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GENERAL ARTICLE

Corneal endothelial morphology and function after torsional and longitudinal ultrasound mode phacoemulsification

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Abstract

Purpose. To study the endothelial cell morphology and corneal thickness changes after phacoemulsification by using the OZil torsional and longitudinal ultrasound techniques (Infiniti Vision System, Alcon Laboratories).

Setting. Department of Ophthalmology, Clinical Center, University of Debrecen, Debrecen, Hungary.

Methods. 52 patients with cataract were randomly assigned to longitudinal ultrasound and torsional mode group. All surgeries were performed through a 2.2 mm clear corneal incision, the method employed being divide and conquer. The endothelial morphometry such as cell density (ECD), mean cell area, coefficient of variation of cell area, and central corneal thickness were examined with specular microscopy (EM-1000, Tomey) preoperatively and 4, 8 weeks postoperatively.

Results. ECD values decreased significantly in both surgical groups ($P < .001$, repeated-mesures ANOVA), the postoperative endothelial cell loss was higher in the longitudinal ultrasound mode group (3.5% and 6.5%, at 4 and 8 weeks after surgery) than in the torsional group (3.3% and 5.5%, at 4 and 8 weeks after surgery), the difference not being significant between the two groups ($P = .164$ and $P = .479$, at 4 and 8 weeks after surgery, Mann-Whitney test). There was no statistically significant difference in any of the assessed parameters between the two surgical groups ($P > .05$). No significant correlation was found between the endothelial cell loss and the nucleus density.

Conclusions. Both phacoemulsification techniques were safe and effective. The torsional handpiece performs oscillatory movements and delivers less energy into the eye than the longitudinal ultrasound technique, therefore providing more favorable energy and thermal safety profile.

Keywords: phacoemulsification, endothelial cell morphology, torsional and longitudinal ultrasound techniques, OZil torsional handpiece

Introduction

In recent years, many surgical techniques have been developed to improve the efficacy and safety of cataract extraction. During phacoemulsification, lens material is fractured

into tiny fragments and can be removed by aspiration. Intraoperatively, several factors lead to endothelial cell damage such as corneal incision, ultrasound time, dissipated ultrasound energy, heat generation, and oxidative stress by the irrigating solution, direct injury by the divided nucleus fragments and the phacoemulsification method [1-13].

The OZil torsional handpiece for the InfinitiTM Vision System (Alcon Laboratories, Inc., Fort Worth, TX, USA) employs a unique cutting effect due to the oscillatory movements of the phaco tip. This side-to-side motion provides an effective shearing of the lens without pushing away the lenticular fragments from the tip. The OZil handpiece operates at a frequency of 32 kHz and offers a safer thermal profile in contrast to the traditional US mode (40 kHz).

The purpose of this comparative, randomized study was to evaluate the corneal endothelial morphology and central thickness alterations after torsional mode phacoemulsification in comparison with conventional longitudinal ultrasound mode cataract extraction.

Patients and methods

Patients

The study involved fifty-two eyes of 52 patients who underwent cataract surgery. Their mean age was 66.83 ± 10.04 years. Preoperatively the patients were randomly assigned to conventional US mode group (26 eyes of 26 patients with a mean age of 64.36 ± 8.86 years) or torsional mode group (26 eyes of 26 patients with a mean age of 69 ± 10.77 years). A complete ophthalmological examination was performed on each patient preoperatively. Nuclear hardness was graded by the surgeon using the LOCS III system [14,15]. The exclusion criteria were any other present or previous eye disorder than cataract, age less than 50 years, high refractive errors (> 4D), low endothelial cell count (< 1500 cell/ mm2), pupillary dilation problem, history of any ocular surgery or trauma, and any intra- or postoperative complication. The study was conducted in accordance with the tenets of the Declaration of Helsinki and informed consent was obtained from all the patients.

Surgical procedures

All the operations were performed by the same surgeon (L.M.), who was experienced in both torsional and longitudinal ultrasound mode phacoemulsification techniques.

All the surgeries were performed under topical anesthesia. 2.2 mm clear corneal incision was made at the steepest meridian of the cornea in all cases. The anterior chamber was filled with ophthalmic viscosurgical device (OVD) and one paracentesis was made in the area of 70 to 90 degree left side to the clear corneal incision. After capsulorhexis, hydrodissection and hydrodelineation were performed. The equipment used for the phacoemulsification was the same in both groups (Infiniti™ Vision System, Alcon Laboratories).

In the longitudinal US mode group, traditional ultrasound was used to remove the nucleus using the bimanual divide and conquer technique [with the straight Mini-Flared ABS tip (Alcon Laboratories)]. In all cases, the same irrigating solution (BSS Plus™, Alcon Laboratories) and OVD (Amvisc Plus™, Bausch and Lomb Incorporated, Rochester, NY, USA) were used. Flow conditions and vacuum settings were standardized for all eyes. The removal of the nucleus was followed by irrigation/ aspiration of the cortex and capsular polishing in both groups. After filling the capsular bag with OVD, the single-piece hydrophobic acrylic intraocular posterior chamber lens (Acrysof™ SA60AT, Alcon Laboratories) was implanted in the bag by using an injector. The OVD was aspirated and the anterior chamber reformed with BSS Plus™. The clear corneal incision was left sutureless. The corneal wound and the side port were hydrated with BSS PlusT™, intracameral cefuroxime (Xorim™, Sandoz Gmbh., Kundl, Austria) and tobramycine (BrulamycinTM, Biogal, Debrecen, Hungary) were administrated. All procedures were uneventful.

For the torsional mode group, the OZil handpiece with the 0.9 mm 45° angled Kelman Mini-Flared ABS tip (Alcon Laboratories) was used, otherwise all steps of the procedure were the same.

Postoperatively, patients received tobramycine + dexamethasone eyedrops (TobraDex™, Alcon Laboratories) 5 times for 4 weeks. The patients were examined on the first postoperative day, when the best corrected distance visual acuity (BCDVA) (using ETDRS

chart with constant illumination), intraocular pressure and slit lamp findings were recorded. A complete ophthalmological examination was performed (including BCDVA, anterior segment biomicroscopy, binocular fundus examination, specular endothelial microscopy, and intraocular pressure measurements) 4 and 8 weeks after the surgery.

Examination strategies

Endothelial cell density (ECD), endothelial cell area, coefficient of variation (CV) of cell area and central corneal thickness (CCT) values were recorded preoperatively, 4 and 8 weeks postoperatively with a contact speular microscopy (EM-1000, Tomey, Tennenlohe, Germany) in all cases. Three photographs were captured from the center of the cornea and the images (at least 75 endothelial cells counted) were analyzed by the instrument-based software (EM-1100, Version 1.2.2) [16,17]. The endothelial cell loss (preoperative ECD - postoperative ECD; in cells/ mm2) and the proportional loss of endothelial cells [(endothelial cell loss/ preoperative ECD) × 100; in %] were calculated.

Statistical analysis

The statistical analysis was performed with SPSS 13.0 for Windows and MedCalc 10.4 statistical softwares. Repeated-measures analysis of variance (ANOVA) was carried out to compare the corneal morphologic parameters obtained before and after surgery. The difference between the two phacoemulsification groups was determined by using the Mann-Whitney unpaired test. Spearman's rank correlation coefficient (r) was calculated for the correlation analysis. A P value less than .05 was considered statistically significant.

Results

The nucleus density (LOCS III) was similar (P = .183) in the two groups (2.57 ± 0.94 in the longitudinal US mode group; 3.06 ± 0.77 in the torsional mode group).

The endothelial cell density and morphometry values as well as the central corneal thickness measurements assessed preoperatively and at 4, 8 weeks after the surgery are summarized in a table (Table 1). The statistical analysis did not disclose a significant difference in any of the assessed parameters between the traditional US and the torsional mode group. In the torsional mode group, the analysis of variance found statistically significant differences in all of the measured variables (P < .05); the test detected a significant difference only in ECD (P < .001) and the cell area values (P = .038) evaluated in the longitudinal US mode group.

Table 1. Endothelial cell density, morphology parameters and pachymetry measurements in the traditional US mode group and the torsional mode group

	Longitudinal US mode group†	*Torsional mode group†*	*P value**
Endothelial cell density, cells/ mm²			
preoperative	2244±198 (2164-2324)	2252±165 (2185-2319)	.519
4 weeks postoperative	2165±204 (2083-2248)	2177±204 (2095-2259)	.164
8 weeks postoperative	2098±218 (2010- 2186)	2129±219 (2040-2217)	.479
P value**	< .001	< .001	
Coefficient of variation			
preoperative	0.48±0.09 (0.41-0.54)	0.42±0.07 (0.38-0.47)	.803
4 weeks postoperative	0.48±0.06 (0.44-0.52)	0.55±0.07 (0.50-0.60)	.056
8 weeks postoperative	0.52±0.07 (0.47-0.56)	0.51±0.08 (0.46-0.57)	.854
P value**	.074	< .001	
Mean cell area, µm²			
preoperative	455±53 (419-491)	454±43 (425-483)	.547

4 weeks postoperative	471±54 (435-508)	482±51 (448-516)	.190
8 weeks postoperative	502±82 (448-557)	507±55 (471-544)	.424
P value**	.038	< .001	
Central corneal thickness, µm			
preoperative	537±46 (506-568)	515±44 (486-545)	.467
4 weeks postoperative	554±60 (514-595)	554±42 (525-582)	.618
8 weeks postoperative	539±45 (509-569)	539±47 (507-571)	.927
P value**	.194	.006	

† Mean±standard deviation (95% confidence interval)
* Mann-Whitney U test
** Repeated-measures ANOVA

At 4 and 8 weeks after surgery, postoperative endothelial cell loss was 79 cells/ mm2 and 146 cells/ mm2 (proportional loss of cells was 3.5% and 6.5%) in the traditional US mode group (P < .001), and slightly lower, 75 cells/ mm2 and 123 cells/ mm2 (proportional loss of cells was 3.3% and 5.5%) in the torsional mode group (P < .001) (Fig. 1,2). The postoperative corneal thickness seemed to be greater in the torsional group (P = .008, at 4 weeks; P = .68, at 8 weeks) compared to the conventional US mode group (P = .442, at 4 weeks; P = .574 at 8 weeks) (Fig. 3).

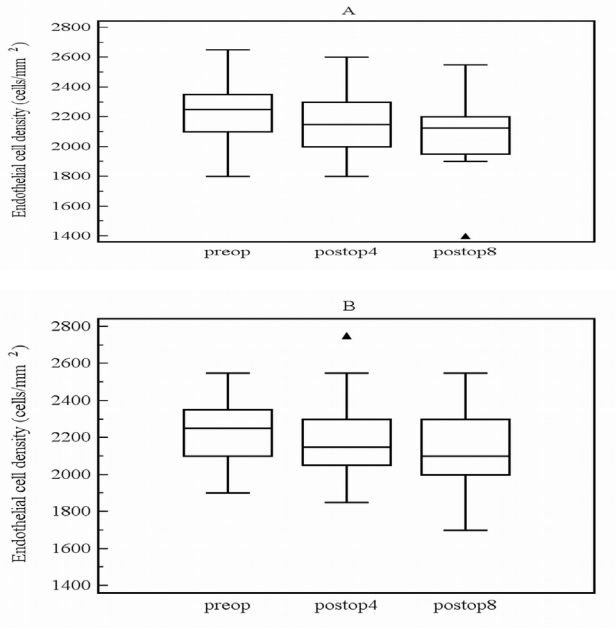

Fig. 1 Box and whisker plots displaying the endothelial cell density (ECD) changes in the conventional US mode group (A) (P < .001) and the torsional mode group (B) (P < .001). The horizontal line in boxes represents the median; the box height indicates the interquartile range; whiskers represent the range of the assessed values preop = preoperative, postop4 = 4 weeks postoperative, postop8 = 8 weeks postoperative

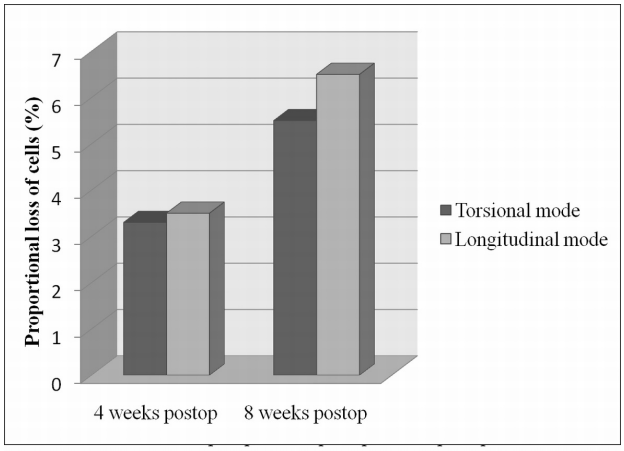

Fig. 2 Proportional loss of endothelial cells at 4 and 8 weeks postoperatively obtained in the longitudinal US and torsional mode group

The statistical anlaysis did not disclose any significant correlations between the postoperative ECD values and the nucleus density (longitudinal US group: r = -0.39, P = .170, at 4 weeks; r = -0.47, P = .090, at 8 weeks; torsional group: r = -0.48, P = .086, at 4 weeks; r = -0.53, P = .052, at 8 weeks).

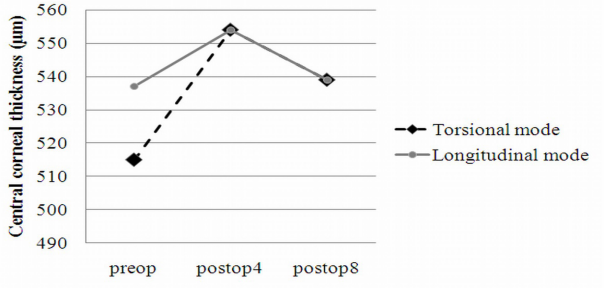

Fig. 3 Central corneal thickness (µm) measured in the longitudinal US and torsional mode group preop = pre-operative, postop4 = 4 weeks postoperative, postop8 = 8 weeks postoperative

Discussion

In the present study, the endothelial function was evaluated after phacoemulsification by using the OZil torsional handpiece in comparison with the traditional longitudinal US technique. A significant decrease in the endothelial cell density was observed both after the conventional US mode and after the torsional mode phacoemulsification procedures (3.3 - 6.5%), however, no statistically significant difference was found between the two surgical groups in the endothelial morphometry either preoperatively or postoperatively. Most of the previous papers reported a higher degree of endothelial cell loss after cataract extraction (4.43 - 22% between 1 day and 3 months postoperatively) [3,4,6-8,12,13,18-24], although the surgical methods performed by the operators and the follow-up periods were not homogeneous. Similar to our study, Storr-Paulsen et al. [18] demonstrated a cell loss of 5.0% 3 months after the surgery when using the divide and conquer technique. Two articles investigated the torsional mode phacoemulsification and noticed significant differences in the endothelial cell loss between the traditional US and the torsional procedure. Both studies detected a larger decrease in the ECD values at 30 days after surgery (-485 cells/ mm2, US mode group; -308 cells/ mm2, torsional mode group) [6] (-259 cells/ mm2, torsional combined with US mode group; -255 cells/ mm2, torsional mode group; -329 cells/ mm2, US mode group) [7] when compared to our results, and reported a statistically significant difference between the US and the torsional group. The CV of the cell area and the mean cell area increased significantly before and after surgery in both of our study groups. The decreased cell density and morphologic changes reflect the endothelial impairment due to intraocular surgical procedures, whereas the increased variation in cell area indicates the healing of the corneal endothelial injury [25,26]. Neither in the cell morphology nor in the central corneal thickness results were statistically significant, a difference between the traditional US and the torsional mode groups.

Several previous studies investigated the association between the ultrasound parameters and the endothelial cell reduction. Pereira et al. [27] and Crema et al. [8] reported no significant correlation between the US time and the endothelial cell decrease. In contrast, the other authors emphasized a strong influence of a longer phaco time on the postoperative cell loss [1,13,28-30]. Phacoemulsification energy and its effect on the endothelial alterations were also examined in a few studies. Lee et al. [1] and Baradaran-Rafii et al. [12] demonstrated an association between the US energy and the cell loss, Walkow et al. [29] observed a strong correlation between these two parameters only in the lateral quadrant of the corneal endothelium. In our study, the nucleus density was not found to be correlated with the endothelial cell loss either in the traditional US or in the torsional mode phaco group, however, Hayashi et al. [30] suggested that the nucleus density might be the main risk factor for decrease of ECD.

Contrary to the conventional longitudinal mode phacoemulsification, in the torsional mode, the OZil phaco tip moves from side to side, therefore less or no chatter or repulsion of the lens material occurs [31]. Lenticular fragments stay in contact with the tip resulting in an improved followability, and accordingly, fewer tiny nuclear particles move into the anterior chamber with reduced risk for endothelial damage [2]. The continuous contact between the tip and the nuclear fragments and the better followability allow the use of a lower vacuum level and a reduced flow rate during the surgery. The optimal fluidics parameters provide a more stable anterior chamber and a more efficient and safer cataract removal. The lack of backward movements results in better cutting efficiency in 100% of the time with reduced heat generation. In addition, the OZil handpiece delivers 20% less energy into the eye compared to the traditional US mode, therefore provides more preferable energy and thermal safety profile [32-34]. The OZil technology is capable of performing horizontal and vertical movements at the same time. The torsional mode, combined with the traditional longitudinal actions, has been shown to be an effective way in the extraction of very dense cataracts [7]. The 45° angled Kelman Mini-Flared tip and its oscillatory movement enable the surgeon a safer lens removal through a clear corneal 2.2 mm incision, which can reduce surgically induced astigmatism, the risk of postoperative infections, offer better visual outcomes and a rapid recovery [35].

We concluded that both phacoemulsification techniques are safe and effective; however, the torsional mode procedure

has several advantages over the traditional ultrasound mode phacoemulsification. The postoperative endothelial cell loss was lower in the torsional group, although a statistically significant difference was not disclosed. The learning curve of the torsional handpiece was short and easy. The OZil technology uses a lower amount of energy with less heat generation, and achives more suitable and constant power distribution during the surgery. It provides a more stable anterior chamber with a reduced turbulence of the irrigation fluid, therefore protecting the corneal endothelium from thermal and mechanical injury.

Conflict of interest

Authors have no proprietary interests or conflict of interest in this study.

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