

Comparative studies between longitudinal and torsional modes in phacoemulsification, using active fluidics technology along with the intrepid balanced tip

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Purpose: To compare and report the intra- and postoperative outcomes of phacoemulsification between longitudinal (LPKE) and torsional (TPKE) mode, using active fluidics along with the intrepid balanced tip.

Methods: This single center prospective randomized comparative study comprised a total 108 consecutive eyes of 108 patients having senile cataract subdivided into nuclear opalescence (NO) grades II–IV according to the lens opacities classification system III (LOCS III). Cataracts of each grade were randomly assigned to two groups LPKE ($n = 54$) and TPKE ($n = 54$) mode, who were operated on by the same surgeon using same machine (Centurion® Alcon Laboratories, Inc., USA) having features of both active fluidics and intrepid balanced tip. Pre-, intra-, and postoperative evaluations were done independently by a different author, who was masked to the surgical procedures. Patients were evaluated on the postoperative days (PODs) 1, 7, 15, and 28. Intraoperative outcome measures were cumulative dissipated energy (CDE) and ultrasound time (UST). Postoperative outcome measures were endothelial cell loss (ECL), central corneal thickness (CCT), and best-corrected visual acuity (BCVA). **Results:** Age, gender, and NO-grade distribution among two modes were comparable ($P > 0.05$). Difference of CDE and UST between modes were found to be significant ($P < 0.001$) in favor of TPKE with all NO-grades. TPKE mode performs better than LPKE mode with regard to ECL, CCT-change, and BCVA-change, although the differences were found to be insignificant ($P > 0.05$). **Conclusion:** When using active fluidics along with the intrepid balanced tip, TPKE mode appeared to be a more efficient mode of PKE with reduced mean UST and CDE across all NO-grades, as compared to LPKE mode. However, ECL, CCT-change, and BCVA-change were seemed to be comparable between the two modes.

Key words: Active fluidics, intrepid balanced tip, longitudinal mode, phacoemulsification, torsional mode

The main aim of cataract surgery by phacoemulsification (PKE) is to surgically remove cataract to obtain the best possible visual outcome. The current trend in modern cataract surgery is to minimize the iatrogenic effects on ocular structures, especially cornea, which is vulnerable to significant threats from ultrasound (US)-energy mediated endothelial cell loss (ECL).^[1] The two commonly used modes of PKE are longitudinal PKE (LPKE) and torsional PKE (TPKE). In these two modes, the tip attached to the OZil phaco probe emulsifies the nucleus either by repulsive forces similar to that in a jackhammer or by shearing forces generated by circular oscillations similar to that produced in turning of a doorknob, respectively.^[2]

Currently, TPKE is considered as the desired mode. It is well established that the efficacy of TPKE mode is much higher than that of LPKE mode in terms of improved followability of the nucleus, decreased dispersion of lens material or chatter, reduced fluid use, and reduced incidence of thermal injury induced by the phaco-tip. The efficiency of phaco-tip cutting

depends on the angulation or bevel of the tip and the angle of bend.^[3]

The latest Centurion® vision system (Alcon Laboratories Inc., Tx, USA), introduced in 2013, has two added features of active fluidics technology (constant intraocular pressure [IOP] maintained by software-mediated rapid detection of dynamic changes within the chamber, thereby, reducing chamber instability and occlusion break surge) and nonflared intrepid balanced tip (a nontapered tip having two opposite bends along its axis where the energy is focused at the distal end only with stroke length of 180 μm). Previous versions of PKE-unit based on gravity-fed infusion have greater chances of chamber instability. Also, the traditional tips had lesser stroke length (stroke length of 100 μm) and efficiency with regard to followability, holding, and rapidity of removal of fragments.^[3-8]

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Several studies have compared the safety and efficacy between LPKE and TPKE modes of power usage in different setups using either dual or multiple machine and/or surgeon, single machine with gravity fluidics, gravity and active fluidics combined, use of different tips, and so on.^[3,9-14] We designed this study to compare intra- and postoperative performances between these two modes in a randomized prospective way utilizing both active fluidics and intrepid balanced tip, simultaneously.

Methods

This single center prospective randomized comparative study was carried out on 108 consecutive eyes of 108 patients (40–70 years age) having senile cataract with nuclear opalescence (NO) grades II–IV (LOCS III)^[15] who presented in our clinic. Patients were randomly assigned (age, gender, NO-grade matched) to two groups, that is, longitudinal (LPKE) and torsional (TPKE) modes, in a ratio of 1:1. For our convenience, different NO-grades were distributed equally into each group.

Approval from the institutional medical ethics committee and informed consent from each patient were obtained beforehand. This study adhered to the tenets of the Declaration of Helsinki.

Exclusion criteria

Patients with any ocular and/or systemic comorbidity affecting vision or clinically proven anterior and/or posterior segment disease, central corneal thickness (CCT) >650 μm , anterior chamber depth (ACD) <2.25 mm, endothelial cell density (ECD) <1,500 cells/ mm^2 , iris synechiae, pupil diameter <6 mm after dilatation, pseudo exfoliation syndrome, subluxated lens, previous history of ocular trauma/surgery or inflammatory disease, eventful or prolonged surgery of duration >15 min, NO-grades other than Gr-II–IV (LOCS III) were excluded from our study, anticipating their possibility to adversely influence the outcomes of our study.

Setting

All the surgeries were performed by a single surgeon (SDG), who had experience in performing high-volume PKE for more than 15 years. All the surgeries were done using the same machine—Centurion vision system (Alcon[®] Laboratories, Inc., Tx, USA) with active fluidics system along with the 0.9 mm 30° intrepid balanced tip. PKE of all the eyes was performed by standard direct chop technique using continuous PKE mode. Intelligent phaco (IP) was kept off at all time, IOP was set at 60 mmHg, limit of vacuum was set at 550 mmHg and flow rate was 35 ml/min. The limit for US-power was set at 60% in LPKE group and 100% torsional amplitude in TPKE group. IA was performed in all cases using aforementioned preset limit of vacuum and flow rate.

Data procurement

In all the cases, patient distribution and counselling, pre- and postoperative examinations and data were recorded by independent author (RM), who was masked to the surgical procedure. Pre- and postoperative best-corrected visual acuity (BCVA) was recorded, intraocular lens (IOL)-power was calculated using SRK-T formula and IOL-Master 500[®] (Carl Zeiss Meditec AG, Jena, D), ECD was recorded using noncontact specular microscope CEM 530[®] (Nidek; Aichi, Japan), and

CCT were recorded using ultrasound pachymetry Echoscan US-4000[®] (Nidek, Aichi, Japan). ECD and CCT-readings were taken five times on each occasion, and the average was recorded. Cumulative dissipated energy (CDE; the total US-energy dissipated at the incision site at foot pedal position- 3) and ultrasound time (UST; total duration of foot pedal excursion in position-3) were taken from the metrics displayed by the machine interface, at the end of each procedure.

Steps of surgery

In all the eyes, pupil was first dilated with 0.8% tropicamide +5% phenylephrine hydrochloride and thereafter anesthetized by instilling topical 0.5% proparacaine hydrochloride eye drop thrice at 10 min interval prior to surgery. After routine preparation of the eye under full asepsis and antisepsis, clear corneal triplanar incision was made using 2.2 mm microkeratome along the steepest axis and two paracenteses were made by 20G-Mvr-blade 40 degrees apart from main incision. Following capsulorhexis, hydrodissection-delineation and rotation, PKE was carried out with the phaco tip bevel up or sideways, keeping predetermined machine parameters according to the mode. In all the eyes, dispersive ophthalmic viscoelastic device (OVD) 3% sodium hyaluronate +4% chondroitin sulfate (Viscoat[®]; Alcon laboratories, Tx, USA) and irrigating fluid BSS-Plus (Alcon Laboratories, Tx, USA) were used. All the eyes received posterior chamber monofocal foldable acrylic hydrophobic single-piece IOL (Acrysof[®] IQ SN60WF; Alcon Laboratories, Tx, USA) in the capsular bag. Once the OVD was cleaned, the wounds were sealed by stromal hydration. Finally, the eye was patched for examination the next day. Other than intracameral moxifloxacin (100 mcg/0.1 mL), we avoided using any intracameral drugs or stain. No major intra- or postoperative complication(s) was seen in any of our cases. Postoperatively, all patients were advised topical moxifloxacin hydrochloride 0.5% four times/day for 2 weeks, prednisolone acetate 1.5% six times/day in tapering doses over the next 4 weeks, and ketorolac tromethamine 0.4% four times/day for 4 weeks. All patients were followed up on the 1, 7, 15, and 28 PODs.

Outcome measures

Intraoperative outcome measures were machine parameters CDE and UST. Postoperative outcomes were ECL, CCT-changes, and BCVA changes.

Statistical procedures

Data were statistically analyzed and interpreted using Windows SPSS software (version 23.0, Chicago, IL, USA). Test for significance (*P*-value) was set at <0.05. Fisher's exact test and *t*-test (Student-*t* and paired-*t*) were applied to categorical variables (expressed as, number and percentage) and continuous variables (expressed as, mean and standard deviation), respectively, wherever applicable.

Results

Demographic profile

As shown in Table 1 (demographic data), a total of 108 eyes (108 patients), 54 eyes in LPKE group and 54 in TPKE group, were enrolled in this study. Intragroup gender distribution (male:female) was 23:31 (*P* > 0.05) in LPKE group and 25:29 (*P* > 0.05) in TPKE group; the ratio of males between the groups was 23:25 (*P* > 0.05), and the ratio of females was 31:29

Table 1: Summary of demographic profile

Variables	Phacoemulsification mode				P
	Longitudinal-LPKE		Torsional-TPKE		
	Frequency (n)	Percentage	Frequency (n)	Percentage	
Gender					
Male	23	42.59	25	46.3	0.870
Female	31	57.40	29	53.7	0.879
Total	54	100.0	54	100.0	
P	0.177		0.563		
Age					
40-50 years	09	16.7	06	11.1	0.593
51-60 years	21	38.9	20	37.0	0.999
61-70 years	24	44.4	28	51.9	0.633
Total	54	100.00	54	100.0	
Mean±SD	58.72±7.83		60.54±7.06		0.207
P	0.059		0.107		
Eye					
Right	25	46.3	20	37.0	0.503
Left	29	53.7	34	63.0	0.549
Total	54	100.0	54	100.0	
P	0.743		0.134		
Cataract distribution					
NO Gr-II	18	33.33	18	33.33	0.999
NO Gr-III	18	33.33	18	33.33	0.999
NO Gr-IV	18	33.33	18	33.33	0.999
Total	54	100.0	54	100.0	
P	0.999		0.999		

SD: Standard deviation, NO: Nuclear opalescence, LPKE: Longitudinal phacoemulsification, TPKE: Torsional phacoemulsification

($P > 0.05$). In both the groups, the maximum number of patients was between the ages of 61 and 70 years, and the minimum was between the ages of 40 and 50 years. The intergroup mean age (\pm SD) was 58.72 ± 7.83 years and 60.54 ± 7.06 years for LPKE and TPKE groups ($P > 0.05$), respectively. Although surgery on right eye predominated in both the groups, the intragroup (Rt vs Lt 25:29, $P > 0.05$ in LPKE; 20:34, $P > 0.05$ in TPKE) and intergroup differences (Rt 25:20 and Lt 29:34 in LPKE and TPKE, respectively; $P > 0.05$) were statistically insignificant. NO grades II-IV, were equally distributed to both the groups ($n = 18$; $P > 0.05$).

BCVA outcome

There was no significant intragroup difference in attaining BCVA 20/30 or 20/20 at any of the follow-up visit ($P > 0.05$). The percentage of patients attaining BCVA 20/20 in the TPKE group was much higher as compared to LPKE group at the corresponding follow-up visit, but the difference was not found to be statistically significant (38.9% vs 31.5% in POD-1; $P = 0.55$, 66.7% vs 63% in POD-7; $P = 0.84$, 85.2% vs 81.5%; $P = 0.80$, 92.6% vs 81.5%; $P = 0.15$, respectively).

CDE and UST outcome

Comparing the overall CDE and UST between the two groups across all NO-grades, the differences were found significant in favor of TPKE (5.99% secs vs 8.73% secs and 75.83 secs vs 94.07 secs in TPKE and LPKE, respectively; $P < 0.001$). The average CDE reduced in TPKE was 2.74% secs (or 31.38% of that used in LPKE; $P < 0.05$) [Table 2].

ECL outcome

Fig. 1 and Table 3 show that at each follow-up, the intragroup mean ECD differences from the baseline was significant ($P < 0.05$), whereby the maximum ECD difference was observed in POD-1 although intragroup mean %ECL at each follow-up PODs-1, 7, 15, 28 was found to be insignificant (5.6%, 5.1%, 4.7%, 4.41% for LPKE, and 5.6%, 4.9%, 4.6%, 4.10% for TPKE; $P > 0.05$). Intergroup overall %ECL (ECD between baseline and POD-28; 4.4% for LPKE and 4.10% for TPKE; $P > 0.05$) was also found to be statistically insignificant. Among all NO-grades, the mean intergroup ECD difference at baseline and each follow-up was found to be statistically insignificant ($P > 0.05$), but there was a trend of increasing ECL with increasing NO-grades in both the groups.

CCT outcome

Fig. 2 and Table 4 show the mean intragroup CCT-changes from the baseline was significant ($P < 0.05$) at each follow-up, whereby the maximum CCT was observed in POD-1. Intergroup mean CCT changes at each follow-up (7.1%, 6.7%, 5.9%, 5.4% for LPKE, 6.85%, 6.54%, 5.98%, 5.26% for TPKE; $P > 0.05$) and overall CCT-change (CCT between baseline and POD-28; 5.41% for LPKE and 5.26% for TPKE; $P > 0.05$) was found to be statistically insignificant. Among all NO- grades, intergroup difference of mean CCT at baseline and each follow-up was found to be statistically insignificant ($P > 0.05$). In POD-1, corneal clarity was found to be lost in two patients

Table 2: Comparison of cumulative dissipated energy (CDE) and ultrasound time (UST) between groups in different grades of cataract

Group	NO Gr-II		NO Gr-III		NO Gr-IV		All grades	
	CDE (%secs)	UST (secs)	CDE (%secs)	UST (secs)	CDE (%secs)	UST (secs)	CDE (%secs)	UST (secs)
LPKE (mean±SD)	5.30±1.65	78.2±11.6	7.20±1.83	92.5±13.3	13.7±1.25	112±15.3	8.73±3.93	94.07±19.3
TPKE (mean±SD)	3.15±0.77	61.3±10.8	5.17±1.55	74.8±10	9.65±1.15	91.4±1.3	5.99±2.97	75.83±14.9
P	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Table 3: Comparison of endothelial cell loss (ECL) between groups

Group	ECD (cells/mm ²)	ECD (cells/mm ²)	ECL (cells/mm ²)	ECL (%)	P
	Preop	POD-28	Overall	Overall	
LPKE (mean±SD)	2,262.02±290.11	2,162.98±282.31	99.04±55.08	4.38	0.89
TPKE (mean±SD)	2,372.06±370.56	2,274.65±361.88	97.41±70.48	4.10	

Table 4: Comparison of central corneal thickness (CCT) changes between groups

Group	CCT (µm)	CCT (µm)	CCT-change (µm)	CCT-change (%)	P
	Preop	POD-28	Overall	Overall	
LPKE (mean±SD)	505.8±29.09	533.17±27.83	27.37±5.478	5.41	0.615
TPKE (mean±SD)	509.46±33.17	536.26±31.74	26.80±6.24	5.26	

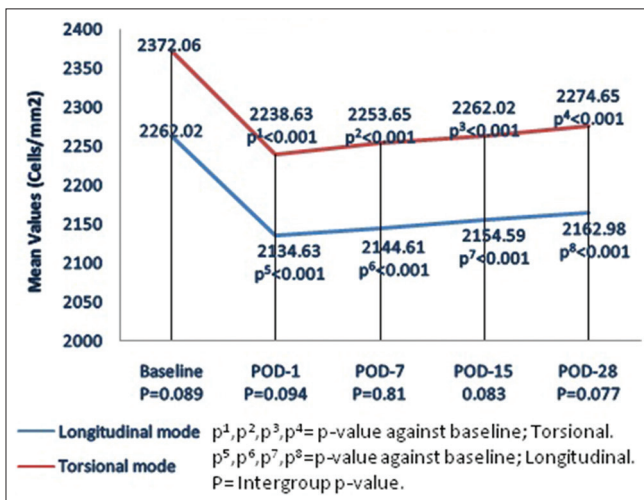


Figure 1: Comparison of endothelial cell density (ECD) between groups, at different postoperative days (PODs)

of TPKE group (one microcystic edema, one striae) and five patients of LPKE group (two microcystic edema, two striae, one folds); this was cleared with hypertonic saline eye drops in the following week.

Discussion

In the present study, we compared and evaluated the outcomes of PKE in different modes (LPKE and TPKE) using the same machine having features of both active fluidics and intrepid balanced tip attached to the OZil phaco probe.

Our results showed that the mean UST and CDE differ significantly between the groups in favor of TPKE mode in all grades of NO ($P < 0.05$). This indicates that the total energy

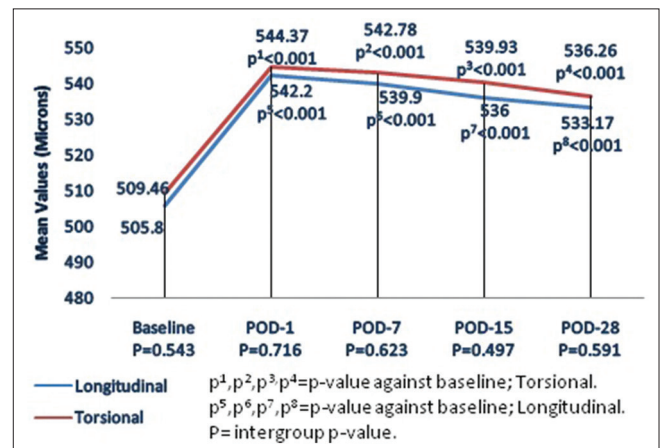


Figure 2: Comparison of central corneal thickness (CCT) between groups, at different postoperative days (PODs)

dissipated in TPKE was much less as compared to LPKE; thus, the efficiency of TPKE was increased by nearly one third. So far, there is no pilot study having a similar surgical setting for these observations to be compared. However, a similar observation was made by previous authors in different grades of NO, even with gravity fluidics and Kelman tip too.^[12,13,16]

Studies reported that, irrespective of modes (torsional or longitudinal), CDE and UST differ significantly in favor of active fluidics and intrepid balanced tip in comparison to active fluidics and Kelman tip or gravity fluidics and Kelman tip, as well.^[3,9,10] Chen *et al.*,^[17] found in their study that CDE varies with the experience of the surgeon and the phaco-technique used, which corresponds to the results of Bojkurt *et al.*'s study,^[14] which included three surgeons and showed an insignificant difference in these metrics between the two modes.

In our study, the overall mean %ECL from the baseline was found to be comparable between TPKE and LPKE modes (4.1% vs 4.4%; $P = 0.89$). However, %ECL was found to be less in the former; this indicates faster EC-replenishment and corneal injury recovery. The reason can be higher efficiency (as evidenced by lesser UST and CDE), lesser fluid turbulence/chatter, or rapidity of fragment removal in TPKE mode.

In different studies, ECL was found to be insignificant between these modes even with gravity fluidics and Kelman tip.^[12,14] We did not find any significant difference of ECL in different NO grades between the groups at any follow-up visit. Interestingly, Kim DH *et al.*^[16] reported significant ECL difference in NO-grades II–IV at POD-7 only but not at POD-30; while using gravity fluidics and Kelman tip, the difference in UST and CDE was cited as the reason. Keeping aside machine and tip factors, several other factors can lead to ECL during PKE, as observed by different authors, such as incision size and design, increasing hardness of nucleus, different PKE techniques, differing composition of irrigating fluids or OVD/drugs, instrumental injury, surgeons' experience, older age, type, and delivery technique of IOL, formation of free radicals, smaller pupil size.^[18-20] In our study, other than modes, we tried our best to avoid the bias arising from all these factors as described in methodology.

Surgical damage to the corneal endothelium leads to transient postoperative increase in CCT.^[21] In our study, the overall mean CCT-change from the baseline as well as CCT difference at any follow-up were comparable between groups ($P > 0.05$). CCT-change was seen to be less in TPKE mode probably because more number of patients in this group had clearer corneas, less ECL, and more rapid recovery of endothelial function. Working with gravity fluidics and Kelman tip in NO grades II–IV, both Kim *et al.*,^[16] and Maalej *et al.*,^[13] reported that CCT-change at early follow-up was significantly less (<0.05) in favor of the TPKE group; however, it was insignificant at POD-30. With different surgeons, Bozkurt *et al.*,^[14] found comparable corneal edema scores between the groups ($P > 0.05$) in early postop period, but on combining both the modes altogether, grade-2 (striae; $n = 18$) and grade-3 (folds; $n = 2$) edema were much more in POD-1 as compared to our study (three striae, one folds). With different machines, Christakis PG *et al.*,^[22] found significantly less corneal edema in TPKE mode ($P < 0.05$) as compared to LPKE, corresponding to the smaller increase in the mean CCT.

BCVA is one of the best outcome metrics to evaluate the quality and efficacy of a surgical technique. Our study showed no statistically significant difference ($P > 0.05$) in this regard between two modes at any of the follow-up visit. However, TPKE mode seems to have marginal advantage of faster visual recovery in early as well as late follow-up phases as compared to LPKE mode. These observations were consistent with other studies as well.^[13,17] We speculate, faster visual recovery in this group was attributed to faster recovery from corneal injury.

The validity of our study was increased by all the surgeries being performed by the same experienced surgeon in the same surgical setup using the same machine, consumables, and IOLs in age and sex-matched patients as described in our methodology. Our study was limited by relatively small study population and the short course of follow-up. Another limitation of our study was not taking account of

other possible confounding factors such as incisional heat generation, aspiration fluid utilized, aspiration time, %US-total equivalent power at FP-3, and hard cataract (Gr-V, VI; LOCSIII). Nevertheless, our results show a consistent and meaningful relevance to support the efficiency of TPKE mode over LPKE mode in different NO-grades. Further studies with larger cohorts in a similar setting would be required to better define these associations.

Conclusion

Together with active fluidics and intrepid balanced tip, torsional mode appeared to be a more efficient mode of PKE with a significant reduction of mean UST and CDE across all NO-grades, as compared to the longitudinal mode. Torsional mode was also found to reduce ECL, CCT-change, and BCVA-change as compared to longitudinal mode, but the difference was not found to be statistically significant.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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