Comparison of Techniques for Corneal Power Assessment After Myopic LASIK Without the Use of Preoperative Data

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ABSTRACT

PURPOSE: To compare the accuracy of different corneal power assessment techniques that do not require preoperative information with the clinical history method.

METHODS: This retrospective study analyzed 50 eyes of 50 patients using 3-month postoperative data. Net corneal powers were obtained with each of the following methods: Maloney, Wang, Sonego-Krone, Srivannaboon, Shammas, Orbscan flat axis, and Gaussian optics formula with Orbscan. Results were compared to the clinical history method using paired sample t test, Bland-Altman plots, and linear regression.

RESULTS: Both the Gaussian optics formula and Wang method were not significantly different from the clinical history method. The Sonego-Krone method significantly underestimated the corneal power, whereas the Maloney, Srivannaboon, Shammas, and Orbscan flat axis methods significantly overestimated the corneal power.


Laser in situ keratomileusis (LASIK) has become a popular form of corneal refractive surgery. As patients who have undergone corneal refractive surgery advance in age, an increasing number will develop visually significant cataracts that require surgery. It has been noted that intraocular lens (IOL) power calculation after corneal refractive surgery may be inaccurate and lead to postoperative refractive surprises.1-4

Inaccurate postoperative refractive outcome after cataract surgery has been reported in patients who have undergone radial keratotomy, photorefractive keratectomy, and LASIK.5-10 Such suboptimal refractive outcomes can be explained partly by the inaccuracy of standard corneal power assessment techniques in estimating the net corneal refractive power. With current keratometers and videokeratoscopes, the radius of curvature of the anterior corneal surface is what is actually measured. The keratometric diopters are derived from the radius of curvature using an effective refractive index in a paraxial formula where K = (n-1)/r. The refractive index between air and the anterior corneal surface is 1.376. Therefore, the refractive power of the anterior corneal surface should be 0.376/r. However, when estimating the IOL power, we are more interested in the net corneal power rather than the power of the anterior corneal surface. The assessment of the net corneal power is based on the assumption that the relationship between the anterior and posterior curvature is a constant. Based on Gullstrand’s eye model, the two refracting surfaces can be considered as one with a fictitious single
refractive index of 1.3375. This is the refractive index that most keratometers use.

After refractive surgery, the anterior corneal curvature has changed whereas the posterior curvature has remained constant; therefore, the basic assumption of Gullstrand’s eye model is no longer valid. The distance between the two refractive surfaces also has been reduced significantly. Using standard corneal power assessment in patients after LASIK will therefore result in a hyperopic surprise.

A number of methods have been suggested to assess the net corneal power in patients who have had myopic LASIK. The clinical history method\textsuperscript{11,12} derives the net corneal power by subtracting the change in spherical equivalent refraction induced by the corneal refractive procedure from the K-value measured before refractive surgery. It has been proposed as being the most reliable\textsuperscript{9,11,13} and has been confirmed in a number of studies.\textsuperscript{5,7,8,14} However, this method requires treatment data and corneal parameters before refractive surgery, which may not be available. In this study, seven different corneal power assessment techniques that do not require preoperative information were compared to the clinical history method.

\section*{PATIENTS AND METHODS}

\subsection*{STUDY POPULATION}

Fifty eyes from 50 consecutive patients were analyzed retrospectively based on the 3-month postoperative data. All patients underwent surgery at a university-based clinic from January 1 to February 28, 2006 by a single surgeon (A.C.K.C.). All patients had LASIK using the ALLEGRETTO Wave Eye-Q system (WaveLight Laser Technologie AG, Erlangen, Germany) with a standard treatment profile and a Hansatome microkeratome (Bausch & Lomb, Rochester, NY) with a 160-μm flap. At 3 months postoperatively, manifest refraction, corneal topography with Orbscan II (Bausch & Lomb, Salt Lake City, Utah), and ultrasound pachymetry (Micropach 200P; Sonomed, Lake Success, NY) were performed.

\section*{CORNEAL POWER ASSESSMENT}

Net corneal powers were assessed by the following seven methods and the clinical history method.

\textbf{Maloney Method.}\textsuperscript{15} This method involves modifying the corneal power at the center of the topographic map according to the formula: central power = (central topographic power × [376/337.5]) – 4.90 diopters (D).

\textbf{Wang Method.}\textsuperscript{15} This method is based on the Maloney method. However, 6.10 D instead of 4.90 D is used as the posterior corneal power to be subtracted.

\textbf{Sonego-Krone Method.}\textsuperscript{16} This method involves the assessment of the central 2-mm power by the Orbscan II total mean power map.

\textbf{Srivannaboon Method.}\textsuperscript{17} This method involves the assessment of the central 4-mm power by the Orbscan II total optical power map.

\textbf{Shammas Method.}\textsuperscript{18} In this method, assessment of net corneal power is based on a best-fit regression formula derived from a dataset of 100 patients.

\textbf{Orbscan Flat Axis.}\textsuperscript{19} This method uses the flattest keratometric power reading (Sim-K) after LASIK as net corneal power.

\textbf{Gaussian Optics Formula With Orbscan.}\textsuperscript{20} This method involves independent assessment of the radius of curvature of the anterior and posterior corneal curvature. The actual corneal power is calculated from these readings together with corneal thickness data.

\textbf{Clinical History Method.}\textsuperscript{11,12} Pre- and postoperative spherical equivalent refractions at the spectacle plane are used to calculate the change in spherical equivalent refraction. The value is then subtracted from the preoperative keratometric value to derive the postoperative value for refractive corneal power. The spectacle plane is used as it has been suggested the spectacle plane gives a better postoperative refractive outcome compared to that obtained from the corneal plane.\textsuperscript{21}

\subsection*{STATISTICAL ANALYSIS}

A paired sample t test was performed between each of these methods and the clinical history method. Normality was assessed using the Kolmogorov-Smirnov test for each paired group. Limits of agreements were defined as 2 standard deviations on either side of the mean.

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|}
\hline
\textbf{Technique} & \textbf{Mean±SD (D)} \\
\hline
Maloney & 37.32±2.52 \\
Wang & 36.12±2.52 \\
Sonego-Krone & 35.49±2.24 \\
Srivannaboon & 36.55±2.20 \\
Shammas & 36.84±2.27 \\
Orbscan flat axis & 37.81±1.94 \\
Gaussian optics formula & 36.36±2.10 \\
Clinical history method & 36.23±2.50 \\
\hline
\end{tabular}
\caption{Mean Corneal Power Calculated by Various Techniques}
\end{table}
**RESULTS**

Fifty eyes of 50 patients were analyzed retrospectively. Only the right eye was used in the study. Mean patient age was 35.4 ± 8.6 years. Mean preoperative manifest refraction spherical equivalent was −7.99 ± 2.28 D. Mean postoperative manifest refraction spherical equivalent was −0.42 ± 0.62 D. Best spectacle-corrected visual acuity was maintained in all patients, and no complications were noted. No patient was excluded from the study during the study period.

Kolmogorov-Smirnov testing for all testing pairs did not show statistical significance (P > .1), indicating the difference for all testing groups followed normal distribution. Table 1 shows the net corneal power calculated by the various techniques.

Comparison of various techniques with the clinical history method showed the Sonego-Krone method significantly underestimated the corneal power, whereas the Maloney, Srivannaboon, Shammas, and Orbscan flat axis methods significantly overestimated the corneal power (Table 2). Both the Gaussian optics formula and the Wang method did not show any statistically significant difference with the clinical history method. The Gaussian optics formula showed a difference of −0.13 ± 0.76 D (P = .23), whereas the Wang method showed a slightly lower difference of −0.11 ± 0.92 D (P = .43); the results were not statistically significant for either method.

The range of standard deviation among the study groups was close (0.68 to 0.95 D). The standard deviation and the range was the smallest for the Gaussian optics formula and the Sonego-Krone method. Using the Bland-Altman plot, the Gaussian optics formula also showed the smallest range of 3.04 D, with limits of agreement of −1.65 and 1.39 D (Table 2). In other words, there was a <5% chance the Gaussian optics formula would underestimate the clinical history method by 1.65 D or overestimate by 1.39 D.

Using linear regression, all methods showed good correlation with the clinical history method. Both the Gaussian optics formula and the Sonego-Krone method showed the highest correlation with the clinical history method (R² = 0.92) (Table 3).

**DISCUSSION**

With the increasing popularity of LASIK surgery, the number of patients with prior corneal refractive surgery who require cataract surgery also has increased. Intraocular lens power calculations in eyes with previous refractive surgery remains a challenge because of the difficulty in accurately assessing postoperative corneal power. A review of the current case series and case reports in the literature shows the clinical history method is the most adopted method and is more accurate than other methods in determining central corneal power. However, because preoperative LASIK corneal K-readings are not always available, it is important to identify an accurate method that does not depend on preoperative LASIK data.

The Maloney method converts the central corneal power obtained from corneal topography back to the anterior corneal power (central topographic power × [376/337.5])¹³,²⁶,²⁷ and then subtracts the posterior corneal power (4.90 D), which is based on Maloney’s own experience.

Using the Maloney method, Wang et al¹⁵ found the method consistently underestimated the IOL power and would result in postoperative hyperopia. Our results are also consistent with the reported findings. Compared to the clinical history method, the Maloney method also overestimated the corneal power by 1.09 ± 0.92 D, which, in turn, would lead to

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**TABLE 2**

Comparison of Various Corneal Power Assessment Techniques With the Clinical History Method

<table>
<thead>
<tr>
<th>Technique</th>
<th>Mean±SD Difference (D)</th>
<th>P Value*</th>
<th>Limits of Agreement (D)</th>
<th>Range (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maloney</td>
<td>1.09±0.92</td>
<td>&lt;.01</td>
<td>−0.75, 2.93</td>
<td>3.68</td>
</tr>
<tr>
<td>Wang</td>
<td>−0.11±0.92</td>
<td>.43</td>
<td>−1.95, 1.73</td>
<td>3.68</td>
</tr>
<tr>
<td>Sonego-Krone</td>
<td>−0.74±0.68</td>
<td>&lt;.01</td>
<td>−2.1, 0.62</td>
<td>2.72</td>
</tr>
<tr>
<td>Srivannaboon</td>
<td>0.32±0.77</td>
<td>&lt;.01</td>
<td>−1.22, 1.86</td>
<td>3.08</td>
</tr>
<tr>
<td>Shammas</td>
<td>0.61±0.85</td>
<td>&lt;.01</td>
<td>−1.09, 2.31</td>
<td>3.40</td>
</tr>
<tr>
<td>Orbscan flat axis</td>
<td>1.58±0.95</td>
<td>&lt;.01</td>
<td>−0.32, 3.48</td>
<td>3.80</td>
</tr>
<tr>
<td>Gaussian optics formula</td>
<td>−0.13±0.76</td>
<td>.23</td>
<td>−1.65, 1.39</td>
<td>3.04</td>
</tr>
</tbody>
</table>

*Paired sample t test.
The Orbscan flat axis technique produced the worst result, with a mean difference of $1.58 \pm 0.95$ D and the limits of agreement at $-3.32$, $3.48$ D. This technique would result in a much higher chance of postoperative hyperopic shift.

From the original article, Shammas et al. used a dataset of 200 eyes for analysis. The first 100 eyes were used to derive a regression formula between the clinical history method and the postoperative LASIK net corneal power. The second 100 eyes were used to validate the formula. The authors found the correlation coefficient between the clinical history method and their method was 0.95. The difference between the 2 mean values was $0.02 \pm 0.58$ D, which was not statistically significant. However, using the same method in our dataset, the difference was $0.61 \pm 0.85$ D; this difference was statistically significant. In addition, the correlation coefficient was lower ($R^2=0.89$).

Both the Gaussian optics formula with Orbscan II and the Wang method provided the closest match with the clinical history method in the current study with no significant difference. The standard deviation and the range of agreement was the smallest with the Gaussian optics formula. However, because the real gold standard is with actual IOL implants and back calculation of the net corneal curvature, the current study can only serve as a theoretical comparison among the different techniques. Further studies with actual IOL implants are required to validate the results.

**REFERENCES**

8. Morris AH, Whittaker KW, Morris RJ, Corbett MC. Errors in in-

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**TABLE 3**

<table>
<thead>
<tr>
<th>Technique</th>
<th>Correlation Coefficient ($R^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maloney</td>
<td>0.87</td>
</tr>
<tr>
<td>Wang</td>
<td>0.87</td>
</tr>
<tr>
<td>Sonego-Krone</td>
<td>0.92</td>
</tr>
<tr>
<td>Srivannaboon</td>
<td>0.91</td>
</tr>
<tr>
<td>Shammas</td>
<td>0.89</td>
</tr>
<tr>
<td>Orbscan flat axis</td>
<td>0.88</td>
</tr>
<tr>
<td>Gaussian optics formula</td>
<td>0.92</td>
</tr>
</tbody>
</table>

*Using linear regression and correlation coefficient; $P<.001$ for all techniques.*


