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 ($P>.05$; 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) ($P=.04$). 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.]

doi:10.3928/1081597X-20120703-04

Laser refractive cataract surgery with an intraocular femtosecond laser became available recently to create controlled incisions through photodisruption in eye tissue.[1] Initial clinical results of our group demonstrated a more predictable capsulorrhexis and reduced effective phacoemulsification energy compared to conventional surgery in porcine and human eyes.[2] With the use of aberration-correcting or multifocal intraocular lenses (IOLs), there is a higher expectation to achieve a precise refractive outcome after cataract surgery. With the increasing use of optical biometry, the error in IOL power calculation is less likely due to imprecise axial length measurement but remains affected by the variability of the effective lens position after surgery.[3,4] Intraocular lens tilt, decentration, and anteroposterior movement contribute to variations in effective lens position and are, among other reasons, caused by variations in capsulotomy size, shape, and position. The use of an intraocular femtosecond laser to perform the capsulorrhexis was shown to result in higher predictability of the capsulotomy,[5,6] which may result in better refractive outcomes. We therefore compared IOL power calculation and refractive outcome in laser refractive cataract surgery and conventional phacoemulsification using optical biometry and three third-generation IOL calculation formulas.

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),

From Semmelweis University Budapest, Faculty of Medicine, Department of Ophthalmology, Budapest, Hungary (Filkorn, Kovács, Takács, Horváth, Nagy); and Medical Faculty Mannheim, University of Heidelberg, Mannheim, Germany (Knorz).

Drs Knorz and Nagy are consultants to Alcon LenSx Inc. All remaining authors have no financial interest in the materials presented herein.

Correspondence: Tamás Filkorn, MD, Semmelweis University Budapest, 1085 Budapest, Mária u. 39, Hungary. Tel: 36 30 2433095; Fax: 36 1 317 9061; E-mail: filkorntamas@freemail.hu

Received: October 10, 2011; Accepted: May 31, 2012

Posted online: July 13, 2012

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.

TABLE 1

Preoperative Patient Demographics: Femtosecond Laser and Conventional Phacoemulsification*

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

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).*

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 applanator 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,[2] 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 [Zsámbék, 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

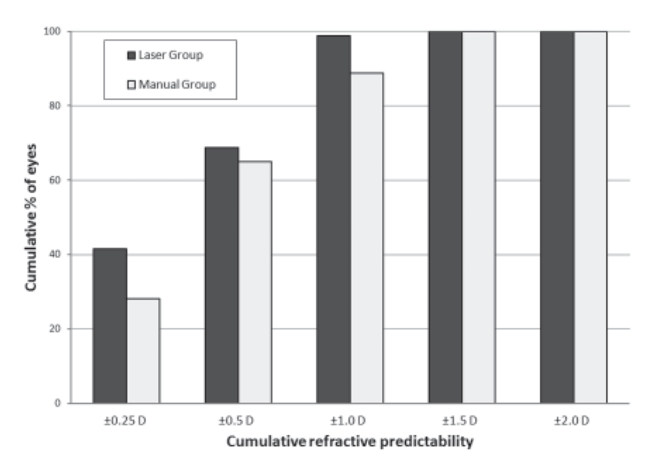

Figure 1. Cumulative refractive predictability of the eyes in the laser and conventional (manual) groups.

TABLE 2

Postoperative Outcomes: Femtosecond Laser and Conventional Phacoemulsification

	Mean±SD (Range)	
Parameter	**Laser Group (n=77)**	**Conventional Group (n=57)**
MRSE (D)*	−0.50±1.06 (−5.00 to +1.25)	−0.58±1.28 (−4.125 to +2.125)
CDVA (logMAR)*	0.03±0.06 (0 to 0.26)	0.02±0.04 (0 to 0.22)
MAE (D)	0.38±0.28 (0 to 1.09)	0.50±0.38 (0 to 1.48)
ME (D)*	−0.03±0.47 (−1.09 to +0.97)	0.07±063 (−1.40 to +1.48)
Avg K (D)*	43.59±1.50 (39.88 to 46.97)	43.22±1.62 (39.98 to 47.58)
Follow-up (wk)*	9.72±2.82 (6 to 12)	9.67±2.66 (6 to 12)

SD = standard deviation, MRSE = manifest refraction spherical equivalent, CDVA = corrected distance visual acuity, MAE = mean absolute error, ME = mean error, K = keratometry
**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.[7]

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=0.14, *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.

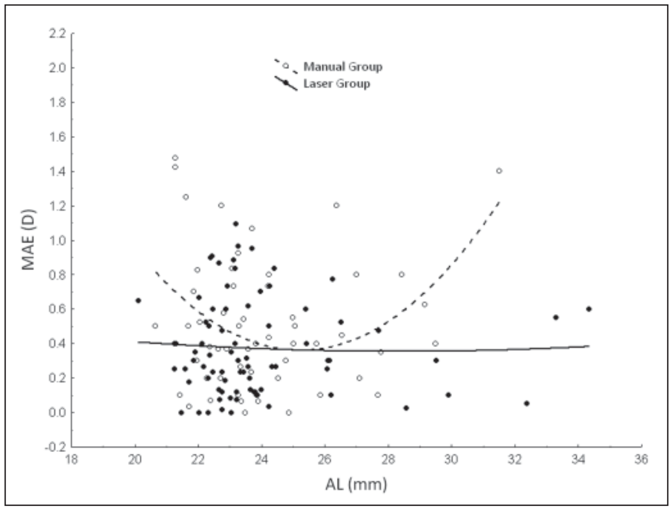

Figure 2. Correlation between axial length (AL) (Lenstar LS900) and mean absolute error (MAE) following laser refractive cataract surgery with a femtosecond laser (laser group) and conventional phacoemulsification (manual group).

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.[8] 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

(I.K., A.T., E.H., M.C.K., Z.Z.N.); statistical expertise (T.F., I.K.); administrative, technical, or material support (Z.Z.N.); supervision (I.K., Z.Z.N.)

REFERENCES

1. Krueger RR, Kuszak J, Lubatschowski H, Myers RI, Ripken T, Heisterkamp A. First safety study of femtosecond laser photodisruption in animal lenses: tissue morphology and cataractogenesis. *J Cataract Refract Surg*. 2005;31(12):2386-2394.
2. Nagy Z, Takacs A, Filkorn T, Sarayba M. Initial clinical evaluation of an intraocular femtosecond laser in cataract surgery. *J Refract Surg*. 2009;25(12):1053-1060.
3. Olsen T. Sources of error in intraocular lens power calculation. *J Cataract Refract Surg*. 1992;18(2):125-129.
4. Norrby S. Sources of error in intraocular lens power calculation. *J Cataract Refract Surg*. 2008;34(3):368-376.
5. Kránitz K, Takacs A, Miháltz K, Kovács I, Knorz MC, Nagy ZZ. Femtosecond laser capsulotomy and manual continuous curvilinear capsulorrhexis parameters and their effects on intraocular lens centration. *J Refract Surg*. 2011;27(8):558-563.
6. Nagy ZZ, Kránitz K, Takacs AI, Miháltz K, Kovács I, Knorz MC. Comparison of intraocular lens decentration parameters after femtosecond and manual capsulotomies. *J Refract Surg*. 2011;27(8):564-569.
7. Akaike H. A new look at the statistical model identification. *IEEE Transactions on Automatic Control*. 1974;19(6):716-723.
8. Olsen T. Prediction of the effective postoperative (intraocular lens) anterior chamber depth. *J Cataract Refract Surg*. 2006;32(3):419-424.
9. Gale RP, Saha N, Johnston RL. National Biometry Audit II. *Eye (Lond)*. 2006;20(1):25-28.
10. Aristodemou P, Knox Cartwright NE, Sparrow JM, Johnston RL. Formula choice: Hoffer Q, Holladay 1, or SRK/T and refractive outcomes in 8108 eyes after cataract surgery with biometry by partial coherence interferometry. *J Cataract Refract Surg*. 2011;37(1):63-71.
11. Lakshminarayanan V, Enoch JM, Raasch T, Crawford B, Nygaard RW. Refractive changes induced by intraocular lens tilt and longitudinal displacement. *Arch Ophthalmol*. 1986;104(1):90-92.
12. Atchison DA. Refractive errors induced by displacement of intraocular lenses within the pseudophakic eye. *Optom Vis Sci*. 1989;66(3):146-152.
13. Erickson P. Effects of intraocular lens position errors on postoperative refractive error. *J Cataract Refract Surg*. 1990;16(3):305-311.
14. Kozaki J, Tanihara H, Yasuda A, Nagata M. Tilt and decentration of the implanted posterior chamber intraocular lens. *J Cataract Refract Surg*. 1991;17(5):592-595.
15. Korynta J, Bok J, Cendelin J. Changes in refraction induced by change in intraocular lens position. *J Refract Corneal Surg*. 1994;10(5):556-564.
16. Korynta J, Bok J, Cendelin J, Michalova K. Computer modeling of visual impairment caused by intraocular lens misalignment. *J Cataract Refract Surg*. 1999;25(1):100-105.
17. Eppig T, Scholz K, Löffler A, Messner A, Langenbucher A. Effect of decentration and tilt on the image quality of aspheric intraocular lens designs in a model eye. *J Cataract Refract Surg*. 2009;35(6):1091-1100.
18. Assia EI, Apple DJ, Barden A, Tsai JC, Castaneda VE, Hoggatt JS. An experimental study comparing various anterior capsulectomy techniques. *Arch Ophthalmol*. 1991;109(5):642-647.
19. Caballero A, López MC, Losada M, Pérez Flores D, Salinas M. Long-term decentration of intraocular lenses implanted with envelope capsulotomy and continuous curvilinear capsulotomy: a comparative study. *J Cataract Refract Surg*. 1995;21(3):287-292.
20. Akkin C, Ozler SA, Mentes J. Tilt and decentration of bag-fixated intraocular lenses: a comparative study between capsulorhexis and envelope techniques. *Doc Ophthalmol*. 1994;87(3):199-209.
21. Oner FH, Durak I, Soylev M, Ergin M. Long-term results of various anterior capsulotomies and radial tears on intraocular lens centration. *Ophthalmic Surg Lasers*. 2001;32(2):118-123.
22. Ohmi S. Decentration associated with asymmetric capsular shrinkage and intraocular lens size. *J Cataract Refract Surg*. 1993;19(5):640-643.
23. Nanavaty MA, Raj SM, Vasavada VA, Vasavada VA, Vasavada AR. Anterior capsule cover and axial movement of intraocular lens. *Eye (Lond)*. 2008;22(8):1015-1023.