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Tissue trauma induced by lens fragmentation patterns in femtosecond laser assisted cataract surgery

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Abstract

Background: To evaluate cumulative dissipated energy (CDE), laser time, central corneal thickness and endothelial cell loss after two different fragmentation pattern by means of femtosecond laser-assisted cataract surgery (FLACS).

Methods: Eighty eyes of 80 patients that underwent FLACS were randomized in two groups: mixed chop and dice lens fragmentation pattern (group 1 with 40 eyes) and mixed chop and cylindrical lens fragmentation pattern (group 2 with 40 eyes).

Results: Cumulative dissipated energy was significantly lower in group 1 compared to group 2 ($p<0.001$). Postoperatively there was a decrement of endothelial cells count at the centre of the cornea in both groups compared with preoperative values with greater decrease in Group 2 ($p<0.001$). The thickness at the tunnel site showed a greater increase in group 2 compared to group 1 immediately after surgery ($p<0.001$) The thickness measured at the center of the cornea increased slightly immediately after surgery and showed a similar decrease in both groups. The increase was greater in Group 2 ($p<0.001$).

Conclusions: Both lens fragmentation patterns were effective in nucleus disassembly. Nevertheless dice pattern was related with a lower amount of CDE and induced lower central endothelial cell loss and lower increase of corneal thickness.

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Introduction

Corneal tissue trauma with corneal edema and endothelial cell loss are potential complications of cataract surgery associated to the surgical technique and ultrasound use during phacoemulsification. Particularly the time and energy of phacoemulsification are directly related to the trauma of the anterior segment structures.[1,2]

Recently, the introduction of femtosecond laser in cataract surgery was aimed at improving the outcome of the procedure. Femtosecond laser can be used to produce four types of incisions: clear corneal incisions, arcuate keratotomy, capsulotomy and nuclear lens fragmentation. [3]

Femtosecond Laser Assisted Cataract Surgery (FLACS) brought some advantages over conventional cataract surgery such as better capsulorrhexis features (circularity, centration), more precise corneal incision architecture with reduced corneal astigmatism and decrease of the ultrasound energy.[4-8]

Previous studies comparing FLACS and manual standard technique with phacoemulsification showed lower phacoemulsification time and energy with an overall reduction of cumulative dissipated energy (CDE).[9,10] It is known that surgical trauma and particularly ultrasound energy were related to ocular inflammation and consequently to corneal tissue injury such as corneal edema and corneal endothelial cell loss. [11-14]

The aim of our study was to evaluate the cumulative dissipated energy, laser time and corneal tissue trauma (central corneal thickness and endothelial cells loss) after two different lens fragmentation pattern during FLACS.

Materials and methods

Eighty eyes of eighty consecutive cataract patients who were candidates to phacoemulsification and IOL implantation and who met the inclusion and exclusion criteria were enrolled after giving informed consent.

The inclusion criteria were: age between 65 and 75 years, nuclear cataract of grade 3 (nuclear opalescence (NO) 3) (Lens Opacities Classification System III), and corneal endothelial cell count greater than 1200/mm^2. The exclusion criteria were: pathological alterations of the anterior segment (such as, corneal opacities, keratoconus, chronic uveitis, zonular dialysis, pseudoexfoliation syndrome, glaucoma, and diabetes), other ocular pathologies impairing visual function, previous anterior or posterior segment surgery, and intraoperative or postoperative complications.

The enrolled patients were assigned to one of the two groups based on a chronological criteria: the introduction of the mixed chop and dice lens fragmentation pattern. Group 1 included the 40 eyes after this modification. A mixed chop and cylindrical lens fragmentation pattern (group 2 with 40 eyes) included the 40 patients prior to the introduction of the newer pattern.

Before cataract surgery, patients underwent a complete ophthalmologic examination including visual acuity evaluation, manifest refraction, slit lamp examination, applanation tonometry, cataract grade/ type assessment and ophthalmoscopy through dilated pupils.

In addition, the corneal endothelial cell count (ECC) (cells/mm^2) was measured centrally by means of corneal confocal laser-scanning microscope (LSM) (HRT II Rostock Cornea Module, diode-laser 670 nm, Heidelberg Engineering GmbH, Germany) as previously described.[7]

Sequential images derived from automatic scans and manual frames were acquired and mean endothelial cell density was calculated by manually counting the number of cells within an area of interest of 250x250

μm. Three images per eye were taken and the mean of the three counts was used for statistical analysis. Cell densities are reported as number of cells per square millimeter (cell/mm^2).

In all cases the corneal thicknesses (CT) at the corneal center and at the incision site were measured with anterior segment optical coherence tomography (AS-OCT) (Model 1000, Carl Zeiss Meditec, Inc., Dublin, CA).

Cross sectional scans at the central cornea were obtained for each patient and scans with the best quality, in terms of visibility of corneal structure, were chosen to measure corneal thickness.

The corneal thickness was calculated using the caliper function for biometric measurements of the software incorporated in the instrument. Measurements were determined by taking the maximum length between the epithelium and endothelium on a line crossing the incision tangent to the corneal surface.

All data was calculated from the best image obtained in a series of three images as determined by a masked examiner.

Surgical procedure

A single experienced surgeon (LM) performed FEMTO-assisted procedures, which included corneal incisions, anterior capsulotomy, phacoemulsification, and IOL implantation. Eyes were dilated and topical anesthesia was administered repeatedly before starting the procedure. All surgical procedures were performed using standard surgical equipment.

FEMTO procedure

The capsulotomy and lens fragmentation were performed using a LensAR platform (Winter Park, FL). The capsulotomy diameter was 4.8 mm with an edge height of 1 mm. Proprietary spot separation and a layer separation were used. Rhexis was centered on the pupil center automatically by the software of the femtosecond laser system and confirmed by the surgeon.

Lens fragmentation was performed after capsulotomy with two different patterns: a mixed chop (two chops) and dice pattern with 500 μ spacing (group 1) and a mixed chop (two chops) and cylindrical pattern (two cylinders) (group 2) both with medium power treatment of 7 μJ. Proprietary spot separation and a layer separation were used. The anterior and posterior offsets for lens fragmentation were 500 and 800 μm, respectively.

Standard surgical procedures after FEMTO surgery

A temporal 2.75 mm three-plane primary clear corneal incision and a secondary one-plane corneal incision were made using disposable keratome knifes.

Standard phacoemulsification was used to complete the surgery with combined longitudinal/torsional ultrasound mode (longitudinal US linear power, 40% limits; continuous torsional phacoemulsification with linear amplitude, 100% limits; and vacuum limit fixed 300 mmHg) using the Alcon Constellation System (Alcon, Fort Worth, TX, USA).

Intraocular lens (AcrySof SN60WF-Alcon Laboratories) was implanted in the capsular bag with a Monarch® III injector and Monarch® D Cartridge. The incision was not hydrated and was not sutured.

Postoperative therapy consisted of ofloxacin 0.3% and dexamethasone 0.2% eye drops four times daily for three weeks.

Main outcome measures

The main outcome measures were uncorrected and distance corrected visual acuity (UDVA and CDVA, respectively), corneal endothelial cell count centrally and corneal thickness centrally and at the incision site.

Intraoperative measurements included mean cumulative dissipated energy and mean laser time. The scheduled follow-ups of the main parameters evaluated

in the study were set at baseline and at, 30, 60, 90 and 180 days postoperatively.

Statistical analysis

All qualitative parameters were summarized as frequency and percentage and quantitative parameters as mean and standard deviation. The effect of lens fragmentation pattern and time and the interaction of these two variables on the three outcome measurements were evaluated with a two-way mixed model with the subjects and time as fixed effects.

RESULTS

Demographics

The mean age was 69.4±3.2 years (range 65–75 years) in group 1 and 69.5±2.7 years (range 65–75 years) in the group 2.

All surgeries were completed and were uneventful. No patient was excluded due to intraoperative or postoperative complications. None of the patients were lost to follow up.

Intraoperative surgical parameters

The mean laser time was not significantly higher in group 1 compared to group 2. The mean cumulative dissipated energy was significantly lower in group 1 compared to group 2 (p<0.001) (Table 1).

Table 1. Mean±standard deviation of surgical intraoperative parameters for_the dice and cylindrical groups.

Variable	dice	Cylindrical	p-value†
Cumulative dissipated	2.54 ± 1.47	5.87 ± 2.08	< 0.001
Laser time (sec)	14.66 ± 7.85	12.47 ± 1.67	0.091

† t-test for unpaired data, dice vs cylindrical

Visual outcome

Postoperatively UDVA and CDVA increased significantly in both groups during the follow-up period (p<0.001) but were not significantly different between the two groups at different time points (Table 2).

Endothelial cell count and corneal thickness at incision site

Postoperatively there was a decrement of endothelial cells count at the centre of the cornea in both groups compared with preoperative values (Figure 1). The decrease was greater in Group 2. Mixed model analysis indicated that the differences between the two groups were effected by group differences (p<0.001), time (p<0.001) and the interaction of group and time (p<0.001).The thickness measured near the tunnel increased immediately after surgery and showed a similar decrease in both groups (Figure 2). The increase was greater in Group

2. Mixed model analysis indicated that the differences between the two groups were effected by group differences (p<0.001), time (p<0.001) and the interaction of grope and time (p<0.001). After 180 days post-operative the thickness did not return to preoperative values. The thickness measured near the center of the cornea increased slightly immediately after surgery and showed a similar decrease in both groups (Figure 3). The increase was greater in Group 2. Mixed model analysis indicated that the differences between the two groups were effected by group differences (p<0.001) and the interaction of group and time (p<0.001) but not with time alone (p=0.538). Overall Group 2 showed a greater variability in thickness following surgery

Discussion

FLACS has demonstrated a reduction of ultrasound energy compared to conventional

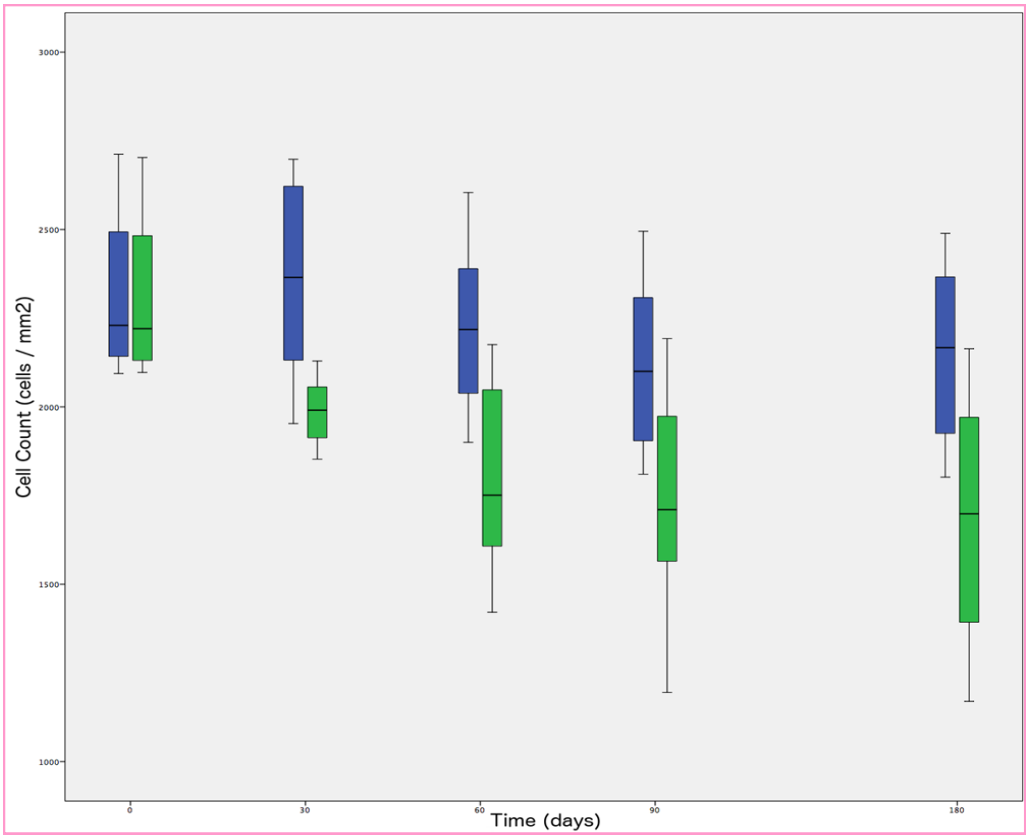


Figure 1. The cell count of the cornea pre-operatively and 30, 60, 90 and 180 days post-operatively for the two groups (Group 1 in blue and Group 2 in green).

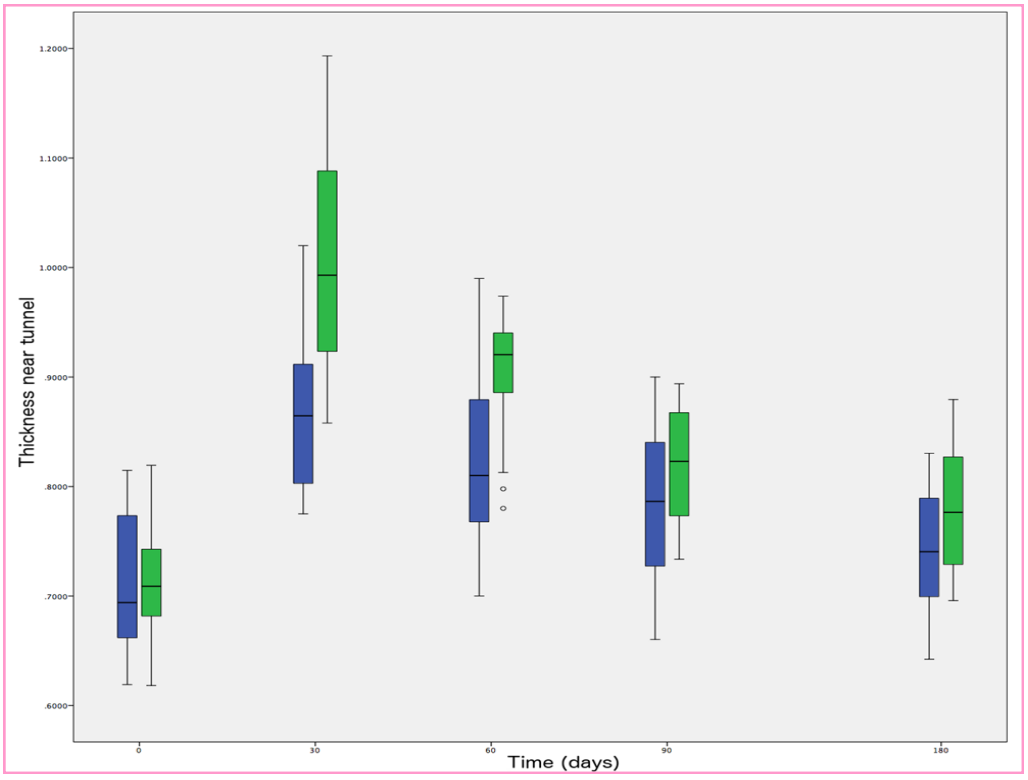


Figure 2. The thickness near the tunnel of the cornea pre-operatively and 30, 60, 90 and 180 days post-operatively for the two groups (Group 1 in blue and Group 2 in green).

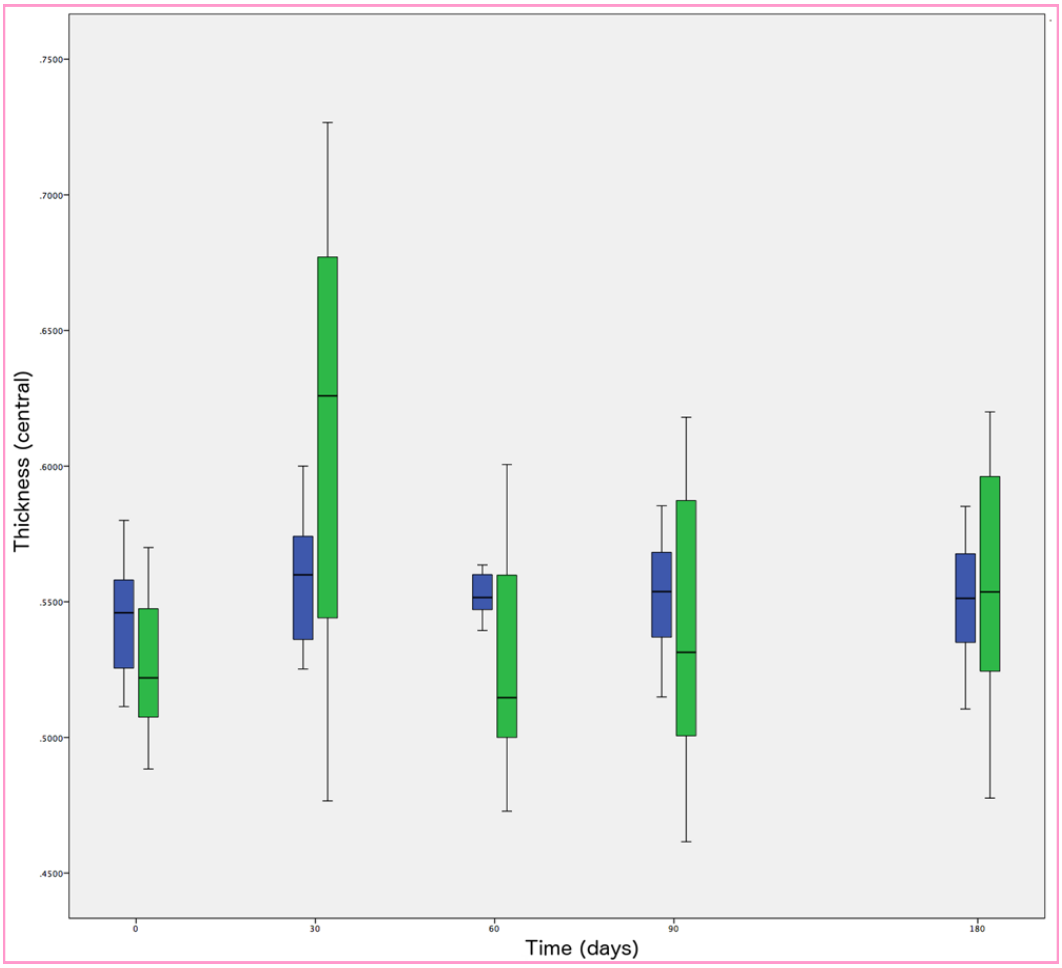


Figure 3.The thickness at the center of the cornea pre-operatively and 30, 60, 90 and 180 days post-operatively for the two groups (Group 1 in blue and Group 2 in green).

Table 2. Mean±standard deviation of uncorrected (UDVA) and distant corrected (CDVA) visual acuity for each group preoperatively and 30, 60, 90 and 180 days postoperatively, expressed as logMAR.

Time	UDVA, mean±SD[a]			CDVA, mean±SD[b]		
	Dice	Cylindrical	p-value[†]	Dice	Cylindrical	p-value[†]
Pre-surgery	0.60±0.10	0.61±0.08	*NS*	0.56±0.24	0.45±0.18	*NS*
30 days	0.35±0.14	0.37±0.15	*NS*	0.21±0.14	0.22±0.15	*NS*
60 days	0.12±0.22	0.13±0.11	*NS*	0.08±0.16	0.09±0.14	*NS.*
90 days	0.11±0.15	0.10±0.13	*NS*	-0.05±0.05	-0.04±0.12	*NS*
180 days	0.11±0.18	0.09±0.14	*NS*	-0.07±0.08	-0.05±0.11	*NS*

[†] mixed model

phacoemulsification due to crystalline lens fragmentation by means of femtosecond laser. The reduced use of ultrasound energy has been associated to lower ocular inflammation and lower tissue trauma in terms of aqueous flare, corneal swelling and corneal endothelial cell loss.[9-14]

The effective phacoemulsification time (EPT) was reduced by 83.6% in patients treated with FLACS when compared with controls ($p<0.001$), with 30% having 0 EPT ($p < 0.001$). The reduced EPT was related to lower postoperative aqueous flare at one day ($p = 0.089$) and at four weeks ($p = 0.0003$) in FLACS compared to manual and to a lower increase in outer retinal thickness measured with OCT ($p = 0.007$). [9]

Lower endothelial cell loss was detected in FLACS vs manual surgery one week postoperatively (7.9 % ± 7.8%vs 12.1 % ± 7.3%) and three months postoperatively (8.1% ± 8.1% vs 13.7% ± 8.4 %). This result was related to lower corneal trauma, decreased post-operative corneal edema and endothelial cell loss . [12]

Kacerovska et al. compared the endothelial cell loss after standard phacoemulsification and FLACS at 1, 7 at 30 days of follow-up. A statistically significant lower percentage of cell loss was noted in the FLACS group at all time points. [13]

In this study we evaluated mean laser time, endothelial cell count, corneal thickness at the center and at the incision site, visual outcome, and cumulative dissipated energy after two different fragmentation pattern by means of FLACS: mixed chop and dice pattern compared to mixed chop and cylindrical pattern.

Cumulative dissipated Energy was significantly lower in the group 1 compared to group 2 and the mean laser time was significantly higher in group 1 compared to group 2. Time and group showed an effect on endothelial cells count with a significant reduction of ECC during time that was significantly different between the two groups ($p<0.001$). Similarly time and group showed a significant effect on corneal thickness at the incision site ($p<0.001$). Time revealed a significant effect on corneal thickness at the central cornea but there was not a significant difference between the two groups.

Our results showed a significant reduction of CDE in the dice group compared to the cylinder group related to a denser crystalline lens fragmentation pattern in the first group by means of femtosecond laser compared to the second group. The reduced thermal trauma in the dice group was related to a reduced endothelial cells loss compared to the cylinder group. Our results were in accordance with a previous study comparing two different lens softening grid sizes by

means of femtosecond laser cataract surgery demonstrating less EPT in the pattern with lower spacing compared to the pattern with larger spacing. [14]

In addition a reduced corneal edema was observed at the incision site and at the center of the cornea in the dice laser group compared to the cylinder group due to the lower thermal trauma. We previously described better tunnel architecture after FLACS compared to manual surgery due to less CDE and less mechanical trauma at the tunnel site.[8] In accordance with our previous results, in this study lower CDE induced less tissue trauma at the tunnel site in the group with more dense fragmentation pattern.

In conclusion femtosecond laser procedures were both safe and efficient nevertheless a higher crystalline lens fragmentation pattern was associated with a lower CDE with a consequentially lower tissue trauma.

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