS: This study was conducted in the Department of Ophthalmology, Sri Aurobindo Institute of Medical Sciences and PG Institute, Indore. At a tertiary eye care centre in Central India (Sri Aurobindo Institute of Medical Sciences, Indore). Duration of the study was 18 months. Sample size was 66 individuals who were with cataract (nuclear sclerosis I to III). Although keratometry was done by both methods and implant power derived separately by computing both readings, decision of which power to be implanted in an eye would depend on the group, in which patient would fall. Group A were prospective candidates who would be implanted intraocular lens (IOL) of that power as assessed by computing MK value, whereas Group B were participants who would be implanted IOL of that power as assessed by computing value obtained by automated keratometry (AK). First patient fell in Group A and second in Group B, third again in Group A till 33 patients had been operated in each group.

RESULTS: Bland–Altman plot thus obtained showed that the two keratometers are comparable. The postoperative refractive errors for the two Groups (A and B), showed that if an error of ±0.50 D or less is considered, then in Group A 81% of patients achieved this and 87% of patients required this as spectacle aid in Group B.

CONCLUSIONS: In this study, we compared the accuracy of AK with that of MK for calculation of implant power. It was concluded from this study that AK is a simple keratometric technique that appeared to be more accurate than MK.

Keywords:
Accuracy of biometry, automated keratometry, keratometry, manual keratometry

Introduction

Cataract extraction is by far the most common intraocular surgery performed worldwide. It is estimated that in India alone, more than 5.1 million patients undergo cataract surgery annually. The evolution of cataract surgery took a giant step in 1949 when Harold Ridley developed and implanted the first intraocular lens (IOL). Thereafter, cataract surgery has been refined and evolved with new techniques and formulas for improved biometric calculation.

The pioneering Russian ophthalmologist S. N. Fyodorov was the first in applying the thin lens formula in calculation of intraocular implant power. It has stood the test of time ever since and forms the basis of IOL power calculation in all subsequent efforts. Implant power can be calculated by knowing three variables – axial length, keratometry, and “A” constant. Axial length is usually measured by application A-scan ultrasound, a widely used technique. A rough assessment of axial length of eyeball and corneal curvature can be made clinically. However, the postoperative
effective lens position (ELP) cannot be measured, and hence predicted from preoperative parameters. This prediction introduces the largest source of error and contributes to the majority of refractive surprises postcataract surgery.\[5\]

Sanders-Retzlaff-Kraff I (SRK-I) formula\[6\] was the most successful linear regression formula at the time. This formula was found adequate for eyes with average axial length between 22 and 24.5 mm. However, if axial length was outside the range (especially in long eyes), the formula proved incorrect due to variable ELP in these eyes. The SRK-II formula\[7\] attempted to ameliorate the predictions by introducing a correction factor for the length of the eye. SRK-II improved predictive power. However, the empirical regression formulæ were quickly superseded by theoretical formulæ.

Cornea is the major refractive element in the eye that accounts for about two-third of the eye’s refractive power. Errors in the measurement of corneal refractive power have impact on measurement and calculation of IOL power. Accurate measurement of corneal refractive power is the turning point. Certainly, measuring cornea’s refractive power is not easy. In IOL power calculation, K-value plays a significant role. Keratometry involves determination of curvature of the anterior corneal surface (steepest and flattest meridians), expressed in diopters or in millimeter of radius of curvature.\[8\] Keratometers estimate corneal refractive power indirectly by measuring the size of an image reflected by the anterior tear film. This is used to estimate the radius of corneal curvature, which is then used in thin lens formula to estimate dioptic refractive power of the cornea assuming an average refractive index. However, this ignores the refractive power of posterior surface of cornea, which is difficult to measure directly.\[9\] Most methods assume that posterior corneal curvature is related to the anterior curvature.\[10,11\] However, how the two curvatures are related is still a subject of debate and refinement.\[12-14\]

The estimation of dioptic power of cornea is further complicated by spherical aberration, an entity which is directly proportional to size of pupil and adds to the dioptic power of cornea.\[15\] Therefore, measurement of pupillary size is also important. Furthermore, the cornea has a prolate configuration to reduce spherical aberration, and the asphericity of both anterior and posterior surfaces of the cornea changes with age\[13,14\] further changing corneal dioptic power.

Objectives
The present research was undertaken to ascertain the accuracy of biometry (by two different keratometric techniques) from mean absolute refractive error present after cataract surgery. Furthermore, to validate the accuracy of biometry using these keratometric techniques the parameter taken into consideration was the percentage of patients having a postoperative spherical error ± 0.5D after implantation in each group. Having used the SRK-II formula in our series, precision of this formula, thus, would automatically be checked.

Inclusion criteria
Cataracts in males and females between 40 and 80 years of age, with attendant and/or patient willing to provide voluntary informed consent for participating in this study.

Exclusion criteria
Nuclear sclerosis above Grade III, any coexistent ocular disease, intraoperative complication, surgical/ocular trauma in same eye, or a refractive error ± 1.5D in fellow eye.

Subjects and Methods
A prospective, comparative, interventional, and randomized cohort study done in 18 months (from January 1, 2015 to June 30, 2016).

After selecting patients having cataract on the basis of lens opacity classification system II, informed written consent to undergo cataract surgery, as well as for participating in study was taken. Thereafter, biometry was done with two “K”-values (manual and automated) for each patient.

Grouping
While performing cataract surgery by small incision self-sealing 6.2-mm triplanar sclerocorneal tunnel centered on the steeper meridian, serially, the first patient was allotted Group A and second patient was allotted Group B, third again group A, and so on till a total of 33 patients had been operated in each group. For both groups axial length was measured using applanation A scan. “A” constant was 118.2 as same implant design was used in all cases. For obtaining IOL power, two keratometric values obtained by two devices for both groups were used with two constants (“A” constant and axial length), thus two predicted postoperative refractive values (one each with implant power) were obtained.

Formula used
\[ P_{\text{IOL}} = A - 2.5L - 0.9K \]
Where,

A is a numerical constant, the “A‑Constant,” which incorporates variation in IOL design and ELP; for our series it was 118.2

\( P_{\text{IOL}} \) is the calculated IOL power;

K is dioptric keratometry measurement, assuming corneal refractive index of 1.3375;

AL is the axial length in mm, which, for this series was in the range 22 mm to 24.5 mm.

Postoperatively at 6 weeks, based on autorefractometer reading, (NIDEK Autorefractometer) spherical value in diopeters was ascertained and record maintained individually for each operated eye. We compared the expected refractive error (obtained preoperatively during biometry, a value predicted by A scan) with residual spherical error in diopeters (obtained postoperatively at the end of 6 weeks) in both groups. A difference of these two abovementioned values in diopeters was calculated individually for each operated eye at the end of 6 weeks after surgery and entered in the Microsoft Excel chart. This was termed as absolute refractive error, which was compared for both groups (AK and MK).

Residual spherical error is merely the spherical refractive component in diopeters taken into consideration (without attention to value of cylinder). Since our target was emmetropia, this spherical error determined postoperatively has been termed “residual.” In both groups, in final follow-up, the variation in residual spherical error from the predicted value obtained during A‑scan biometry was calculated individually for all operated eyes and stratified for residual error in diopeters. \( P \) value was calculated for both groups using unpaired “t”‑test. A difference in \( P \leq 0.05 \) has been considered to show a statistically significant difference and more than that has been considered insignificant.

To compare keratometric concordance between Bausch and Lomb manual “K”‑reading and the KM500 (NIDEK) autokeratometric individual “K”‑values, we chose to compare by the Bland‑Altman graphs/charts. These are difference plot and are a graphical method to compare the agreement between two clinical measurements. Figure 1 displays a scatter diagram of the differences plotted against the averages of the two measurements. Horizontal lines are drawn at the mean difference, and at the limits of agreement, which are defined as the mean difference plus and minus 1.96 times the standard deviation of the differences. Descriptive statistics for differences between manual and AK are given in Table 1.

Observations and Results

Observation‑at the end of 6 weeks

In the MK group, maximum patients had a residual spherical error amounting to \( \leq 0.5 \)D (81.81%) which was followed by 6 patients (18.18%) having residual spherical error between \( > ±0.5 \) and \( ±1.5 \)D. None of the patients fell in the group with residual spherical error \( > ±1.5 \)D. Similarly, in the AK group, maximum patients had a residual spherical error \( \leq 0.5 \)D (87.87%), which was followed by 4 patients (12.12%) having residual spherical error \( > ±1.5 \)D. None of the patients fell in the group with residual spherical error \( > ±1.5 \)D.

The mean refractive error in the MK group was 0.1009 ± 0.0907D and the residual spherical error was -0.265 ± 0.380D. The \( t \)‑value for this group was 2.42 with a \( P = 0.019 \). The mean refractive error in the AK group was -0.09 ± 0.102 diopters, and the residual spherical error was -0.167 ± 0.363 diopters. The \( t \)‑value for this group was 1.15 with a \( P = 0.254 \).

The error found in AK group following cataract surgery was not significant.
Table 2: Postoperative residual spherical error (D)

| Residual spherical error (D) | MK Group A, number of patients (%) | AK Group B, number of patients (%) |
|-----------------------------|-----------------------------------|-----------------------------------|
| ≤±0.5                      | 27 (81.81)                        | 29 (87.87)                        |
| >±0.5–±1.5                 | 6 (18.18)                         | 4 (12.12)                         |
| >±1.5–±2.5                 | 0                                 | 0                                 |
| >±2.5                      | 0                                 | 0                                 |
| Total                      | 33 (100)                          | 33 (100)                          |

MK = Manual keratometry, AK = Automated keratometry

Table 3 shows a comparison of mean values of spherical error in diopters between both the groups. The mean value of spherical error in diopters by manual method was -0.27 ± 0.38, while that calculated by automated method was -0.17 ± 0.36. The difference was found to be statistically insignificant (P > 0.05), showing that there was no significant difference in the mean spherical error in diopters as assessed for Group A and Group B [Table 3 and Figure 3].

In our study, we found maximum number of patients in the range of 0.0D to < ±0.25D postoperatively. A total of 19 patients (57.57%) in MK group and 24 patients (72.72%) in AK group had spherical error < 0.25D from the calculated value which clearly shows the precision of biometry by the two keratometry techniques. However, considering error between > ±0.25D and ± 0.5D, there were 8 patients (24.24%) in MK group and 5 patients (15.15%) in AK group which was followed by > ±0.5D in 6 patients (18.18%) in MK group and 4 patients (12.12%) in AK group [Table 4 and Figure 4].

Table 5 shows a comparison of the mean absolute refractive error in both the groups. The mean absolute refractive error by manual method was -0.15 ± 0.38D, while that calculated by automated method was -0.07 ± 0.39D. The difference was found to be statistically insignificant (P > 0.05).

**Discussion**

This study has been carried out on 66 patients having various levels of lens opacification who presented in the Department of Ophthalmology.

This study was done on two groups of patients using two different keratometric methods for implant power calculation, thereafter, cataract surgery was done by a 6.1-mm self-sealing triplanar sclerocorneal tunnel. We made precise observations on age, sex, and prevalence of various cataract grades. We compared absolute refractive error in both AK and MK groups and their mean values.

Considering the postoperative spherical value (residual spherical error), we found that in MK group, maximum number of patients had a residual spherical error amounting to ≤ ±0.5D (81.81%) which was followed by 6 patients (18.18%) having residual spherical error between > ±0.5D to ± 1.5D. Considering patients, if any, having an error amounting to > ±1.5D postoperatively, there were none. Similarly, in the AK group maximum number of patients developed a residual spherical error ≤ ±0.5D (87.87%), which was followed by 4 patients (12.12%) having residual spherical error between > ±0.5 and ± 1.5D. If a refractive error > ±1.5D was considered, there were none.

With such results, we can say that maximum number of patients had spherical value ≤ ±0.5D at 6-week postoperatively.

In our study, the mean value of sphere by manual method was -0.27 ± 0.38D, while that calculated for automated group was -0.17 ± 0.36D. The difference was found to be statistically insignificant (P > 0.05). The mean refractive error in the MK group was 0.1009 ± 0.0907D, and the residual spherical error was -0.265 ± 0.380D. The t-value for this group was 2.42 with a P = 0.019.
Thus, our study revealed significant error in the MK group postcataract surgery with IOL implantation.

Considering all the preoperative, intraoperative, and postoperative requisites, we can say that the accuracy of biometry done by MK was not adequate to meet the desirable outcome.

The mean refractive error in the AK group was $-0.091 \pm 0.102$ diopters and the residual spherical error was $-0.167 \pm 0.363$ diopters. The $t$-value for this group was 1.15 with a $P = 0.254$. The error found in AK group following cataract surgery was not significant. Hence, considering all other criteria (on which the surgical outcome can depend) to be constant, implant power calculated by computing keratometric values using AK were appropriate and more accurate as compared to that done by MK.

Manning et al. 1997 calculated the mean absolute refractive error (difference between the actual refractive outcome and predicted refractive outcome) and found it to be $0.37 \pm 0.30$ D using MK values and $0.45 \pm 0.19$ D using AK values. They considered AK and MK to be equally precise. Previous studies on the use of AK in preoperative ocular biometry and calculation of implant power arrived at differing conclusions. Lusby et al. 1987 using the Humphrey autokeratometer in 497 consecutive eyes, thought that its accuracy was probably not adequate for implant power calculations. Similar conclusion was derived by Sunder Raj et al. 1990 from their study that AK was inadequate for biometry.

However, Knorz et al., 1989 claimed that AK could be a useful alternative to MK in the preoperative determination of IOL power. The present study validated higher precision of automated keratometer for the implant power calculation.

To cross-check the precision of A-scan biometry done in course of the present study, we used three-dimensional graph devised by Ladas et al. 2015 and plotted 33 individual values separately for Group A and B [Figures 5 and 6].

To our surprise, almost all biometries (30 out of 33 in Manual and 32 out of 33 in Automated) coincided within the super surface of three-dimensional graph, where they should lie.

To prevent implant power calculation surprises disclosed postoperatively; this is a useful means by which surgeons can check accuracy following biometry.

**Conclusions**

NS II and NS III are equally prevalent. Postoperatively, an absolute refractive error $\leq 0.25$D could be achieved in 72.72% of participants in AK group, whereas only 57.57% in the MK group could attain this. All other variables for implant power calculation being comparable and statistically insignificant between the two groups, it is evident that AK is a more accurate

**Table 4: Absolute refractive error (D)**

| Absolute refractive error (D) | MK, n (%) | AK, n (%) |
|------------------------------|-----------|-----------|
| $<±0.25$                     | 19 (57.57)| 24 (72.72)|
| $>±0.25$–$±0.5$              | 8 (24.24) | 5 (15.15) |
| $>±0.5$                      | 6 (18.18) | 4 (12.12) |
| Total                        | 33 (100)  | 33 (100)  |

MK = Manual keratometry, AK = Automated keratometry

**Table 5: Comparison of mean absolute refractive error in diopters between the two groups - manual and automated (n=66)**

| Parameter                   | Mean±SD       | t (df) | P    |
|-----------------------------|---------------|--------|------|
|                             | Manual group  | Automated group |
| Absolute refractive error (D)| $-0.15±0.38$  | $-0.07±0.39$  | 0.829 | 0.410 |
|                             | (33)          | (33)    |

SD = Standard deviation, NS = Not significant

**Figure 4:** Absolute refractive error for the Groups A and B

**Figure 5:** Plot of 33 biometries based on manual keratometry readings using Ladas super formula
device for biometry. If residual spherical refractive error in diopters is considered following SICS in both groups, a comparison of the two groups, wherein number of patients accepting < ±1D is done, then we conclude that 96.96% of patient accepted this correction in both groups. However, comparing the percentage of patients requiring up to ± 0.5D in the two groups, it was found that whereas 87.87% of patients in AK group needed this, only 81.81% of patients in MK group accepted this. With biometry done using AK, not only is the required residual spherical refractive error smaller but also more number of patients have accepted this smaller value as compared to MK group where a higher value (by ± 0.10D) had to be given.

Although comparison of SRK-II with any other newer generation formulas was not the objective of this study, yet, we observed reasonably good accuracy of biometry using this formula for eyes within normal axial length (22–24.5 mm).

If absolute refractive error is considered, statistically insignificant difference was noted between these two groups. However, from surgeon’s perspective, a happy patient is one who has no or low refractive aid in the form of glasses, which was better accomplished in the AK group.

**Ethical approval**

The study was conducted in accordance with the Declaration of Helsinki and was approved by the local ethics committee of the institute. Informed written consent was obtained from all patients prior to their enrollment in this study.

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Nil.

**Conflicts of interest**

The authors declare that there are no conflicts of interests of this paper.

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