Effect of femtosecond laser fragmentation of the nucleus with different softening grid sizes on effective phaco time in cataract surgery

Ina Conrad-Hengerer, MD, Fritz H. Hengerer, MD, Tim Schultz, MD, H. Burkhard Dick, MD

PURPOSE: To compare the effect of different fragmentation softening grids in femtosecond laser–assisted cataract surgery on effective phacoemulsification time (EPT).

SETTING: Ruhr University Eye Clinic, Bochum, Germany.

DESIGN: Prospective randomized clinical trial.

METHODS: The study evaluated the feasibility of using a femtosecond laser (Catalys Precision Laser System) to perform capsulotomy and lens fragmentation in the treatment of patients with senile cataract. Patients were evaluated preoperatively with the Lens Opacities Classification System III (LOCS III). Patients had laser refractive cataract surgery with 350 μm fragmentation grids or with 500 μm fragmentation grids. Both groups had phacoemulsification using pulsed ultrasound energy, and the EPT was evaluated.

RESULTS: Eighty patients were treated with 350 μm fragmentation grids and 80 patients with 500 μm fragmentation grids. The mean preoperative LOCS III grade was 3.7 ± 0.8 (SD) in the 350 μm group and 3.5 ± 0.8 in the 500 μm group. The mean laser treatment time was 66.4 ± 14.4 seconds in the 350 μm group and 52.8 ± 11.9 seconds in the 500 μm grid group and the mean EPT, 0.03 ± 0.05 seconds and 0.21 ± 0.26 seconds, respectively.

CONCLUSION: The use of the femtosecond laser–assisted system in cataract surgery with 350 μm grid softening led to a statistically significant lower EPT than the 500 μm grid.

Financial Disclosure: Dr. Dick is a member of the medical advisory board of Optimedica Corp. No other author has a financial or proprietary interest in any material or method mentioned.

J Cataract Refract Surg 2012; ■ ■ ■ ⃝ 2012 ASCRS and ESCRS

The femtosecond laser has been used clinically in a variety of anterior segment applications. These include creation of a corneal flap for laser in situ keratomileusis refractive surgery, arcuate incisions for modifying corneal astigmatism, and penetrating keratoplasty for corneal transplantation.

In the past 3 years, femtosecond lasers have been used in cataract surgery for capsulotomy creation, lens fragmentation, and corneal incision creation. The safety of femtosecond laser technology with regard to the parameters in current use and as proposed in this trial has been shown in preclinical animal experiments of retinal damage, corneal endothelial cell preservation, and the use of the femtosecond laser for lamellar keratoplasty and presbyopia correction. Additional studies evaluated the possible effects of the femtosecond laser on the retina, centration of the intraocular lens (IOL), and higher-order aberrations after laser capsulotomy. Bali et al. reported their clinical experience with the first 200 eyes having laser cataract surgery in a single center.

This paper reports the reduction in the ultrasound energy required to break up and remove the cataractous lens after pretreatment using 2 grid sizes with
a femtosecond laser. Studies12–14 have shown that the reduction in the amount of ultrasound energy from the phacoemulsification probe can diminish the risk for capsule complications and corneal endothelial injury. Phaco time and average phaco power are known to have a positive correlation with the nuclear opalescence/nuclear color grading results of nuclear cataract on the Lens Opacities Classification System III (LOCS III) scale.15 Therefore, we designed our study to report the total reduction in ultrasound energy and in different groups based on LOCS III grading. We wanted to know whether reducing the grid size from 500 μm to 350 μm is more efficient in decreasing phaco energy.

**Patients and Methods**

Patients in this trial were scheduled for elective unilateral cataract surgery and IOL implantation by the same experienced surgeon (H.B.D.) at the Department of Ophthalmology, University of Bochum, Germany. The study received approval of the Ethics Committee, Ruhr University of Bochum, and all aspects of the Declaration of Helsinki were observed. Patients enrolled had a visually significant cataract and were willing to volunteer for the trial after giving an informed consent. They were enrolled from January to March 2012.

The exclusion criteria included a history of serious coexisting ocular disease (eg, pseudoxfoliation syndrome, uncontrolled glaucoma, optic atrophy, ocular tumors), use of topical or systemic steroids or nonsteroidal antiinflammatory drugs during the previous 3 months, relevant corneal opacities, poorly dilating pupils (pupil size ≤6.0 mm), known zonular weakness, age younger than 22 years, and participation in another clinical study.

The LOCS III16 nuclear opalescence grading score was used. An independent physician estimated preoperative nuclear opalescence using a BQ 900 slitlamp (Haag-Streit) at maximum illumination without light filtering. Intraoperative measurements were the femtosecond procedure time, the capsulotomy size, the absolute phacoemulsification time, the effective phacoemulsification time (EPT), and the mean phaco power. The IOL power calculations were performed using noncontact partial coherence laser interferometry (IOLMaster, Carl Zeiss Meditec AG).

**Surgical Technique**

The femtosecond laser treatment (Catalys Precision Laser System, Optomeda) was applied before ultrasound phacoemulsification and IOL implantation were performed. All patients were placed in a reclining chair and positioned supine beneath the system. The 2-piece Liquid Optics Interface, consisting of a suction ring and a nonapplanating immersion lens, was engaged by the surgeon while he controlled the patient chair using video imaging for alignment. Once suction was confirmed, the system automatically measured the dimensions of the anterior chamber and the lens with spectral-domain optical coherence tomography, identified the ocular surfaces, and created laser exclusion zones. The results were displayed to the surgeon for verification. At this point, the surgeon had the option of using the video graphic user interface to reposition and/or redesign the capsulotomy and lens fragmentation procedures. The attempted capsulotomy diameter was 5.0 mm in all cases. A standardized lens-softening pattern (quadrant grid size) with a 350 μm grid size was used in 1 study group and a 500 μm grid size in the other study group after randomization (Table 1 and Figure 1). Once the surgeon verified all parameters, he began the selected treatment. The capsulotomy was performed first, after which the patterns were created. The femtosecond laser pulses were focused starting at the predefined distance from the posterior capsule (posterior safety margin) and moved in the anterior direction through the crystalline lens (Table 1 and Figure 2). The laser does not create planes across the lens in the coronal plane. The gas released from cavitation bubbles creates a pneumodissection effect that further separates the crystalline lens along the natural lamellar structure, reducing the need for hydrodissection and sometimes creating cubes of softened lens. However, the laser itself does not cut cubes but rather slices the lens.

All patients had small-incision phacoemulsification using topical anesthesia and a clear corneal incision of 2.75 mm width. The 2-step main clear corneal incision was placed at 12 o’clock and created using a 2.75 mm metal keratome (slit knife 2.75 angled, Alcon Laboratories, Inc.). The single-plane side-port incisions were placed at 9 o’clock and 3 o’clock and made with a 1.2 mm metal keratome (Side-port knife, dual bevel, 1.2 angled, Alcon Laboratories, Inc.). After instillation of sodium hyaluronate 1.0% (Healon) into the anterior chamber to protect the endothelium, the anterior capsule was pulled out with a Koch capsulorrhexis forceps (Geuder AG).

Ultrasound phacoemulsification was performed using a Stellarsis machine (Bausch & Lomb) in both study groups. The standard microflow needle had an inner tip diameter of 0.91 mm that decreased to 0.51 mm at the end of the tip; the angulation was 30 degrees at the opening. The following settings were used: maximum phaco power 60%, bottle height 100 cm, and maximum vacuum created by venturi pump up to 600 mm Hg. First, the epinuclear bowl was removed by aspiration with the phaco tip. A second

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capsulotomy</td>
<td></td>
</tr>
<tr>
<td>Incision depth (μm)</td>
<td>600</td>
</tr>
<tr>
<td>Pulse energy (μJ)</td>
<td>4.0</td>
</tr>
<tr>
<td>Expected pupil diameter (mm)</td>
<td>6.0</td>
</tr>
<tr>
<td>Capsulotomy diameter (mm)</td>
<td>5.0</td>
</tr>
<tr>
<td>Lens softening</td>
<td></td>
</tr>
<tr>
<td>Segmentation soft spacing (μm)</td>
<td>500 or 350</td>
</tr>
<tr>
<td>Segments (quadrants)</td>
<td>4</td>
</tr>
<tr>
<td>Anterior capsule safety (μm)</td>
<td>500</td>
</tr>
<tr>
<td>Posterior capsule safety (μm)</td>
<td>500</td>
</tr>
<tr>
<td>Anterior pulse energy (μJ)</td>
<td>8.0</td>
</tr>
<tr>
<td>Posterior pulse energy (μJ)</td>
<td>10.0</td>
</tr>
<tr>
<td>Horizontal spot spacing (μm)</td>
<td>10</td>
</tr>
<tr>
<td>Vertical spot spacing (μm)</td>
<td>20</td>
</tr>
</tbody>
</table>
instrument (Neuhann manual chopper, Geuder AG) was inserted through 1 paracentesis and the nucleus grooved by the stop-and-chop technique in the fragmented area (quadrant grid size, Figure 1). Next, with or without phaco energy, the softened nucleus was aspirated. Residual cortex removal and posterior capsule polishing were performed through the nasal and temporal incisions using bimanual irrigation/aspiration.

Outcome Measures

The EPT was the primary endpoint of study. The EPT is determined by multiplying the total phaco time by the mean power used and is a metric for the length of phaco time at 100% power in the continuous mode. There are variations in ultrasound phacoemulsification systems by different manufacturers, and the EPT is a common metric for comparison. Furthermore, the absolute phaco time and the mean phaco power were evaluated.

After the anterior chamber and capsular bag were reinflated with an ophthalmic viscosurgical device (OVD), a pre-loaded heparin-coated hydrophobic IOL (Polylens H10, Polytech) was injected into the capsular bag without enlarging the corneal tunnel. After the OVD was removed, the eye was covered with a patch.

Standard topical ofloxacin and dexamethasone eyedrops were administered 4 times daily for the first week, after which they were gradually tapered over 6 weeks.
Statistical Analysis

Descriptive statistical analysis was performed using SPSS software (version 19.0, SPSS Inc.). The t-test was used to compare the sample means. A P value less than 0.05 was considered statistically significant. Continuous variables were described with the mean, standard deviation, median, minimum, and maximum values. Boxplots were used for analysis of the EPT.

RESULTS

The study enrolled 160 eyes, 80 eyes in the 350 μm grid group and 80 in the 500 μm grid group. The mean age of the patients was 71 years (SD) (32 men [40%], 41 right eyes [51%]) in the 350 μm group and 72 (48 men [60%], 39 right eyes [49%]) in the 500 μm group.

The proportion of patients in each LOCS III lens opacity group was not statistically significantly different between groups. However, the mean preoperative LOCS III grade was 3.7 (0.8 in the 350 μm group and 3.5 (0.8 in the 500 μm group, showing a slight tendency toward more dense cataracts in the 350 μm group.

The mean absolute phaco time was significantly lower in the 350 μm group (2.05 ± 3.08 seconds) than in the 500 μm group (5.85 ± 5.55 seconds) (Figure 3). The mean overall EPT was also statistically significantly lower in the 350 μm group (0.03 ± 0.05 seconds) than in the 500 μm group (0.21 ± 0.26 seconds) (Figure 4). The mean phaco power was lower in the 350 μm group (1.6% ± 3.1%) than in the 500 μm group (2.5% ± 2.3%), with no significant difference between the groups (P=.052) (Figure 5).

The femtosecond laser creation of the capsulotomy and lens fragmentation (ie, procedure time) lasted a mean of 66.4 ± 14.4 seconds (range 33.7 to 100.6 seconds) in the 350 μm grid group and 52.8 ± 11.9 seconds (range 27.5 to 97.4 seconds) in the 500 μm grid group (Figure 6). The capsulotomy took approximately 4 seconds in every case; however, the lens fragmentation time varied according to the volume treated, as determined automatically by pupil dilation and lens thickness (Figure 2).

In both groups, a free-floating anterior capsule was detected in all eyes without adhesions or tags. No eye developed anterior capsule tears, posterior capsule rupture, zonular dehiscence, vitreous prolapse or loss, phaco burn, or phaco bite. A second docking attempt was required 12 times; however, there was no docking abort or suction loss during imaging or femtosecond laser treatment. No adverse intraoperative or postoperative events occurred during the 4-week follow-up.

DISCUSSION

We evaluated 2 sizes of lens softening patterns in femtosecond laser preparation for lens fragmentation before ultrasound phacoemulsification. The primary endpoint was EPT. Secondary endpoints were the duration of the femtosecond laser procedure for capsulotomy and softening, the attachment of the anterior capsule, and related complications. To our knowledge, this is the first prospective clinical trial comparing EPT between different softening grid sizes in lens fragmentation patterns. The femtosecond laser technique using the 350 μm
grid pattern was associated with a significant decrease in EPT compared with the 500 μm grid pattern.

An unpublished study using a 500 μm grid softening pattern showed that the EPT was greatly reduced compared with the EPT in standard phacoemulsification. In this study, we reduced the EPT further by using a 350 μm grid, thus coming closer to the goal of zero phaco time. One key to reduced phaco time is the density of the fragmentation pattern. Previous studies of laser refractive cataract surgery systems found a moderate reduction in LOCS grade 1 and grade 2 cataracts with a segmentation pattern only. Our present study describes the almost complete elimination of phaco time in a patient population that included more advanced cataracts. The femtosecond laser system we used allows the surgeon to prepare the cataractous lens in 2 separate ways: that is, lens segmentation and lens softening. The segmentation pattern is divided into quadrants, sextants, or octants. The grid spacing pattern softens the lens, with grids available between 100 μm and 2000 μm. The characteristics of the laser (eg, pulse duration and energy level) allow a dense pattern to be delivered in an acceptable time. Without these laser characteristics, the delivery of the fragmentation pattern would take significantly longer.

Over the past 2 decades, studies have evaluated several methods to reduce the amount of total ultrasound energy used to remove cataracts; all found incremental improvements with power modulations, chopping techniques, and microincision cataract surgery. A study comparing biaxial microincision cataract surgery and small-incision cataract surgery in complicated cataract cases found a similar reduction in phaco time and power.

Reduced phaco time diminishes the total number of joules of energy delivered to the eye, better preserving the ocular structures. A previous study found a correlation between reduced EPT and improved uncorrected distance visual acuity 1 day postoperatively. Less energy delivered to the eye may be associated with an earlier improvement in postoperative visual acuity as a result of less endothelial cell loss and corneal edema and less anterior chamber cells and flare caused by alteration of the blood–aqueous barrier. The results in the present study are encouraging in that for the first time, there was near elimination of the need for phacoemulsification with the femtosecond laser system, even in eyes with LOCS III nuclear opalescence grade 4; the EPT was less than 1 second in both softening grid groups. Although further clinical studies are necessary to compare the advantages and disadvantages of custom fragmentation and softening patterns in relation to the size of the phaco tip, lumen, and the system used, it seems intuitive that future clinical studies might continue to find a reduced need for ultrasound energy after femtosecond laser pretreatment and to find clinical advantages, such as faster visual rehabilitation or a reduction in postoperative endothelial cell loss with smaller grid patterns.

In both grid groups in our study, there were no intraoperative complications and the clinical results were highly satisfying. Although numerous factors in device design, instrumentation, and surgical experience contribute to complication-free cataract surgery, studies and experience tell us that the quality of the capsulorrhexis at the beginning of cataract surgery is an important factor in reducing surgical complications. In this study, all laser capsulotomies had an intended diameter of 5.0 mm with a qualitative assessment of near perfect centration. The results in
this study confirm previous findings and support the robustness of capsulotomy size and centration across institutions and operators when using the femtosecond laser system. Most notable in the secondary endpoints in this study was the 100% rate of free-floating capsulotomies, which compares favorably with a recently published rate of 17.5%. Free of tags and attachments, these capsulotomies did not lead to difficulties and complications, such as anterior radial tears, posterior capsule tears, vitreous loss, or posterior lens dislocation.

Although the early results with femtosecond technology in cataract surgery are promising, additional prospective randomized trials examining the efficacy and safety of this technology have to be performed.

The choice of the grid pattern used for lens fragmentation and softening is an important factor in further reducing the EPT. This may have important implications for the future as we continue to strive toward eliminating ultrasound energy by enhancing microincision surgery and by developing new IOL designs.

**WHAT WAS KNOWN**

- Femtosecond laser–assisted cataract surgery reduces phaco time comparison with the time for standard phacoemulsification.

**WHAT THIS PAPER ADDS**

- This study demonstrates further significant reduction in EPT with the use of a femtosecond laser with a smaller lens-softening grid.

**REFERENCES**


21. Wilczynski M, Drobniowski I, Synder A, Omulecki W. Evaluation of early corneal endothelial cell loss in bimanual microincision cataract surgery (MICS) in comparison with...


OTHER CITED MATERIAL

A. Conrad-Hengerer I, Hengerer FH, Schultz T, Dick HB. Effect of femtosecond laser fragmentation on effective phacoemulsification time in cataract surgery, unpublished data

First author:
Ina Conrad-Hengerer, MD
Center for Vision Science, Ruhr University Eye Clinic, Bochum, Germany