Effect of fluidics on corneal endothelial cell density, central corneal thickness, and central macular thickness after phacoemulsification with torsional ultrasound

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Aim: To study the relative effects of high and low fluidic parameters on endothelial cell density (ECD), central corneal thickness (CCT), and central macular thickness (CMT) after phacoemulsification with torsional ultrasound. **Settings and Design:** Prospective, randomized clinical trial based on a tertiary eye hospital. **Subjects and Methods:** The study included 65 patients in each group. Patients were randomized to either the high or the low flow group using a computerized random number table. The study was patient and examiner masked. All patients underwent phacoemulsification with torsional ultrasound. Visual acuity, ECD, CCT, and CMT were measured for all patients preoperatively at 2 weeks and 6 weeks postoperatively. **Statistical Analysis Used:** The Shapiro–Wilks test was used to assess the normality of the data. Mann–Whitney U-test with the P value set at 0.05 was used to compare the two groups. **Results:** Cumulative dissipated energy was significantly higher in the low flow group (16.44 ± 9.07 vs. 11.74 ± 6.68; $P = 0.002$). No statistically significant difference was noted between the two groups in the ECD, CCT, CMT, or corrected distance visual acuity at the end of 6 weeks. **Conclusions:** No significant difference was noted in the postoperative outcome between high and low flow groups. Parameters can be modified to suit the surgeon's preference, as both high and low flow parameters were found to have comparable postoperative outcomes.

Key words: Fluidics, phacoemulsification, torsional

High fluidic parameters are known to cause turbulence in the anterior chamber,[1] thereby causing lenticular particles to bounce off the endothelium and iris. This could lead to damage of endothelial cells and an increased release of prostaglandins that could enhance postoperative inflammation and increase central macular thickness (CMT).[2] Surgery with low flow settings tends to be slower, thereby subjecting the anterior chamber to turbulence for longer duration. In this study, we examined the relative effects of high and low fluidic parameters on endothelial cell density (ECD), central corneal thickness (CCT), and CMT after phacoemulsification with torsional ultrasound.

Subjects and Methods

This prospective, randomized clinical trial was conducted between May 2012 and October 2013 at a super-specialty eye hospital and research center. An institutional review board approval was obtained, and the study was conducted in strict adherence to the tenets of the "Declaration of Helsinki." Patients were included in the study after an informed consent, and the study was patient and examiner masked.

Preoperative examination included a detailed slit lamp examination with grading of the cataract according to the LOCS III classification.[3] Fundus examination was done to rule out pre-existing retinal pathology in all patients. Intraocular pressure was measured with Goldmann applanation tonometry. Noncontact specular microscopy was done to assess the corneal endothelium on the EM 3000 (Tomey, Nishi-Ku, Nagoya, Japan). After acquisition of images, the machine displays 15 images and one selects the best image for analysis. After analysis, it displays the ECD as cells per 1 mm^2 and the pachymetry in microns (μm). The anterior chamber depth and axial length were measured by Immersion Ultrasound A scan (Alcon Inc, Fort Worth, Tx). The CMT was measured by optical coherence tomography (OCT) on the Spectralis® (Heidelberg Engineering Gmbh, USA, Software Version 5.3).

Inclusion criteria

Indian patients presenting to the cataract clinic with age-related cataract irrespective of the grade of sclerosis were recruited. Only one eye of patient was included in the study. Exclusion criteria included eyes with corneal pathologies such as dystrophies, degenerations, opacities, endothelial decompensation or ECD <1500 cells/mm^2, shallow anterior chamber (<2.1 mm), small pupils (<5 mm), history of previous intraocular surgery, eyes with glaucoma, preexisting uveitis,

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posterior polar or subluxated cataracts, zonular laxity, any preexisting retinal pathology, and patients with diabetes mellitus. It was decided that patients with intraoperative complications would be excluded from the study for further analysis, but the case and complications would be noted. Patients recruited were randomized to either the high flow or the low flow group using a computerized random number table method, so that there were equal numbers in both the arms.

Surgical Technique

The surgical parameters used are shown in Tables 1 and 2. Torsional ultrasound amplitude was set at 100% (0–100% linear control; OZil® Intelligent Phaco [IP] [Alcon Inc, Fort Worth, Tx] "on") across both groups. In IP, the machine provides a short burst of longitudinal power on sensing occlusion to prevent clogging of the tip. A single surgeon operated in all patients included in the study. The surgeon was not masked to the parameters used. All patients were operated under topical anesthesia with proparacaine hydrochloride 0.5% eye drops (Paracain, Sunways [India] Pvt, Ltd). Two 1.1 mm wide side port incisions were made. A dispersive ophthalmic viscosurgical device (OVD) comprising 3.0% sodium hyaluronate and 4.0% chondroitin sulfate (Viscoat, Alcon Inc, Fort Worth, Tx) was injected, and a temporal 2.2 mm bi-planar limbal incision was made. A continuous curvilinear capsulorrhexis was then performed which was followed by hydrodissection. Phacoemulsification was then performed in torsional mode using a 0.9 mm mini-flared ABS (aspiration bypass system; Alcon, Inc.) 45° Kelman tip with an ultrasleeve on the Infinity Vision Phacoemulsification System (Alcon, Inc.). Parameters used depended on the grade of the cataract and the group; the patient was assigned to high flow or low flow as mentioned in Table 2. The bimanual irrigation and aspiration settings were identical in both groups. Direct chop was performed in all patients. The same parameters were used for chopping and quadrant removal. The total surgical time and the time taken for nucleus management were noted. After nucleus

Table 1: Energy parameters in high and low flow group

	≤NC* Grade 3, LOCS† III	≥NC Grade 4, LOCS III
Torsional energy amplitude (%)	100	100
Mode	Pulse-30 PPS	Burst
On-time	60%	On 30 ms, off 15 ms

*Nuclear cataract, †Lens opacity classification system

Table 2: Surgical parameters for direct chop

Parameter	Vacuum (mmHg)	Aspiration flow rate (cc/min)	Bottle height (cm)
High flow (Group 1)			
≤NC* grade 3, LOCS‡ III	450	40	100
≥NC grade 4, LOCS III	500	45	110
Low flow (Group 2)			
≤NC grade 3, LOCS III	300	25	60
≥NC grade 4, LOCS III	350	25	70

*Nuclear cataract, ‡Lens opacity classification system

management and bimanual irrigation and aspiration (I/A), an AcrySof SN60WF (Alcon Inc, Fort Worth, Tx) intraocular lens was implanted in the capsular bag with a D-cartridge (Alcon Inc, Fort Worth, Tx) under continuous irrigation. The side ports and main wound were hydrated until the intraocular pressure had been normalized, and the wounds were sealed.

The amount of fluid used (in mL) and cumulative dissipated energy (CDE) were noted at the end of each case from the metrics of the phacoemulsification machine. Postoperatively, all patients were started on 0.5% moxifloxacin eye drops (Vigamox, Alcon Inc, Fort Worth, Tx) four times a day for 2 weeks, 1% prednisolone acetate eye drops (Pred Forte, Allergan, Irvine, CA) four times a day that was tapered and stopped over 4 weeks, and 0.1% nepafenac eye drops (Nevanac, Alcon Inc, Fort Worth, Tx) thrice a day for 6 weeks. Patients were examined on the first postoperative day and then again at 2 weeks and 6 weeks. Specular microscopy was done for assessment of endothelial cell counts and CCT at 2 weeks and 6 weeks. Assessment of corrected distance visual acuity (CDVA) and macular OCT was done at 6 weeks.

The primary outcome measures were the change in ECD, CCT, and CMT from preoperatively to 2 weeks and 6 weeks postoperatively. The secondary outcome measures evaluated were the CDVA and the difference in the surgical parameters namely the amount of fluid used, CDE, and nucleus management time between the two groups.

Statistical methods

Sample size calculation was computed using the formula:

$$n = \frac{Z^2_{1-\alpha/2} \left[2\,S_p^2 \right]^{[4]}}{d^2}$$

Where,

$$S_p^2 = \frac{S_1^2 + S_2^2}{2}$$

S_1^2 : Standard deviation in the first group
S_2^2 : Standard deviation in the second group
S_p^2 : Pooled standard deviation
d : Precision
α : Significance level.

The sample size was calculated based on published data showing change in CMT after phacoemulsification.[5] With an alpha error of 5% and power of 80%, the sample size was calculated to be 57 in each group. To accommodate for loss to follow-up (approximately 10%), a number of 65 in each group were fixed as the sample size. A randomization table was then made to respect that figure.

The normality of the distribution of data was assessed by the Shapiro–Wilks test. As the data was not normally distributed, the nonparametric Mann–Whitney U-test with the $P = 0.05$ was used to compare the two groups.

Results

A total of 6324 patients were examined in the cataract clinic in the study period. We recruited 130 patients in the study. Grade of the cataract varied from Grade 2 to Grade 4 according to the LOCS III classification. The high flow group

had 65 patients, of whom 37 were females and 28 were males. The low flow group had 65 patients, of whom 38 were females and 27 were males. The mean age of the patients was 64.90 years ± 9.19 (standard deviation [SD]) in the high flow group and 63.94 years ± 7.84 (SD) in the low flow group. The difference in age between the groups was not statistically significant (*P* = 0.148). There was no statistically significant difference in the grade of cataract between the groups.

Table 3 shows the preoperative values of ECD, CCT, and CMT; there was no statistical difference between the two groups. Table 4 shows the comparison of the CDVA, CDE, nucleus management time, and amount of fluid used between the two groups. The total CDE was lesser in the high flow group (*P* = 0.002) while the amount of fluid used was greater in the same group (*P* = 0.006). No statistically significant difference was observed in the CDVA (*P* = 0.062) or nucleus management time between the groups (*P* = 0.647).

No intraoperative complication occurred in any eyes in either group, and hence no patient was excluded on those

groups. Table 5 shows the change in ECD, CCT, and CMT in the two groups at the end of 6 weeks. No statistically significant difference was noted in the change in ECD, CCT, or CMT (*P* = 0.135, *P* = 0.197, and *P* = 0.393) at the end of 6 weeks.

Discussion

Recent advances in technology have given the surgeon the option of operating with high fluidic parameters. Surgeons with a high volume set up and those who can deliver good results despite short surgical times often use these parameters. Cautious surgeons on the contrary opt for more controlled low flow parameters in a bid to reduce trauma, which could be associated with turbulent fluidics.[1]

The effect of these various parameters on ocular structures has been of concern and efforts have been made in the past to evaluate the same. Loss of corneal endothelial cells and corneal edema indicated by reduction in ECD and increase in corneal thickness have been accepted as indicators of intraoperative trauma.[6] Baradaran-Rafii *et al*.[7] conducted a study where they compared two groups, one with high vacuum and high flow rates (400 mmHg vacuum; 40 cc/min flow rate) and the other with low vacuum and low flow group (200 mmHg vacuum and 20 cc/min flow rate) and found that endothelial cell loss was related to the total ultrasound energy used.

A similar study by Vasavada *et al*.[8] in 2010 evaluated the effect of different flow parameters on the CCT, ECD, and anterior segment inflammation and found that low fluidic parameters led to a lesser increase in the CCT in the initial week after surgery and decreased anterior segment inflammation in comparison to the group with high flow parameters. There was no difference between the groups when CCT was compared at the end of 1 month or 3 months. No statistically significant difference was observed between the preoperative and postoperative ECD in both groups. They evaluated the outcomes of different flow parameters using longitudinal ultrasound. Hence, we conducted this study to look if similar results would be obtained with torsional phaco settings as well. We also observed a paucity of literature on the effect of different flow parameters on the posterior segment, and hence designed a study to evaluate the effect of vacuum, total energy, and flow rates on both anterior and posterior segment structures.

In our study, we found no statistical difference in the ECD or CCT at 2 or 6 weeks between the two groups. In the study by Vasavada *et al*.,[8] the increase in ECD and CCT at 1 week postoperatively could be due to the use of longitudinal phacoemulsification. On the other hand, torsional phacoemulsification used in our study is known to cause lesser

Table 3: Preoperative values of ECD*, CCT†, and CMT‡

Parameter	Mean±SD		*P*
	High flow group	Low flow group	
ECD*	2550±343.07	2489.58±234.61	0.237
CCT†	523.68±35.36	514.94±38.90	0.183
CMT‡	224.94±37.70	222.71±28.37	0.742

*ECD: Endothelial cell density (corneal), †CCT: Central corneal thickness, ‡CMT: Central macular thickness, SD: Standard deviation

Table 4: CDVA*, intraoperative surgical time, fluid used, and CDE†

Parameter	Mean±SD		*P*
	High flow group	Low flow group	
CDVA*	0.96±0.12	0.90±0.16	0.062
CDE†	11.74±6.68	16.44±9.07	0.002
Nucleus management time (s)	152.50±94.54	155.99±83.60	0.647
Longitudinal phaco (IP‡) time (s)	3.10±2.36	3.46±2.47	0.399
Fluid used (mL)	62.05±19.24	52.63±13.52	0.006

*CDVA: Corrected distance visual acuity, †CDE: Cumulative dissipated energy, ‡Intelligent Phaco (Infinity Vision Phaco System [Alcon, Inc.]), SD: Standard deviation

Table 5: Changes in ECD*, CCT† and CMT‡

Parameter	Mean±SD		*P*	95% CI for mean (lower bound-higher bound)
	High flow group	Low flow group		
Change in ECD* at 2 weeks	320.70±386.44	245.82±261.92	0.997	187.70-395.85
Change in ECD at 6 weeks	282.93±383.76	243.24±251.52	0.135	165.40-369.78
Change in CCT† at 2 weeks	1.41±20.25	0.24±24.41	0.110	−7.37-5.82
Change in CCT at 6 weeks	3.41±17.13	1.76±25.15	0.197	−3.41-8.95
Change in CMT‡ at 6 weeks	3.22±19.40	0±8.95	0.393	−2.92-6.88

*ECD: Endothelial cell density (corneal), †CCT: Central corneal thickness, ‡CMT: Central macular thickness, SD: Standard deviation, CI: Confidence interval

chatter intraoperatively, with lesser loss of endothelial cells and corneal edema postoperatively.[9,10] In addition, in the present study, CDE in the high flow group was significantly ($P = 0.002$) lesser than in the low flow group. The advantage of posterior plane phacoemulsification in the low flow group might have been balanced by the reduction in phaco energy noted in the high flow group in the present study. Since dense cataracts were not included in the study by Vasavada *et al.*, we consider the results of our study, which included all grades of cataract, to be more relevant to that subgroup of patients as well.

The incidence of macular edema and clinical CME postcataract surgery has been well researched.[11,12] Although the incidence of clinical CME after phacoemulsification is low in comparison to intra- or extra-capsular cataract surgery, incidence of angiographic CME and increase in macular thickness has been found to be significant.[13,14] OCT is now widely used and has become an integral part of modern retina practice[15-18] including in the diagnosis of subclinical CME. However, literature on the relationship between different flow parameters and change in CMT is lacking. In the present study, the change in CMT was studied on the Spectralis OCT. In the high flow group, the mean CMT increased by 3.22 μm (±19.40 SD) compared to 0 μm (±8.95 SD) in the low flow group. The difference was not statistically significant ($P = 0.393$). A study by Cheng *et al.* suggested a correlation between increase in macular thickness and the amount of phaco energy,[5] whereas von Jagow *et al.*[19] found no correlation between increase in macular thickness and surgical parameters used. No correlation was found in our study between the change in CMT and CDE, fluid used, or surgical time.

Conclusion

In our study, CDE was found to be higher in the low flow group and the total amount of fluid used in the high flow group. No significant differences were found in outcomes namely, a change in CCT or ECD between the groups. We did not notice a difference in intraoperative complications between the groups. One of the limitations of the study is that we included only uncomplicated cases. In challenging situations or for beginners,[8,20-23] the flow parameters would have to be adjusted accordingly; in other cases, the flow parameters can be modified to suit the individual surgeon's style, with both high and low flow parameters having similar postoperative outcome when torsional phacoemulsification is used.

Conflicts of interest
There are no conflicts of interest.

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