Ultrasound energy and endothelial cell loss with stop-and-chop and nuclear preslice phacoemulsification

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PURPOSE: To evaluate ultrasound (US) energy and endothelial cell loss in cataract surgery using the stop-and-chop and nuclear preslice techniques.

SETTING: Vision Institute, Federal University of São Paulo, São Paulo, Brazil.

METHODS: This prospective clinical trial comprised 43 patients (50 eyes) with senile nuclear cataract who were randomly assigned to 1 of 2 groups: stop-and-chop (n = 26) or nuclear preslice (n = 24). The groups were divided according to nuclear density (NO_3 NC_3 and NO_4 NC_4) using the Lens Opacity Classification System III. A full ophthalmic examination including biometry, specular microscopy, and pachymetry was performed preoperatively and postoperatively. The following parameters were evaluated: age, anterior chamber depth, lens thickness, axial length, phaco time and power, effective phaco time (EPT), infusion volume, ocular inflammation, endothelial cell loss, and best corrected visual acuity (BCVA).

RESULTS: Phacoemulsification time, power, and EPT were significantly higher in the stop-and-chop group. Infusion volumes did not vary significantly between the groups. A significant decrease in endothelial cell density occurred postoperatively and was similar with both techniques (stop-and-chop, 8.70%; nuclear preslice, 8.72%). The BCVA improved significantly in both groups. No significant correlations were found between endothelial cell loss and either technique.

CONCLUSIONS: Ultrasound energy consumption was lower with the nuclear preslice technique. Both techniques had similar results including endothelial cell loss.

J Cataract Refract Surg 2006; 32:1661–1666 © 2006 ASCRS and ESCRS

The corneal endothelium damage during phacoemulsification can be caused by factors such as irrigation flow, turbulence and movement of fluids, presence of air bubbles, direct trauma caused by instruments or lens fragments, and the phaco time and power needed to achieve nuclear emulsification.[1] To reduce the energy applied, aspects related to the phacoemulsifier—such as ultrasound (US) modes, special tips, microprocessors, and high-vacuum systems—must be considered, as must the surgical technique, nucleus consistency, and surgeon experience.[1,2]

The use of high-vacuum and flow-rate parameters, changes in US features, and mechanical fracture of the nucleus without sculpting a groove (phaco-chop techniques) reduce the energy released during surgery,[3] preventing eye injury and inflammation and promoting faster visual rehabilitation.[2]

Several techniques to reduce the amount of US energy to the eye have been developed.[4,5] In the phaco-chop techniques, their variants,[6,7] and phaco prechop techniques,[3,8] preoperative nuclear segmentation is performed. This can reduce the phaco time needed to sculpt a central groove in the nucleus by 50% and minimizes handpiece movement, reducing mechanical and thermal damage.[3]

The corneal endothelial cell count after phacoemulsification is an indicator of surgery-induced damage to the

Accepted for publication May 9, 2006.

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No author has a financial or proprietary interest in any material or method mentioned.

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0886-3350/06/$-see front matter
doi:10.1016/j.jcrs.2006.05.006

cornea. Other parameters are the energy dissipated and turbulence and movement of fluids in the anterior chamber.[9–11] This study evaluated the use of US energy and loss of endothelial cells with the stop-and-chop and nuclear preslice techniques in an attempt to determine factors that are damaging to the corneal endothelium.

PATIENTS AND METHODS

The study comprised 43 patients (50 eyes). The Medical Ethics Committee approved the study. Patients with NO_3 NC_3 and NO_4 NC_4 nuclear cataract, based on the Lens Opacities Classification System III (LOCS III)[12] grading system, were selected and randomly assigned to the stop-and-chop group or nuclear preslice group. All surgery was performed by the same experienced surgeon (L.L.F.) at the Vision Institute, Federal University of São Paulo.

Exclusion criteria included cornea guttata, Fuchs' dystrophy, pseudoexfoliation, glaucoma, dry eye, history of uveitis, previous eye surgery, diabetes mellitus, and intraoperative and postoperative complications such as posterior chamber rupture with vitreous loss, intraocular lens (IOL) decentration, Descemet's membrane detachment, or exacerbated postoperative inflammation with ocular hypertension (Table 1).[11,13]

All patients had preoperative clinical and ophthalmic examinations including visual acuity measurement, biomicroscopy, tonometry, indirect ophthalmoscopy, pachymetry, keratometry, biometry, and specular microscopy. Age, best corrected visual acuity (BCVA), anterior chamber depth (ACD), lens thickness, axial length, US pachymetry, and endothelial cell density were assessed preoperatively.[14]

The parameters evaluated intraoperatively were phaco time and mean power; effective phaco time (EPT), which expresses how long phaco energy would have been delivered if 100% power had been used (EPT = phaco time × phaco power)[2]; and infusion volume. The postoperative parameters were intraocular inflammation (cells and flare), US pachymetry, BCVA, endothelial cell density, and percentage of cell loss 90 days after surgery.

Two experienced examiners categorized lens opacity. The stop-and-chop and nuclear preslice groups were divided according to cataract nuclear density (NO_3 NC_3 and NO_4 NC_4).[12]

The surgical technique was randomly assigned. The equipment and materials used were a Legacy 20000 phacoemulsifier (Alcon Laboratories), MaxVac cassette with a 0.9 mm, 30-degree microtip, balanced salt solution, hydroxypropyl methylcellulose (Celoftal) ophthalmic viscosurgical device (OVD), and the AcrySof MA30BA IOL (Alcon Laboratories). The phacoemulsifier parameters were standardized (Table 2).

Table 1. Patients excluded because of intraoperative and postoperative complications.

Complication	Stop and Chop	Preslice
Intraocular lens decentration	1	—
Posterior chamber rupture with vitreous loss	—	1
Exacerbated postoperative inflammation	—	1
Descemet's membrane detachment	1	—

Table 2. Standardized parameters of the Legacy 20000 phacoemulsifier.

Parameter	1st Phase	2nd Phase
Phacoemulsification		
Bottle height (cm)	90	110
Power (%)	60	45*
Vacuum (mm Hg)	60	380
Aspiration flow rate (cm^3/min)	60	45
Irrigation/aspiration		
Bottle height (cm)	95	—
Vacuum (mm Hg)	500+	—
Aspiration flow rate (cm^3/min)	40	—

*80 ms bursts

The stop-and-chop technique[6] comprised creating an incision in the temporal limbus, creating a side-port incision 80 degrees from the main incision, making a 5.5 mm capsulorhexis with a Utrata forceps (SKM), performing hydrodissection, sculpting a central groove according to the parameters for the first phase (Table 2), fracturing the nucleus into halves using a Nagahara chopper (Rumex) and phaco tip, and cracking the halves into smaller fragments. The fragments were emulsified in the capsular bag using the parameters for the second phase (Table 2), and the IOL was placed in the capsular bag.

In the nuclear preslice technique,[8] the incisions, capsulorhexis, and hydrodissection were the same as in the stop-and chop technique. They were followed by aspiration of the anterior cortex according to the parameters for the first phase and insertion of Dodick-Kammann nucleus choppers (Katena) through the main incision and paracentesis. The choppers were positioned at the lens equator beneath the anterior capsule 180 degrees apart. They were brought together to create the first nuclear fracture, after which 1 chopper was held at the center while the other was pulled toward it, producing the second and third fractures, resulting in 4 nuclear quadrants. Under the parameters for the second phase, the quadrants were emulsified in the capsular bag and the IOL was inserted.

Full ophthalmic examinations were conducted 1, 7, 15, 30, and 90 days postoperatively and comprised ocular inflammation, BCVA, US pachymetry, and specular microscopy measurements. Ocular inflammation was subjectively assessed under the slitlamp by the same investigator (F.P.) who was masked to the surgical technique. Postoperative treatment consisted of topical tobramycin 0.3% with dexamethasone 0.1% (TobraDex) every 4 hours on the first postoperative day and then tapered over 30 days.

To evaluate risk factors for endothelial loss, attempts were made to correlate surgery-related endothelial cell loss with patient age, phaco time and power, infusion volume required, ACD, and axial length.

RESULTS

Of the 43 patients, 21 were men and 22 women. Their age ranged from 53 to 86 years. In the stop-and-chop group (26 eyes), the mean age of the 15 men (57.7%) and 11 women (42.3%) was 70 years. In the nuclear preslice group (24 eyes), the mean age of the 10 men (41.7%) and 14 women (58.3%) was 67 years. Preoperative BCVA ranged from 20/50 to 20/200 (logMAR 0.4 to 1.0). Table 3 shows

Table 3. Mean values of the preoperative parameters using the stop-and-chop and nuclear preslice techniques.

Parameter	Stop and Chop	Nuclear Preslice	Calc Z	*P* Value*
Age (y)	70	67	−1.177	.24
ACD (mm)	3.16	3.23	−0.865	.39
Lens thickness (mm)	4.47	4.45	−0.039	.97
Axial length (mm)	23.67	23.35	−0.748	.45
Pachymetry (μm)	514	504	−1.097	.27
Specular microscopy(cells/mm^2)	2560	2504	−0.660	.51
Visual acuity(decimal/logMAR)	0.28/0.58	0.26/0.63	−1.143	.25

ACD = anterior chamber depth; Calc Z = calculated Z
*$P > .05$ (Mann-Whitney test)

the parameters evaluated preoperatively. The groups were considered homogeneous because there were no significant differences in the preoperative variables (Mann-Whitney test).

Table 4 shows the intraoperative parameters according to nuclear density. Phaco times were significantly longer for stop-and-chop independent of nuclear density (Figure 1); NO_3 and NC_3 cataracts required significantly shorter phaco times than denser cataracts irrespective of technique.

The difference between groups in mean phaco powers for NO_3 NC_3 and NO_4 NC_4 were statistically significant ($P = .001$). There were no significant differences in phaco power between cataracts of different densities (Table 4).

The EPT was longer in the stop-and-chop group because this variable included the phaco time and power used. No significant differences in infusion volumes were found. Mean consumption of BSS was approximately 120 mL with both techniques (Table 4).

Intraocular inflammation (ie, anterior chamber flare and cells) decreased significantly 1, 7, 15, and 30 days postoperatively with both techniques. However, no significant differences in ocular inflammation were found between techniques. There were no significant differences between preoperative and postoperative pachymetries.

The mean postoperative BCVA was 0.87 (logMAR 0.07) in the stop-and-chop group and 0.88 (logMAR 0.06) in the nuclear preslice group. Thirty days after surgery, all patients had a BCVA of 20/32 (logMAR 0.20) or better (Table 5).

Table 6 shows preoperative and postoperative endothelial cell densities and endothelial loss. There was a statistically significant postoperative decrease in endothelial cells in both groups. The mean endothelial cell loss (% change) was similar between groups. There were no significant differences in endothelial cell loss between cataracts of different densities with either technique (Table 7).

Table 8 shows the correlations between endothelial cell loss and the study's variables. No significant correlation (Spearman rank) was found between endothelial cell loss and any variable with either technique.

Table 4. Mean values of intraoperative parameters evaluated with the stop-and-chop and nuclear preslice techniques.

	Stop and Chop		Nuclear Preslice		
Parameter	NO_3 NC_3	NO_4 NC_4	NO_3 NC_3	NO_4 NC_4	*P* Value
Phaco time (s)	20.0	28.5	10.4	20.0	.001*
Phaco power (%)	11.8	13.9	6.5	7.3	.001*
EPT (s)	2.46	4.09	0.80	1.57	.001*
Volume (mL)	117.0	123.0	120.0	118.0	.845†

EPT = effective phaco time
*$P \leq .05$ (Kruskal-Wallis test)
†$P > .05$ (Mann-Whitney test)

DISCUSSION

Phacoemulsification is the worldwide standard for cataract surgery.[15,16] According to Wong et al.,[1] US energy during nuclear emulsification is associated with endothelial

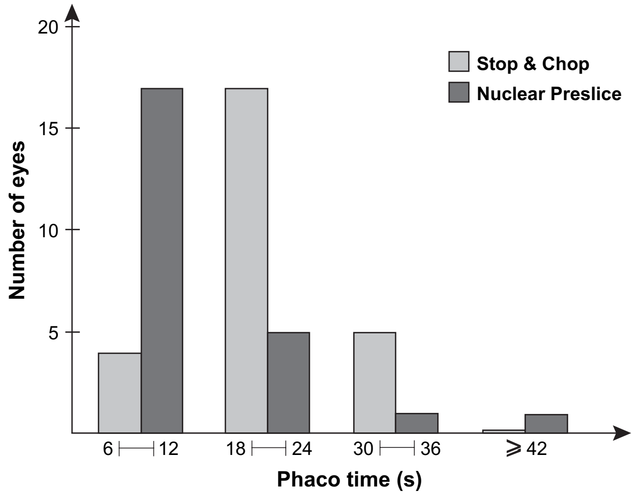

Figure 1. Phaco time distribution in cataract surgery using the stop-and-chop and nuclear preslice techniques.

Table 5. Preoperative and postoperative BCVA in cataract surgeries using the stop-and-chop and preslice techniques.

	Number (%)			
	Stop and Chop		Preslice	
LogMAR Visual Acuity (Snellen)	Preop	Postop	Preop	Postop
0.0–0.1 (20/20–20/25)	—	25 (96.2)	—	22 (91.7)
0.2–0.3 (20/32–20/40)	—	1 (3.8)	—	2 (8.3)
0.4–0.5 (20/50–20/63)	12 (46.2)	—	6 (25.0)	—
0.6–0.7 (20/80–20/100)	13 (50.0)	—	15 (62.5)	—
0.8–1.0 (20/125–20/200)	1 (3.8)	—	3 (12.5)	—

Table 6. Preoperative and postoperative endothelial cell density and loss in cataract surgeries using the stop-and-chop and preslice techniques.

Parameter	Stop and Chop	Preslice	Calc Z	*P* Value
Mean endothelial cell density (cells/mm^2) ± SD				
Preoperative	2560 ± 164	2504 ± 133	—	—
Postoperative	2331 ± 160	2287 ± 147	—	—
Calc Z	−4.330	−3.457	—	—
P value	.001*	.001*	—	—
Cell loss (% change)	−8.70	−8.72	−0.427	.669†

Calc Z = calculated Z
*Significant (Wilcoxon test)
†Not significant (Mann-Whitney test)

cell loss. Based on this information, the present study sought to determine how US energy and endothelial loss can be reduced in cataract surgery.

Investigations have examined the effects of phaco time on the corneal endothelium during phacoemulsification.[9–11,14,17] In our study, phaco times were significantly longer and phaco powers significantly higher with the stop-and-chop technique than with nuclear preslice. Also, phaco times and powers required for emulsification increased with nuclear density. These results corroborate the findings of Akahoshi[3] that presurgical nuclear segmentation (phaco prechop techniques) leads to a significant reduction in the phaco times required to sculpt a central groove.

In a randomized prospective study, Wong et al.[1] used a Legacy system and found a mean phaco time of 1.2 minutes ± 0.1 (SD) for phaco chop and 2.4 ± 0.1 minutes for divide and conquer, with cataracts graded according to LOCS. Díaz-Valle et al.[18] report a mean of 0.76 ± 0.32 minutes with the divide-and-conquer technique. Ram et al.[19] report 0.91 ± 0.37 minutes for phaco chop and 1.56 ± 0.89 minutes for in situ fracture using post-mortem eyes from an eye bank. However, because these studies did not specify cataract densities, comparisons with the current investigation are not possible.

Table 7. Mean endothelial cell loss in surgeries using the stop-and-chop and preslice techniques by cataract density (NO_3 NC_3; NO_4 NC_4).

	Stop and Chop		Preslice	
	NO_3 NC_3	NO_4 NC_4	NO_3 NC_3	NO_4 NC_4
Cell loss (% change)	−7.93	−10.44	−7.90	−10.09
Calc Z	−1.056		−0.388	
P value*	.291		.698	

Calc Z = calculated Z
*$P > .05$ (Mann-Whitney test)

Table 8. Correlation of the variables and the loss of endothelial cells in cataract surgeries with the stop-and-chop and preslice techniques.

	Stop and Chop		Preslice	
Variable	*R*	*P**	*R*	*P**
Age (y)	−0.077	0.710	0.120	0.576
Phaco time (s)	−0.061	0.768	0.031	0.886
Phaco power (%)	−0.359	0.072	0.036	0.868
Infusion volume (mL)	−0.003	0.989	0.030	0.891
ACD (mm)	0.265	0.190	0.187	0.380
Axial length (mm)	0.100	0.629	0.029	0.894

ACD = anterior chamber depth; *P* = *P* value; *R* = Spearman correlation coefficient
*$P > .05$

In the present study, surgeries performed using the stop-and-chop technique had significantly higher EPTs than those performed with nuclear preslice. Other investigators, such as Vajpayee et al.,[20] compared phaco-chop and stop-and-chop procedures and found similar EPTs. Fine et al.[2] evaluated EPT values for cataracts of different densities and found higher EPT values and worse visual acuity within the first 24 hours after surgery in eyes with denser cataracts.

Studies report that the use of larger infusion volumes during surgery risks damage to the corneal endothelium.[9–11] According to Centurion,[21] the fluid dynamics required for maintaining anterior chamber volume, removing emulsified fragments, and cooling the titanium tip account for the increased consumption of solution. We found a mean consumption of BSS of approximately 120 mL with both techniques, regardless of cataract density. Other investigators[9] compared surgical techniques with and without nuclear cracking and found similar results; they conclude phaco times are shorter and endothelial cell injury less pronounced with nuclear cracking.

In the present study, there were no differences between techniques in postoperative BCVA. Thirty days after surgery, all patients had a BCVA of 20/32 or better. These results are similar to those of Wong et al.[1] and others.[20,22]

Endothelial cell loss is a major concern because a primary complication of cataract surgery is postoperative corneal decompensation.[11,13] Studies of diverse phacoemulsification techniques[4,9,10,14,17,18,20,22] report endothelial cell loss ranging from 3% to as high as 23%. In our study, we found a statistically significant decrease in postoperative endothelial density with both techniques, although the mean cell loss 90 days after surgery was similar (8.70%, stop-and-chop; 8.72%, nuclear preslice). Vajpayee et al.,[20] comparing phaco chop and stop and chop, obtained results similar to ours.

Although we used ACD, lens thickness, and axial length to compare the stop-and-chop and nuclear preslice groups, we did not find positive correlations between ACD, lens thickness, or axial length and endothelial loss. Walkow et al.[14] found cell loss was significantly more pronounced in eyes with a shorter axial length and with longer phaco times, although ACD and lens thickness did not correlate with cell loss, only with patient age. This might be explained by the deepening of the anterior chamber during surgery and the greater mean distance from the phaco tip to the corneal endothelium.

Patient age is an important determinant of visual acuity outcomes. In our study, no significant correlation was found between age and surgery-induced endothelial loss. Hayashi et al.[23] found endothelial loss was correlated with age, nuclear density and size, infusion volume, and longer phaco times, implicating nuclear density as a primary risk factor for endothelial loss. In our study, denser nuclei (NO_4 NC_4) led to more pronounced endothelial loss than less dense nuclei (NO_3 NC_3), although the differences were not significant.

The literature reports a positive correlation between the use of US energy in surgery and endothelial loss.[1,4,9,14,17] Our results show that even though cataracts of higher density required longer phaco times, no significant endothelial loss occurred. This might be the result of the surgeon's expertise and use of smaller infusion volumes and dispersive OVD fluid.

We found no significant correlations between endothelial cell loss and the variables evaluated. Therefore, the variables cannot be considered risk factors for endothelial loss. Further investigations based on a greater number of surgeries might establish whether the factors are detrimental.

CONCLUSION

Our study showed that US energy consumption was lower (shorter phaco time and lower phaco power) with the nuclear preslice technique than with the stop-and-chop technique. Although no statistically significant increase in endothelial cell loss was observed, denser cataracts required significantly longer phaco times than less dense cataracts regardless of the technique used. Despite a significant decrease in endothelial cells after surgery, endothelial loss was similar with both techniques.

No significant correlations were found between endothelial cell loss and patient age, phaco time and power, infusion volume, ACD, or axial length. It was not possible, however, to establish whether these variables are potentially damaging to the corneal endothelium.

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