Comparison of IOL Power Calculation and Refractive Outcome After Laser Refractive Cataract Surgery With a Femtosecond Laser Versus Conventional Phacoemulsification

Tamás Filkorn, MD; Illés Kovács, MD, PhD; Ágnes Takács, MD; Éva Horváth, MD; Michael C. Knorz, MD; Zoltán Z. Nagy, MD, DSC

ABSTRACT

PURPOSE: To compare intraocular lens (IOL) power calculation and refractive outcome between patients who underwent laser refractive cataract surgery with a femtosecond laser and those with conventional cataract surgery.

METHODS: In this prospective study, 77 eyes from 77 patients underwent laser refractive cataract surgery (laser group; Alcon LenSx femtosecond laser), and conventional cataract surgery with phacoemulsification was performed in 57 eyes from 57 patients (conventional group). Biometry was done with optical low coherence reflectometry (Lenstar LS900, Haag-Streit AG), and IOL calculation was performed with third-generation IOL formulas (SRK/T, Hoffer Q, and Holladay). The refractive outcome was analyzed using the mean absolute error (MAE; difference between predicted and achieved postoperative spherical equivalent refraction), and multivariable regression analysis was performed to compare the two groups.

RESULTS: No significant differences were found between age, axial length, keratometry, and preoperative corrected visual acuity in the laser and conventional groups (P > 0.05; Mann-Whitney U test). At least 6 weeks after surgery, MAE was significantly lower in the laser group (0.38 ± 0.28 diopters [D]) than in the conventional group (0.50 ± 0.38 D) (P = 0.04). The difference was the greatest in short (axial length < 22.0 mm, 0.43 ± 0.41 vs 0.63 ± 0.48) and long (axial length > 26.0 mm, 0.33 ± 0.24 vs 0.63 ± 0.42) eyes.

CONCLUSIONS: Laser refractive cataract surgery with a femtosecond laser resulted in a significantly better predictability of IOL power calculation than conventional phacoemulsification surgery. This difference is possibly due to a more precise capsulorrhexis, resulting in a more stable IOL position. [J Refract Surg. 2012;28(8):540-544.]

PATIENTS AND METHODS

PATIENTS

In this prospective study, 77 eyes from 77 patients underwent laser refractive cataract surgery with an intraocular femtosecond laser (Alcon LenSx, Ft Worth, Texas) (laser group),
and conventional cataract surgery with phacoemulsification was performed on 57 eyes from 57 patients (conventional group). Table 1 shows the preoperative demographics; no significant differences were noted between groups regarding these parameters (P>.05; Mann-Whitney U test). Patients were randomly assigned to each group using a computer randomization chart. Exclusion criteria were previous ocular surgery, corneal diseases such as keratoconus, known zonular weakness, corneal astigmatism >3.00 diopters (D), anterior capsule tear, posterior capsule rupture, severe macular disease, and amblyopia. Every patient underwent a complete ophthalmologic evaluation, which included uncorrected (UDVA) and corrected distance visual acuity (CDVA), applanation tonometry, slit-lamp microscopy, and funduscopy. The study was conducted in compliance with the Declaration of Helsinki, as well as with applicable country and local requirements regarding ethical committee/institutional review board, informed consent, and other statutes or regulations regarding protection of the rights and welfare of human subjects participating in biomedical research.

**Surgery**

Patients in the conventional group had uneventful cataract surgery with a 2.75-mm clear corneal incision at 120°, a side-port at 60°, manual continuous curvilinear capsulorrhexis (CCC) with an attempted diameter of 4.5 mm, phacoemulsification (Accurus; Alcon Laboratories Inc, Ft Worth, Texas) with the same technique (chop), and IOL implantation in the capsular bag. Patients in the laser group underwent a laser procedure prior to the phacoemulsification surgery. All laser procedures were performed using the Alcon LenSx laser system. After pupillary dilation and instillation of topical or retrobulbar anesthesia, a curved applicator with a suction ring was applied. A 2.75-mm clear corneal laser incision at 120° and a 1.2-mm side-port at 60° were placed in all eyes. The capsulorrhexis was centered to the dilated pupil with a diameter of 4.5 mm and followed with a cross-shaped nucleus fragmentation with a diameter of 4.5 mm, extending 500 μm above the posterior capsule to 300 μm below the anterior capsule. Proprietary energy and spot separation parameters, which had been optimized in previous studies, were used for all laser procedures. Loss of suction or capsular tag did not occur in any case in this study sample. Neither astigmatic keratotomy nor limbal relaxing incisions were performed. After the laser procedure, the corneal incisions were opened using a blunt spatula, viscoelastic material was injected (Provisc, Alcon Laboratories Inc), and the anterior capsule was removed with forceps. The nucleus fragments were removed using phacoemulsification, followed by irrigation-aspiration and implantation of an IOL in the bag.

Several IOLs were used in the course of this study (Alcon AcrySof MA30AC, n=37; MA60AC, n=23; SA60AT, n=8; Bausch & Lomb [Rochester, New York] LI60AO, n=43; Oculentis [Preisvergleich, Germany] L-302-1, n=16; and Medicontur [Zsümbeök, Hungary] 690AB, n=7). The average power of the implanted IOLs was 20.34±5.92 D (range: −2.00 to +32.00 D). All operations were performed by the same surgeon (Z.Z.N.).

**IOL Calculation**

All patients had axial length and keratometry measurements by low coherence optical reflectometry (Lenstar LS900; Haag-Streit AG, Koeniz, Switzerland) before surgery. All three available third-generation IOL formulas (SRK/T, Hoffer Q, and Holladay 1) and optimized IOL constants were used for IOL calculation. To determine which formula to use, patients were divided into four subgroups. The Hoffer Q was used for short eyes (axial length <22.0 mm; n=20 [10 laser group and 10 conventional group]), the average of the three formulas for medium eyes (axial length 22.00 to 24.49 mm; n=81 [51 laser group and 30 conventional group]), the Holladay 1 for medium long eyes (axial length 24.50 to 25.99 mm; n=11 [4 laser group and 7 conventional group]), and the SRK/T

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Laser Group (n=77)</th>
<th>Conventional Group (n=57)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>65.18±12.6 (23 to 88)</td>
<td>64.37±12.37 (23 to 86)</td>
</tr>
<tr>
<td>Axial length (mm)</td>
<td>23.93±2.62 (20.12 to 34.33)</td>
<td>24.07±2.28 (20.66 to 31.5)</td>
</tr>
<tr>
<td>Average K (D)</td>
<td>43.53±1.53 (39.67 to 47.56)</td>
<td>43.13±1.64 (39.89 to 47.45)</td>
</tr>
<tr>
<td>SE (D)</td>
<td>−1.62±5.55 (−23.00 to +7.75)</td>
<td>−1.37±5.27 (−18.00 to +8.50)</td>
</tr>
<tr>
<td>CDVA (logMAR)</td>
<td>0.45±0.29 (0 to 1.3)</td>
<td>0.37±0.26 (0 to 1.22)</td>
</tr>
</tbody>
</table>

SD = standard deviation, K = keratometry, SE = spherical equivalent, CDVA = corrected distance visual acuity

*No statistically significant differences were found between groups (Mann-Whitney U test).
for long eyes (axial length ≥26.0 mm, n=22 [12 laser group and 10 conventional group]), as recommended in our national biometry protocol.

Postoperative refraction and CDVA were measured 6 to 12 weeks after surgery. Patients with CDVA 20/40 or worse were excluded (one patient in each group) to avoid errors in manifest refraction.

Mean absolute error (MAE) was calculated as the difference of the postoperative manifest refraction (spherical equivalent) and the predicted postoperative target refraction and used to analyze the accuracy of the power IOL calculation.

The MAE was calculated for all eyes to compare the two groups depending on the different IOL calculation formulas in all axial length subgroups. The percentage of eyes within ±0.25, ±0.50, ±1.00, ±1.50, and ±2.00 D of MAE was also determined.

**STATISTICAL ANALYSIS**

Statistical analyses were performed with SPSS 15.0 software (SPSS Inc, Chicago, Illinois). The Mann-Whitney U test was used for between-group comparisons of age and axial length. P<.05 was considered statistically significant. Correlation between MAE and axial length was tested using linear and nonlinear regression analysis. Multivariable regression analysis was performed to determine the effect of the type of surgery on postoperative refractive error after adjusting for the effect of axial length and IOL type. Akaike’s Information Criterion was used to find the best fitting model.  

**RESULTS**

Table 2 presents the postoperative data. Comparing refractive predictability, 41.6% of eyes were within ±0.25 D of target refraction in the laser group compared to 28.1% of eyes in the conventional group; 68.8% and 64.9% were within ±0.50 D, respectively; and 98.7% and 87.7% were within ±1.00 D, respectively. All eyes were within ±1.50 D in both groups (Fig 1).

Using the IOL power calculation formulas described above, the MAE was 0.38±0.28 D for all eyes in the laser group and 0.50±0.38 D for all eyes in the conventional group. The correlation between axial length and MAE in the two groups is shown in Figure 2. Significant cubic correlation was found in the conventional group (r=0.48) and laser group (r=0.42), both in favor of the laser group. No correlation was found in the conventional group (r=0.14, P=.011), whereas no correlation was found in the laser group (P>.05).

In multivariable modeling, the type of surgery showed significant effect on the postoperative MAE after adjusting for the effect of axial length and IOL type (P=.04). In the laser group, the MAE was lower than in the conventional group, with an average difference of 0.12 D. The IOL type had no effect on postoperative refractive error (P=.19) in the multivariable regression analysis. Differences were largest in short (axial length <22.0 mm; MAE=0.43±0.41 vs 0.63±0.48) and long eyes (axial length ≥26.0 mm; MAE=0.33±0.24 vs 0.63±0.42), both in favor of the laser group.

Analyzing the mean error (ME), no significant difference was noted between groups (−0.03±0.47 vs 0.07±0.63, P>.05 [Mann-Whitney U test]). No correlation was found between ME and axial length in the laser group (P=.41). In the conventional group, a weak
but significant correlation ($r = -0.29$, $P = .03$) was present, in which more myopic errors were found in eyes with long axial length.

**DISCUSSION**

Cataract surgery is also refractive surgery and the use of modern aberration-correcting or multifocal or accommodating IOLs requires a high degree of refractive predictability. Optical biometry reduces the error in axial length measurements, but calculation errors are still caused by variations in effective lens position.\(^4\) Despite precise calculation of the effective lens position, the real IOL position and refractive effect depend on other factors, such as lens thickness, refraction, and age.\(^6\) Our IOL calculation results are in agreement with previously published large studies using ultrasound\(^9\) and laser interferometry\(^10\) for IOL calculation.

We found a subtle but significant difference (0.12 D) in postoperative IOL power calculation error and better refractive outcomes after laser refractive cataract surgery with an intraocular femtosecond laser than after conventional phacoemulsification cataract surgery, when evaluated in multivariate analysis. The difference between IOL power calculation errors was highest in short (0.20 D) and long (0.30 D) eyes. Presumably, the higher the IOL power (short eyes), the higher the refractive change due to IOL displacement.\(^11\) Moreover, it was previously shown that IOL tilt, decentration, and anteroposterior movement are greater in long eyes.\(^6\) In previous studies, we measured and compared sizing and positioning parameters of femtosecond laser capsulotomy with manual continuous curvilinear capsulorrhexis.\(^5\) We found that more precise capsulotomy sizing, circularity, and centering can be achieved with a femtosecond laser. Properly sized, shaped, and centered femtosecond laser capsulotomies resulted in better overlap parameters. More consistent capsulorrhexis may explain smaller variations in IOL position, effecting the refractive outcome.\(^5,6\)

Intraocular lens misalignment is a well-known factor that can induce changes in postoperative refraction.\(^11-15\) Several studies used different methods for IOL power calculation, but did not differ in conclusions. Intraocular lens decentration and tilt induce myopic shift and oblique astigmatism, cause lateral shift of focus, and the resulting refractive error depends on the amount of decentration and tilt. Longitudinal IOL position errors are the principal component of visual outcome, whereas alignment errors have minor but significant effects on postoperative refraction.\(^14\) Some authors used a computer program to model the visual impairment caused by IOL misalignment.\(^16\) Aberration-free IOLs were proven to be less sensitive to decentration and tilt than aberration-correcting IOLs.\(^17\) The type and shape of the capsulorrhexis has a major effect on IOL position. Conventional CCC was shown to be safer and less likely to be associated with anterior capsular tears than a can opener or linear capsulotomy,\(^18\) and showed less IOL decentration and tilt.\(^19-21\) Even with an intact CCC, asymmetric capsular shrinkage, which is affected by capsulotomy shape, increases IOL decentration.\(^22\) Furthermore, the size of the capsulotomy and the area and regularity of anterior capsule–IOL overlap influence the IOL position.\(^23\)

In previous studies, our research group established that the decentration and tilt of an IOL can be significantly decreased when the capsulorrhexis is performed with a femtosecond laser as compared to the standard conventional technique.\(^5,6\) In this study, we found that the use of an intraocular femtosecond laser resulted in significantly lower IOL power calculation errors as expressed by a smaller MAE than in manual capsulorrhexis. The more predictable size, shape, and position of a femtosecond laser–created capsulorrhexis may contribute to minimized IOL misalignment, decentration, and tilt and therefore results in a smaller variability of the precalculated effective lens position. A limitation of our study is that several different IOL types were used; however, statistical analysis did not show a correlation based on IOL type.

**AUTHOR CONTRIBUTIONS**

Study concept and design (T.F., Z.Z.N.); data collection (T.F., A.T., E.H.); analysis and interpretation of data (T.F., I.K., M.C.K.); drafting of the manuscript (T.F.); critical revision of the manuscript
REFERENCES


