Comparison of Intraocular Lens Decentration Parameters After Femtosecond and Manual Capsulotomies

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ABSTRACT

PURPOSE: To evaluate a laser technique and manual technique to perform capsulorrhexis in cataract eyes.

METHODS: Anterior capsulotomy was performed with an intraocular femtosecond laser (LenSx Lasers Inc) in 54 eyes (FS group) and manual continuous curvilinear capsulorrhexis was performed in 57 eyes (CCC group). Circularity and area of capsulotomy and IOL decentration were measured using Photoshop CS4 Extended (Adobe Systems Inc) 1 week after surgery. Average keratometry, axial length, and preoperative anterior chamber depth were examined with the Lenstar LS 900 (Haag-Streit AG).

RESULTS: No statistically significant differences were noted between groups in axial length, preoperative refractive state, and in the area of capsulotomy. Circularity values were significantly better in the FS group (P=.032). We found incomplete overlap of capsulotomies in 28% of eyes in the CCC group and 11% in the FS group (P=.033). Significant correlations were noted between axial length and area of capsulotomy, and between average keratometry and area of the capsulotomy in the CCC group (R=0.278, P=.036; and R=−0.29, P=.033, respectively), but both did not correlate in the FS group (P>.05). In the CCC group, the pupillary area correlated significantly with the area of the capsulotomy (R=0.27, P=.039). Significant correlation was noted between IOL decentration and axial length in the CCC group (R=0.30, P=.026), but there was no correlation in the FS group (P>.05).

CONCLUSIONS: Femtosecond laser capsulorrhexis was more regularly shaped, showed better centration, and showed a better intraocular lens/capsule overlap than manual capsulorrhexis. [*J Refract Surg.* 2011;27(8):564-569.]

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Myopia and cataract are common disorders in the human population. Highly myopic eyes are more likely to develop cataract.[1] Cataract surgery has become a common, safe, and effective intervention performed worldwide.[2] However, surgery in eyes with long axial length is associated with increased risk of intra- and postoperative complications.[3]

Posterior capsular opacification is the most common surgically related cause of reduced vision after cataract surgery. Capsulorrhexis size, centration, and completely overlapping anterior capsule on the optic edge of the intraocular lens (IOL) affect the severity of this disorder. Although new IOL designs have diminished the incidence of posterior capsular opacification, a precise anterior capsulotomy is a crucial step in preventing the migration of lens epithelial cells.[4-6] Complete overlap helps prevent not only posterior capsular opacification but also results in better IOL centration and less myopic shift by maintaining the IOL in the proper position.[7,8]

In recent years, the most commonly applied technique during phacoemulsification is continuous curvilinear capsulorrhexis. Popularized by Gimbel and Neuhann,[9-11] it has several surgical and postoperative advantages, but special attention and surgical expertise are needed to complete it successfully. In highly myopic eyes, the larger size of the eye and pupillary diameter and optical distortion by the cornea may deceive surgeons to prepare a larger capsulorrhexis than intended.[12-14] This makes IOL malpositioning (eg, decentration, tilt, and luxation due to improper fixation in a larger capsular bag) more likely and may cause myopization and an increase in higher order aberrations.[15-17]

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With the advent of femtosecond lasers in cataract surgery, a predictably sized, centered, and shaped anterior capsulotomy became possible through tissue reaction known as photodisruption.[18,19]

In a previous study, we demonstrated that laser capsulorrhexis in animal eyes is superior in precision and predictability to manual capsulorrhexis whereas strength (tear resistance) is the same.[19] The purpose of the current study is to evaluate the difference between standardized femtosecond laser capsulorrhexis and manual capsulorrhexis in both normal cataractous and highly myopic cataractous eyes.

PATIENTS AND METHODS

Patients

In this study, femtosecond laser capsulotomies were carried out in 54 eyes of 53 patients and manual continuous curvilinear capsulorrhexis was performed in 57 eyes of 52 patients. All patients were examined 1 week after surgery. Each patient underwent complete ophthalmologic evaluation. Patients with previous ocular surgery, trauma, active ocular disease, poorly dilated pupils, or known zonular weakness were excluded from the study. Patient demographics are shown in Table 1.

Using computer randomization, patients and their right/left eyes were randomly selected for femtosecond and manual surgery.

Surgery

All surgeries were performed by the same surgeon (Z.Z.N.). Pupils were dilated with one drop of tropicamide 0.5% every 15 minutes for 45 minutes and topical anesthesia was achieved by the instillation of proparacaine HCl 0.5%.

In the laser capsulorrhexis group (FS group), surgery was started in a laser room outside the operating room, and a 4.5-mm capsulorrhexis was performed using the LenSx femtosecond laser system (LenSx Lasers Inc, Aliso Viejo, California). The eye was fixated with a curved applanator and the exact location of the lens and capsule was determined using optical coherence tomography built into the laser. The capsulotomy procedure was performed by scanning a cylindrical pattern starting at least 100 µm below the anterior capsule and ending at least 100 µm above the capsule. Proprietary energy and spot separation parameters, which had been optimized in previous studies, were used for all capsulotomies.

Following the laser procedure, all patients were brought into the operating room and standard phacoemulsification (Accurus; Alcon Laboratories Inc, Ft Worth, Texas) was performed. A 2.8-mm clear corneal

TABLE 1

Demographic Data of Patients Undergoing Femtosecond Laser Capsulorrhexis and Manual Continuous Curvilinear Capsulorrhexis

Demographic	FS Group	CCC Group	*P* Value*
No. of eyes (patients)	54 (53)	57 (52)	>.05
Mean age (y)	65±13	68±15	>.05
Sex (M:F)	15:39	17:40	>.05

FS = femtosecond, CCC = continuous curvilinear capsulorrhexis
**t test.*

incision was created, viscoelastic (Provisc, Alcon Laboratories Inc) was injected, and the cut capsule was removed with a capsulorrhexis forceps. In the manual capsulorrhexis group (CCC group), continuous curvilinear capsulorrhexis was performed with the aid of a cystotome and a capsulorrhexis forceps. The surgeon aimed for a 4.5-mm capsulorrhexis, but no guides were used during surgery. After hydrodissection, phacoemulsification of the nucleus and aspiration of the residual cortex were performed. A three-piece acrylic IOL was implanted in-the-bag in all eyes (MA60AC, Alcon Laboratories Inc) using the Monarch II injector and a C cartridge (Alcon Laboratories Inc). After IOL implantation, the viscoelastic material was removed from the anterior chamber and the capsular bag by irrigation/aspiration. All incisions were left sutureless. For the first 10 days postoperatively, all patients received a combination of antibiotic and steroid eye drops (Tobradex, Alcon Laboratories Inc).

Measurements

To document capsulotomies and IOL position, digital retroillumination photographs were taken 1 week after surgery with dilated pupils. Photos were imported into Adobe Photoshop CS4 Extended (Adobe Systems Inc, San Jose, California) to measure the area of the capsulorrhexis and its circularity. Circularity is a parameter used to determine the regularity of the shape of the capsulotomy according to the following formula: circularity=4Π (area/perimeter^2). Values of 1.0 indicate a perfect circle.

We also evaluated whether the capsulotomy showed circular overlap over the edge of the IOL optic or if there was only partial overlap. We did not evaluate the extent of the partial overlap, eg, 3 clock hours or 90°.

TABLE 2

Comparison of Lens Decentration Parameters of Femtosecond Laser Capsulorrhexis vs Manual Continuous Curvilinear Capsulorrhexis

	Median±Quartile Range		
Parameter	**FS Group**	**CCC Group**	***P* Value***
Axial length (mm)	23.78±2.46	23.39±3.46	>.05
Refractive state (SE)	−0.75±7.1	−0.75±5.5	>.05
Area of capsulotomy (mm^2)	16.91±1.78	17.78±2.8	>.05
Circularity of capsulotomy	0.86±0.04	0.85±0.03	.032
Complete overlap (%)	89	72	.033
Incomplete overlap (%)	11	28	.033

FS = femtosecond, CCC = continuous curvilinear capsulorrhexis, SE = spherical equivalent refraction
**Mann-Whitney U test.*

Intraocular lens decentration was evaluated according to the method by Becker et al.[20] The previously described method was altered by changing the reference point to the center of the pupil because both the femtosecond and manual capsulotomies were aligned with the pupil center. Adobe Photoshop gives a vector (determined by its length and angle to the horizontal plane) between the pupil center and center of the IOL. The length of the vector shows the total decentration of the IOL in reference to the pupil. To eliminate the effect of mydriatic drops on changing the position of the pupil center, the same amount and type of mydriatic drops were used to dilate the pupils before surgery and before taking the photographs.[21] For evaluating the correlation between axial length and pupillary area, each patient's pupil area was also measured by Adobe Photoshop.

To eliminate the magnification effect of the cornea, the diameter of the implanted IOL (6 mm) was used as a scale to recalculate all of the above mentioned parameters.

Keratometry, axial length, and preoperative anterior chamber depth were measured with the Lenstar LS 900 (Haag-Streit AG, Koeniz, Switzerland). Refractive power of the cornea is influenced by both its anterior and posterior surface; however, to simplify clinical measurements, only the power of the anterior surface was measured.

Statistical Analyses

Statistical analyses were performed with SPSS 16.0 (SPSS Inc, Chicago, Illinois). Departure from normal distribution assumption was tested by the Shapiro-Wilks W test. Patient demographic data show mean and standard deviation due to normal distribution. Descriptive statistics show median and quartile range due to non-normal distribution of data. Correlations between parameters were tested with the Spearman rank correlation test. Statistical analysis was performed by comparing two samples at a time using the Student *t* test and Mann-Whitney U test, depending on the departure from normal distribution.

RESULTS

Patient and Capsulotomy Characteristics

No intra- or postoperative complications were noted. No statistically significant differences between the FS group and CCC group regarding age, sex distribution, axial length, refractive state, and area of capsulotomies were noted. However, circularity values in the FS group were significantly higher than in the CCC group, and the percentage of complete anterior capsule/IOL overlap was significantly higher in the FS group (Table 2).

Overlap Characteristics

The area of all capsulotomies proved to be smaller than the optical zone of the implanted IOL in all eyes. We found incomplete overlap in 28% (16/57 eyes) in the CCC group and 11% (6/54 eyes) in the FS group. The difference between groups was statistically significant (P=.033) (Table 2).

Anatomical Characteristics of Eyes and Associations With Capsulotomy Parameters

A statistically significant correlation was found between axial length and average keratometry values (R=−0.22, P=.018) and between axial length and preoperative anterior chamber depth (R=0.27, P=.007).

According to our data, a statistically significant correlation was also noted between axial length and area of pharmacologically dilated pupil (R=0.19, P=.049) (Fig 1).

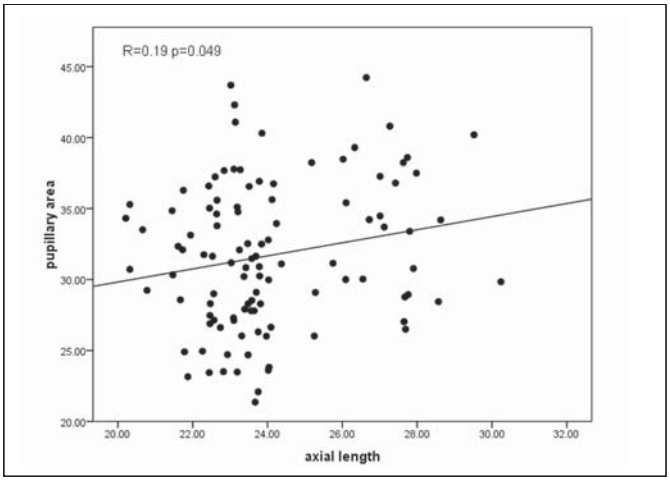

Figure 1. Correlation between axial length and area of dilated pupils (R=0.19; *P*=.049).

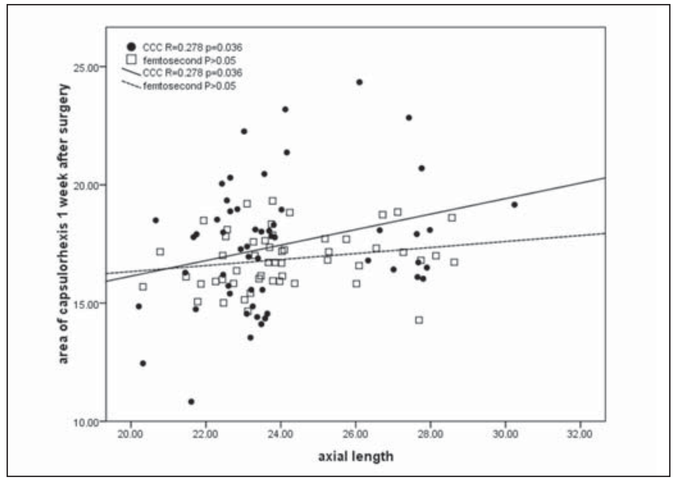

Figure 2. Correlation between axial length and area of capsulorrhexis 1 week after surgery. The correlation was significant in the manual capsulotomy group (CCC) (R=0.278, *P*=.036) but not in the laser capsulotomy group (femtosecond) (*P*>.05).

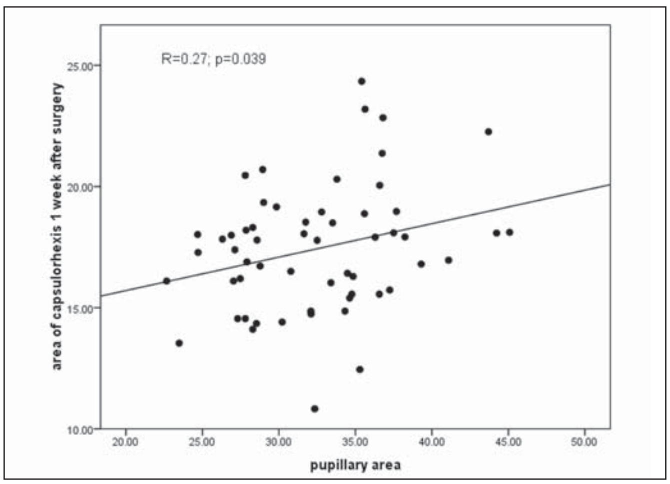

Figure 3. Correlation of pupillary area with area of capsulorrhexis 1 week after surgery in the manual capsulotomy group (R=0.27, *P*=.039).

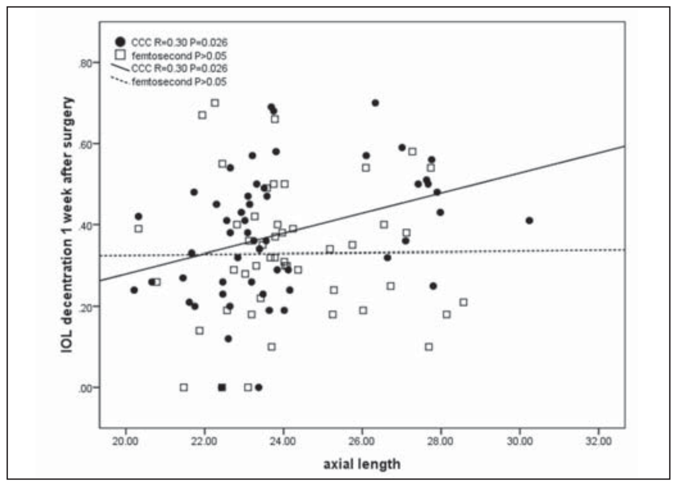

Figure 4. Correlation between axial length and intraocular lens decentration 1 week after surgery. The correlation was significant in the manual capsulotomy group (CCC) (R=0.30, *P*=.026) but not in the laser capsulotomy group (femtosecond) (*P*>.05).

Figure 2 shows significant correlations between axial length and area of capsulorrhexis in the CCC group (R=0.278, *P*=.036), but no statistically significant correlation was noted between these parameters in the FS group (*P*>.05). A statistically significant correlation between the average keratometry value of the cornea and the area of capsulorrhexis (R=−0.29, *P*=.033) in the CCC group was noted. No correlation was found between anterior chamber depth and capsulotomy area in either study group (*P*>.05).

As shown in Figure 3, the pupillary area correlated significantly with the area of capsulorrhexis in the CCC group (R=0.27, *P*=.039).

Values of IOL decentration showed a significant correlation with axial length in the CCC group (R=0.30, *P*=.026), but no statistically significant correlation was noted between IOL decentration and axial length in the FS group (*P*>.05) (Fig 4).

DISCUSSION

The purpose of our study was to investigate the difference between a femtosecond laser capsulotomy and a manual continuous curvilinear capsulorrhexis during cataract surgery. We evaluated capsulotomy size, circularity, IOL centration, and IOL/capsulotomy overlap and correlated these findings to pupillary area, axial length, and average keratometry.

Special anatomical characteristics of myopic eyes make cataract surgery a challenge for experienced surgeons including the creation of a properly sized and centered capsulorrhexis and IOL implantation in the correct position.[14,22-25]

Our results are in accordance with previous reports of the association between axial length and average keratometry values and between axial length and preoperative anterior chamber depth.[22,23] Previous articles reported larger pupillary diameters in myopic eyes under mesopic conditions.[24,25] According to our data, a statistically significant correlation was also noted between axial length and area of pharmacologically dilated pupils (see Fig 1). The cornea magnifies the anterior capsule approximately 1.15 times.[26] This distortion effect varies according to individual anterior segment anatomy. There is no reliable reference marker to aid the surgeon in creating the correct size and shape of continuous curvilinear capsulorrhexis, unless an intraocular device is used. Most commonly, the pupil margin is used as a reference, despite large variation in pupil diameter. Figure 3 shows that even an experienced surgeon tends to prepare larger capsulotomies in eyes with larger pupils.

Another variable that introduces error in capsulotomy sizing is the magnification caused by the cornea. Figure 5 shows how the diameter of the capsulorrhexis varies depending on corneal magnification. Figure 5A represents a myopic eye and Figure 5B a hyperopic eye. The average keratometry value of a flatter myopic cornea seems to virtually compensate larger pupil diameters due to relatively smaller magnification effect. Our results confirm the previously reported fact that axial length is in inverse proportion to average keratometry.[22] According to our results, a statistically significant correlation exists between average keratometry and capsulorrhexis area 1 week after surgery. In addition, the optical effect of the anterior chamber depth on magnification should also be considered. However, we found no correlation between preoperative anterior chamber depth and area of capsulotomy 1 week after surgery. As a consequence of these effects, a manual capsulorrhexis is often larger in myopic eyes. Using a laser, these errors can be eliminated, which is shown by the lack of a correlation between capsulorrhexis and axial length in the laser group (see Fig 2).

Intraocular lens implantation in myopic eyes during conventional cataract surgery may lead to a higher risk of IOL decentration due to larger capsular bag and larger capsulorrhexis.[14] We did not find a correlation between IOL centration and axial length in the laser group, but one was found in the manual capsulotomy group (see Fig 4), which suggests that IOL centration is better after femtosecond laser capsulotomy. This is supported by our finding that an incomplete overlap between anterior capsule and IOL occurred more frequently in the manual capsulotomy group than in the laser group (Table 2).

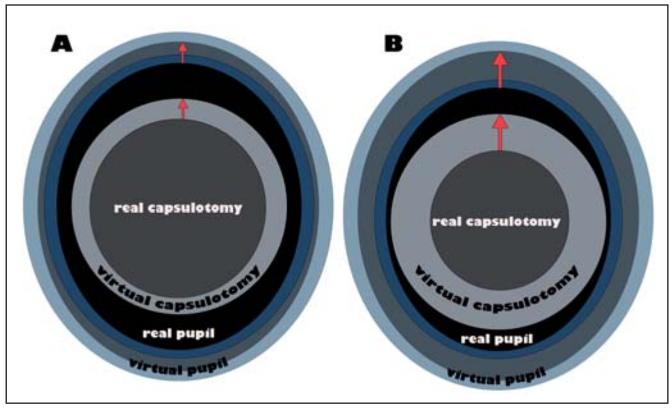

Figure 5. Distortion effect of **A)** myopic and **B)** hyperopic corneas. Red arrows show the magnification effect of the cornea depending on average keratometry values.

A decentered IOL with an incomplete anterior capsule overlap may cause myopization and, more importantly, a higher incidence of posterior capsule opacification due to an incomplete barrier effect; however, longer-follow up is needed to confirm these possibilities.

Our results show that capsulorrhexis performed with a femtosecond laser is more regularly shaped, does not correlate with pupil size and axial length, and results in a better IOL/capsule overlap and better IOL centration than manual capsulorrhexis.

AUTHOR CONTRIBUTIONS

Study concept and design (Z.Z.N., K.K.); data collection (Z.Z.N., K.K., A.I.T., K.M., I.K.); analysis and interpretation of data (Z.Z.N., K.K., I.K., M.C.K.); drafting of the manuscript (Z.Z.N.); critical revision of the manuscript (K.K., A.I.T., K.M., I.K., M.C.K.); statistical expertise (Z.Z.N., K.K., K.M.); administrative, technical, or material support (Z.Z.N., A.I.T., M.C.K.); supervision (K.K., I.K.)

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