Central Corneal Volume and Endothelial Cell Count Following Femtosecond Laser–assisted Refractive Cataract Surgery Compared to Conventional Phacoemulsification

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ABSTRACT

PURPOSE: To compare the effect of conventional phacoemulsification and femtosecond laser–assisted cataract surgery on the cornea using Scheimpflug imaging and noncontact specular microscopy.

METHODS: In each group, 38 eyes (38 patients) underwent cataract surgery using either femtosecond laser–assisted (Alcon LenSx laser) (femtolaser group) or conventional phacoemulsification (phaco group). Central corneal thickness, 3-mm corneal volume, and Pentacam Nucleus Staging (PNS) were determined by a rotating Scheimpflug camera (Pentacam HR, Oculus Optikgeräte GmbH), and the volume stress index was calculated at 1 day and 1 month postoperatively. Endothelial cell count was measured by noncontact specular microscopy preoperatively, 1 day, 1 week, and 1 month postoperatively.

RESULTS: Central corneal thickness was significantly higher in the phaco group (607±91 μm) than in the femtolaser group (580±42 μm) on day 1, but did not differ significantly preoperatively and at 1 week and 1 month. Volume stress index at day 1 was significantly lower in the femtolaser group than in the phaco group ($P<.05$) but did not differ significantly at 1 month. Multivariate regression analysis showed that the type of surgery had a significant effect on central corneal thickness.

CONCLUSIONS: Femtosecond laser–assisted cataract surgery causes less corneal swelling in the early postoperative period and may cause less trauma to corneal endothelial cells than manual phacoemulsification. [*J Refract Surg*. 2012;28(6):387-391.]

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With the advent of femtosecond laser–assisted cataract surgery, a highly controlled and reproducible capsulotomy, efficient lens fragmentation or liquefaction, and precise and reproducible creation of a corneal incision became possible.[1-6]

Corneal edema is one of the most frequent early postoperative complications of phacoemulsification, which can sometimes lead to permanent and serious visual disturbances. Postoperative corneal swelling and endothelial cell loss are related to many factors, including phacoemulsification time and energy, cataract density, corneal pathology, anterior chamber depth, axial length, ocular trauma, free radical development, mechanical and heat injury, phacoemulsification technique, experience of the surgeon, and use of viscoelastic material.[7-13]

Corneal swelling can be determined by many techniques, including ultrasound or optical pachymetry, anterior segment optical coherence tomography (OCT), or Scheimpflug imaging.[14,15] Using the Pentacam HR (Oculus Optikgeräte GmbH, Wetzlar, Germany) as a three-dimensional method for evaluating the whole anterior segment adds the capability of measuring central corneal volume within a 3-mm area.[15]

Central corneal swelling must be discussed separately from peripheral corneal edema because of the difference in its origin and nature of its development. Pentacam analysis showed that although 3-mm corneal volume often returns to preoperative values by 1 month after phacoemulsification, 10-mm corneal volume remains high over 3 months, indicating that recovery from surgery takes longer near the incision site than at the central cornea.[15,16]

Suzuki et al[17] created a new formula that provides information about endothelial cell function, called volume stress index (VSI), a parameter that indicates the volume-homeo-

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TABLE 1

Demographics of Patients Treated With an Intraocular Femtosecond Laser Before Phacoemulsification and Phacoemulsification Only

Demographic	Femtolaser Group	Phaco Group	*P* Value
Age (y)	65.81±12.42	66.93±10.99	>.05
Gender (M:F)	10:28	15:23	>.05
MRSE (D)	−1.00±4.70	−1.00±5.50	>.05

MRSE = manifest refraction spherical equivalent

static function for each corneal endothelial cell. This method is based on measuring the postoperative alteration of central corneal volume (in a 3-mm diameter area) and central endothelial cell density.

In our study, we aimed to analyze postoperative central corneal edema, endothelial cell count, and endothelial cell function, expressed by VSI, following femtosecond laser–assisted phacoemulsification compared to conventional phacoemulsification.

PATIENTS AND METHODS

Based on our preliminary data, at least 32 patients were required to achieve 90% power in statistical calculations. In this prospective study, femtosecond laser–assisted cataract surgery was performed in 38 eyes from 38 patients (femtolaser group) and conventional phacoemulsification in 38 eyes from 38 patients (phaco group) with various grades of cataract between February 2010 and February 2011. Patients were randomly assigned (using computer randomization) to either group by the surgeon (Z.Z.N.). Patients showing low cooperation, dense (grade 4+) or white cataract, corneal scars or opacities, anterior segment abnormalities, floppy iris syndrome, and poor pupillary dilation were not included in the study.

Demographics are shown in Table 1, and preoperative values in Table 2. No significant differences were present between groups.

The study was designed in accordance with the rules of the university's ethical committee. All study procedures followed the tenets of the Declaration of Helsinki. Informed consent was obtained.

All operations were performed under topical (proparacaine HCL 0.5%) anesthesia by the same surgeon (Z.Z.N.). Pupillary dilation was achieved with the instillation of one drop of tropicamide 0.5% every 15 minutes, three times before surgery.

In the phaco group, 2.8-mm clear corneal and side-port incisions were made with a disposable keratome (Alcon Laboratories Inc, Ft Worth, Texas). Continuous curvilinear capsulorrhexis was performed with a cystotome and a capsular forceps, and a divide-and-conquer phaco technique was used.

In the femtolaser group, the LenSx femtosecond laser system (Alcon LenSx Inc, Aliso Viejo, California)

TABLE 2

Anterior Segment and Surgical Parameters of Eyes Treated With an Intraocular Femtosecond Laser and Phacoemulsification and Phacoemulsification Only

Parameter	Femtolaser Group	Phaco Group	*P* Value
Preop CCT (μm)	545±32	550±39	>.05
Preop CV 3-mm (mm^3)	3.9±0.2	4.0±0.3	>.05
Corneal ECD (cells/mm^2)	2861±215	2841±215	>.05
ACD (mm)	2.57±0.39	2.62±0.45	>.05
Lens thickness (mm)	4.5±0.5	4.4±0.5	>.05
Axial length (mm)	24.1±3.0	23.9±2.9	>.05
Preop IOP (mmHg)	16.0±3.2	15.6±2.9	>.05
Scheimpflug-measured lens nuclear density	2.32±0.97	2.13±1.22	>.05
Phaco energy (%)	12.7±8.3	20.4±12.6	<.05
Phaco time (s)	0.56±0.6	0.67±0.75	>.05
Effective Phaco Time (s)	0.10±0.12	0.12±0.13	>.05

CCT = central corneal thickness, CV = corneal volume, ECD = endothelial cell density, ACD = anterior chamber depth, IOP = intraocular pressure was used to generate a 4.75-mm capsulotomy, lens fragmentation in a cross pattern, and two corneal incisions (a 2.8-mm two-plane main incision and a 1.0-mm single-plane side-port incision) as described previously.[3] Following femtosecond laser treatment, the corneal incisions were opened with a blunt spatula and the anterior chamber was filled with viscoelastic material (Provisc, Alcon Laboratories Inc). The edge of the laser-dissected anterior capsule was checked for complete separation with a cystotome, and the dissected capsule was pulled out of the eye with a forceps. Following hydrodissection, standard phacoemulsification was used to remove the four quadrants of the nucleus pre-chopped by the laser. In both groups, the Infinity phaco system was used (Alcon Laboratories Inc; vacuum 380 mmHg fixed, aspiration rate 35 cc/min fixed, bottle height 110 cm), and after cortex removal and implantation of the one-piece hydrophobic acrylic IOL (Alcon Laboratories Inc), the viscoelastic material was completely removed by irrigation-aspiration. Gentle hydration of the main corneal incision was performed in both groups.

Pre- and Postoperative Measurements

All patients underwent a complete ophthalmologic evaluation including corrected distance visual acuity, manifest refraction, slit-lamp examination, and intraocular pressure (IOP) measurement. Biometry was performed using a non-contact optical low-coherence reflectometer (Lenstar LS 900; Haag-Streit AG, Koeniz, Switzerland).

Pentacam HR Scheimflug imaging was used to measure 3-mm central corneal volume (3-mm CV) and thickness as well as nucleus density preoperatively (Pentacam Nucleus Staging [PNS]). Central endothelial cell count was measured with a Konan Noncon Robo Specular Microscope NSP-9900 (Konan Medical Inc, Hyogo, Japan). All measurements were repeated at 1 day, 1 week, and 1 month postoperatively. Examiners were not aware of which surgical procedure had been used when performing the postoperative examinations.

Volume stress index was calculated according to the formula described by Suzuki et al[15,17] as recommended: $VSI = \Delta V \div (CD \times 7.065)$ ($\Delta V = V2 - V1$). V2 is the 3-mm CV after phacoemulsification, V1 is the 3-mm CV before phacoemulsification, and $7.065 = 1.5 \times 1.5 \times 3.14$ (a 3-mm diameter area).

Statistical Analyses

Statistical analyses were performed with Statistica 8.0 (Statsoft Inc, Tulsa, Oklahoma). Departure from normal distribution assumption was tested by the Shapiro-Wilks W test. Due to normality of data, descriptive statistics show mean and standard deviation. For group comparisons of continuous variables, the independent-sample *t* test was used. To analyze changes in central corneal thickness over the time course, a repeated-measures analysis of variance was used. To test the effect of type of surgery on postoperative central corneal thickness, a multivariable regression analysis was performed. Preoperative central corneal thickness, central endothelial cell count, anterior chamber depth, PNS, and effective phacoemulsification time were incorporated as covariates in the multivariable regression model to adjust for their effects on postoperative central corneal thickness. Variables were kept in the model if they were associated with a P value $<.05$ and the overall fit of the model improved as indicated by the change of R^2, which was used to find the best fitting multivariable model. In all analyses, $P<.05$ was considered statistically significant.

TABLE 3

Central Corneal Thickness Comparison

	Central Corneal Thickness (µm)			
Group	**Preop**	**1 Day**	**1 Week**	**1 Month**
Femtolaser	545±31	580±42*	554±36	545±31
Phaco	550±39	607±91*	559±52	557±42

$P<.05$ compared to preoperative values using repeated measures analysis of variance.

RESULTS

Pentacam Nucleus Staging showed a statistically significant positive correlation with effective phacoemulsification time in both groups ($r=0.35$, $P<.05$, femtolaser group, and $r=0.5$, $P<.05$, phaco group). Central corneal thickness values in the two groups are shown in Table 3 and Figure A (available as supplemental material in the PDF version of this article). The final multivariable model, which included central endothelial cell count, PNS, preoperative central corneal thickness, and group as predictors, had the best-fit index with $R^2=0.48$. In this multivariable modeling, the type of surgery showed a significant effect on central corneal thickness at the first postoperative day whereas it was adjusted for the effect of the other factors.

In the femtolaser group, postoperative central corneal thickness on day 1 was significantly lower compared to the phaco group, with a mean difference of 29 µm (Table 3). Central endothelial cell count ($P<.05$), PNS ($P<.05$), and preoperative central corneal thick-

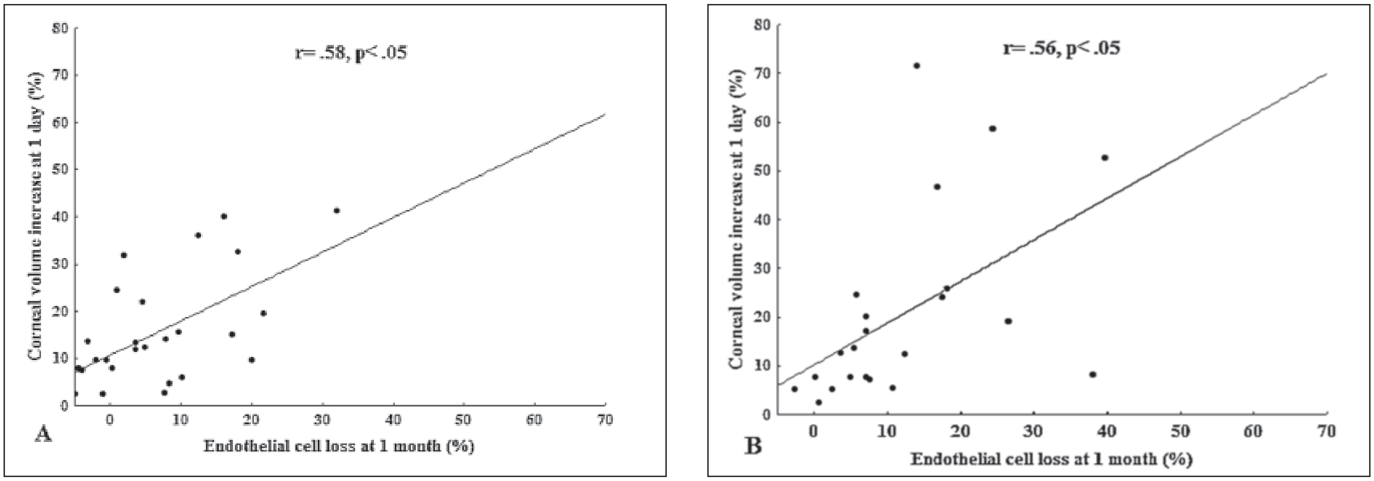

Figure 1. Correlation between corneal volume increase at 1 day (%) and endothelial cell loss at 1 month (%) in eyes treated with an intraocular femtosecond laser and phacoemulsification (femtolaser group) and with phacoemulsification only (phaco group). **A)** Femtolaser group, r=0.58, $P<.05$. **B)** Phaco group, r=0.56, $P<.05$.

TABLE 4

Corneal Endothelial Cell Count Comparison

	Endothelial Cell Count (cells/mm²)			
Group	**Preop**	**1 Day**	**1 Week**	**1 Month**
Femtolaser	2861±216	2860±217	2730±205	2738±245
Phaco	2841±215	2719±350	2669±377	2542±466

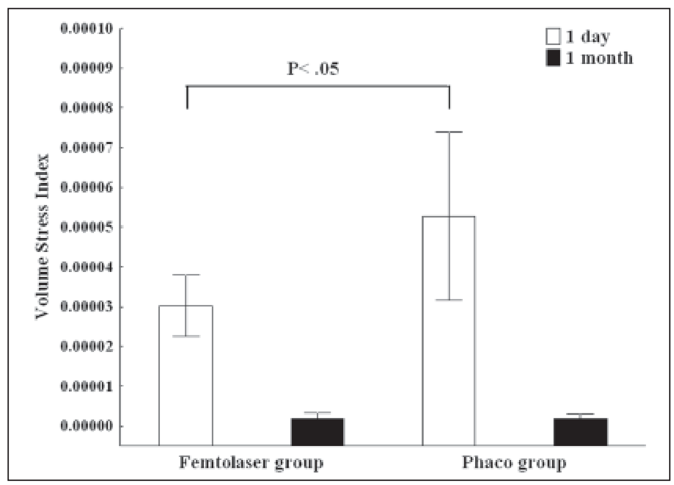

Figure 2. Volume Stress Index in eyes treated with an intraocular femtosecond laser and phacoemulsification (femtolaser group) and with phacoemulsification only (phaco group) ($P<.05$ at 1 day and $P>.05$ at 1 month).

ness ($P<.001$) had a significant effect on postoperative central corneal thickness. Anterior chamber depth and effective phacoemulsification time had no effect on postoperative central corneal thickness ($P>.05$). Corneal endothelial cell counts were slightly lower in the phaco group at all postoperative follow-up examinations, but differences were not statistically significant, possibly due to the large standard deviation in the phaco group (Table 4).

Figure 1 shows a significant positive correlation between the 3-mm corneal volume increase at postoperative day 1 and endothelial cell loss at 1 month postoperative in both groups.

Volume stress index was $3.0\pm2.3\times10^{-5}$ in the femtolaser group and $5.3\pm6.0\times10^{-5}$ in the phaco group at postoperative day 1 and this difference proved to be statistically significant. The difference between the groups regarding VSI was not significant at 1 month, being $1.7\pm3.7\times10^{-6}$ and $1.7\pm3.5\times10^{-6}$, respectively (Fig 2).

DISCUSSION

In our prospective study, we focused on the effect of femtosecond laser preoperative treatment of the nucleus on the postoperative central corneal thickness and central endothelial cell function, expressed by the VSI. We used Pentacam densitometry (PNS) to determine lens density, because it is an objective method and correlates strongly with the Lens Opacities Classification System (LOCS) III.[18] Cataract grades did not differ significantly between groups (Table 2).

Elnaby et al[19] described that mean effective ultrasound time intraoperatively and percentage of endothelial cell loss at 3 months postoperatively were significantly lower when the phaco prechop technique was used compared to the divide-and-conquer technique.

We also found that postoperative central corneal thickness was significantly lower in the femtolaser group compared to the phaco group on day 1, but not significantly different at 1 week and 1 month (Table 3). We also found a significantly lower VSI in the femtolaser group than in the phaco group 1 day postoperatively (see Fig 3). Phacoemulsification energy was also significantly higher in the phaco group than in the femtolaser group, and both phacoemulsification time and effective phacoemulsification time were higher in the phaco group, but differences were not statistically significant (Table 2). Corneal endothelial cell counts were lower in the phaco group at all postoperative follow-ups, but differences were not statistically significant, possibly due to the high standard deviation in the phaco group (Table 4).

Our study has a few limitations, eg, lack of an extended analysis of endothelial cell morphology (coefficient of variation, percentage of hexagonal cells). In addition, patients were not matched according to lens density, although mean values did not differ significantly between groups (Table 2), and randomization was done by the surgeon and not by randomization tables.

Despite these limitations, our findings indicate that pre-chopping the nucleus with a femtosecond laser reduces phacoemulsification power and endothelial cell trauma, as compared to standard phacoemulsification.

AUTHOR CONTRIBUTIONS

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

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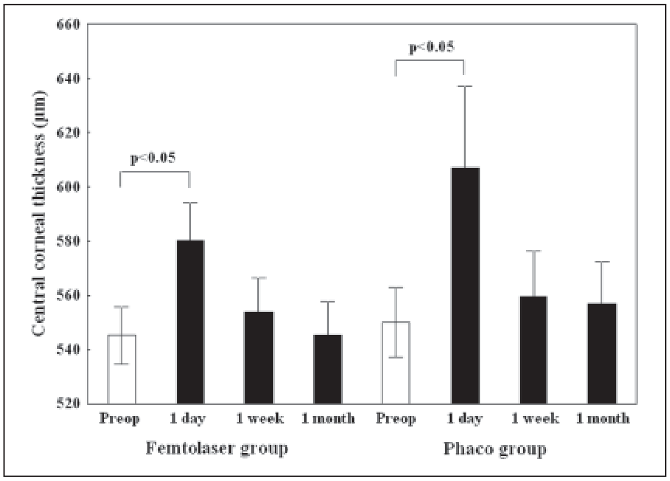

Figure A. Mean values of central corneal thickness in eyes treated with an intraocular femtosecond laser and phacoemulsification (femtolaser group) and with phacoemulsification only (phaco group) at different time points ($P<.05$ using repeated measures analysis of variance; whisker: 95% confidence limits of mean).