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Comparative Study of Outcomes of Longitudinal and Torsional Modes in Phacoemulsification Using Gravity Fluidics along with Intrepid Balanced Tip

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ABSTRACT

Purpose: To compare the outcomes of longitudinal and torsional modes of phacoemulsification with foldable intraocular lens implantation surgery using an intrepid balanced tip with gravity fluidics system.

Methods: This single-centre prospective study comprised a total of 80 eyes of 80 patients having senile cataract with nuclear opalescence (NO) grade II-IV (LOCS III). Cataracts of each grade were randomly assigned into 2 groups LPKE and TPKE mode. All the patients were operated by the same surgeon using the same machine having gravity fluidics using an intrepid balanced tip. Patients were evaluated on postoperative days (PODs) 1,7,15 and 30 for BCVA, CCT, and ECD. Intraoperative outcome measures were cumulative dissipated energy (CDE) and ultrasound time (UST). Postoperative outcome measures were best corrected visual acuity (BCVA), central corneal thickness (CCT), and endothelial cell density (ECD) on days 1,7,15, and 28.

Results: The difference of CDE and UST between the 2 modes was found to be significant ($p<0.001$) in favor of TPKE mode in all NO grades. TPKEmode performs better than LPKE mode regarding ECL, CCT change, and BCVA change, although the differences were insignificant ($P > 0.05$).

Conclusion: When using gravity 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 seemed to be comparable between the two modes.

Key Words: *Gravity fluidics, intrepid balanced tip, longitudinal mode, phacoemulsification, torsional mode*

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INTRODUCTION

Phacoemulsification (PKE) has become the standard of care for cataract removal throughout the world surpassing the older methods such as intracapsular and extracapsular cataract extraction, hence advancements in technology as well as in the procedure of phacoemulsification continue to evolve [1]. While an efficient phaco system should aim at smooth, fast, and well-controlled phacoemulsification, minimum complication rates must accompany to compliment the same. The intensity and duration of ultrasonic insult have a bearing on endothelial losses.

The two commonly used modes of phacoemulsification are *Longitudinal phacoemulsification* (LPKE) and *Torsional phacoemulsification* (TPKE). In these two modes, the tip attached to the *OZil*® phaco probe emulsifies the nucleus either by repulsive forces like that in a jackhammer or by shearing forces generated by circular oscillations like that produced in the turning of a doorknob, respectively [2].

In conventional ultrasound (US) mode, the US power to emulsify the lens is derived from the longitudinal excursion of the phacoemulsification needle [3] i.e., the phaco tip moves forward and backward at a high frequency thus producing repulsion effect because the phaco tip pushes the nucleus away with each stroke as it moves forward. Thus, the US is interrupted and the efficiency of phacoemulsification is compromised [4].

Currently, torsional phacoemulsification is considered the desired mode. The efficacy of the torsional phacoemulsification mode is much higher than that of longitudinal phacoemulsification 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.

Torsional phacoemulsification causes less repulsion of nuclear materials than conventional phacoemulsification, so lens materials stay at the tip most of the time. Consequently, less vacuum level is used with the torsional mode compared to the longitudinal mode, this counteracts surge and the outcome is a safer surgery.

Several studies have been done to compare the safety and efficacy between longitudinal phacoemulsification and torsional phacoemulsification modes of power usage in different setups using either dual or multiple machines and/or surgeon, a single machine with active fluidics, gravityand active fluidics combined, use of different tips and so on [5-11].

The current trend in modern cataract surgery is to deliver the lowest energy in the eye and reduce ultrasound time simultaneously 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) [12].

This study is designed to compare intraoperative and postoperative performances between these two modes in a randomized prospective way using an intrepid balanced tip along with gravity fluidics.

METHODS

It was a Prospective hospital-based (single centre) comparative study in which patients who attended the OPD with the diagnosis of senile cataract were randomly allotted into 2 groups after taking into consideration the inclusion and exclusion criteria. Written informed consent was obtained from all the patients after giving them a full explanation of the study.

Grading of the cataract into grades was done according to Lens Opacities Classification System III (LOCS III). Subjects with cataract grade II-IV were taken for the study. Equal number of patients were then randomly assigned to 2 groups.
GROUP 1- Torsional phacoemulsification mode
GROUP 2- Longitudinal phacoemulsification mode

The study is approved by the institutional medical ethics committee and adhered to the tenets of the Declaration of Helsinki.

Inclusion Criteria

Patients with senile cataracts with nuclear opalescence (NO) grades II-IV according to lens opacities classification system III (LOCS III)

Exclusion Criteria

Patients with any ocular and/or systemic comorbidity affecting vision, any 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) <1500 cells/mm^2**,** presence of iris synechiae**,** pupil diameter <6 mm after dilatation**,** pseudoexfoliation syndrome**,** subluxated lens**,** previous history of ocular trauma/surgery or inflammatory disease**,** eventful or prolonged surgery of duration >15 min**,** NO grades other than grade II-IV (LOCS III)and the subjects who do not give consent were excluded from the study.

Setting

All surgeries were performed by the same experienced surgeon using the standard protocolwho 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) with gravity 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.Phaco settings in chop mode were vacuum kept at 400mm of Hg (linear) and the aspiration flow rate was 40cc/min (panel) with amplitude of longitudinal and torsional set at 100% and 0% according to the study group. The aspiration flow rate was kept at 35cc/minute (panel) and the vacuum was set at 500 mm of Hg (linear) for IA.

Data Procurement

In all the cases, patient distribution and counseling, pre- and postoperative examinations, and data were recorded by an independent author, who was masked to the surgical procedure. Pre- and postoperative best-corrected visual acuity (BCVA) was recorded in LogMAR units, intraocular lens (IOL)-power was calculated using IOL-Master 500® (Carl Zeiss), and ECD and CCT were recorded using a noncontact specular microscope Topcon SP-3000P. 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, the 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 intervals prior to surgery. The patient was then shifted to the operation table. Dressing and draping were done with proper aseptic measures. A universal eye speculum was applied. A side port was made with a 1mm 15° lance tip at the appropriate position of the limbus followed by injection of viscoelastic (sodium hyaluronate 1.4%) to maintain the anterior chamber. A clear corneal incision was made with a 2.2mm clear corneal keratome to create the main port. Continuous curvilinear capsulorhexis of around 5 to 5.5mm was created with capsulorhexis forceps. Next, hydro dissection was done followed by injection of 2% hydroxypropyl methylcellulose in the anterior chamber. Free nucleus rotation was ensured. Phacoemulsification was carried out by the Phaco chop technique with the phaco tip bevel up or sideways. The phacoemulsification machine used for all the surgeries was the *Centurion Silver system* by *Alcon*®. The remaining cortex was removed by coaxial irrigation and aspiration followed by implantation of an aspheric, biconvex, foldable, acrylic hydrophobic posterior chamber intraocular lens in the capsular bag under 1.4% sodium hyaluronate. The residual viscoelastic was then removed by irrigation and aspiration using Visco settings. The side port and the main port were then sealed by stromal hydration. Preservative-free antibiotic eye drop (moxifloxacin 0.5%) was given intracamerally and the patient was then shifted to the eye ward. Post-operatively, every patient was prescribed topical antibiotic steroid combination eye drop (moxifloxacin 0.5% w/v and dexamethasone phosphate 0.1% w/v) which was tapered over 6 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 (LogMAR units).

Statistical Procedure

Data were statistically analyzed and interpreted using Microsoft Excel (Office 2019). The 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 80 eyes (80 patients), 40 eyes in the TPKE group, and 40 in the LPKE group were enrolled in this study. Intragroup gender distribution (male: female) was 20:20 in TPKE group and 18:22 in LPKE group; the ratio of males between the groups was 20:18, and the ratio of females was 20:22. In TPKE group, the maximum number of patients was between the ages of 56-65 years, while in LPKE group maximum patients were >65 years age and the minimum were between the ages of 35-45 years. Although surgery on the right eye predominated in the TPKE group while in the LPKE group left eye predominated, the intragroup (Rt vs Lt 23:17 in TPKE; 19:21 in LPKE) and intergroup differences (Rt 23:19 and Lt 17:21 in TPKE and LPKE, respectively; $P > 0.05$) were statistically insignificant. The maximum number of patients operated on were of NO grade III. The intergroup distribution of cataract grade was 15:14 for grade II, 17:17 for grade III, and 8:9 for grade IV for TPKE and LPKE groups respectively. The intragroup variation for grades I, II, and III was 15:17:8 for the TPKE group and 14:17:9 for the LPKE group.

BCVA OUTCOME

There was no significant intragroup difference in attaining BCVA 0.18 or 0 LogMAR units at any of the follow-up visits ($P > 0.05$). 35 out of 40 patients (87.50%) in TPKE group vs 31 out of 40 patients (77.50%) in LPKE grouphad BCVA 0 LogMAR units at POD-28 indicating that the percentage of patients attaining BCVA 0 LogMAR units in the TPKE group was higher as compared to the LPKE group at the final follow up visit i.e., POD-28 but the difference was not found to be statistically significant.

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 (8.93% secs vs 12.31% secs and 47.93 secs vs 56.14 secs in TPKE and LPKE, respectively; $P < 0.001$). The average CDE reduced in TPKE was 3.38% secs (or 27.45% of that used in LPKE; $P < 0.05$).[Table 2]

ECL OUTCOME

The maximum ECD difference from baseline was observed in POD-1 although intragroup mean %ECL at each follow-up PODs-1, 7, 15, and 28 were found to be insignificant (5.58%, 4.21%, 3.19%, 2.42% for TPKE and 7.44%, 4.84%, 3.77%, 2.96% for LPKE; $P > 0.05$). Intergroup overall %ECL (ECD between baseline and POD-28; 2.42% for TPKE and 2.96% for LPKE; $P > 0.05$) was also found to be statistically insignificant. A trend of increasing ECL with increasing NO-grades was noted in both groups. [Table 3 and Figure 1]

CCT OUTCOME

The maximum CCT was observed in POD-1. Intergroup mean CCT changes at each follow-up (5.42%, 4.23%, 3.16%, 1.94% for TPKE, 5.53%, 4.33%, 3.32%, 2.05% for LPKE; P > 0.05) and overall CCT-change (CCT between baseline and POD-28; 1.94% for TPKE and 2.05% for LPKE; P > 0.05) was found to be statistically insignificant.In POD-1, corneal clarity was found to be lost in one patient of the TPKE group (striae) and three patients of the LPKE group (two microcystic edema, one DM folds); this was cleared with hypertonic saline eye drops in the following week. [Table 3 and Figure 2]

Table 1: Summary of Demographic Profile

VARIABLES	PHACOEMULSIFICATION MODE				
	TPKE		LPKE		
	Frequency (n)	Percentage	Frequency (n)	Percentage	
GENDER					
Male	20	50.00	18	45.00	
Female	20	50.00	22	55.00	
Total	40	100.00	40	100.00	
p-value					0.823**
AGE					
35-45 years	5	12.50	3	7.50	
46-55 years	8	20.00	6	15.00	
56-65 years	16	40.00	15	37.50	
>65 years	11	27.50	16	40.00	
Total	40	100.00	40	100.00	
Mean±SD	59.18±10.25		61.98±8.54		
p-value					0.859**
EYE					
Right	23	57.50	19	47.50	
Left	17	42.50	21	52.50	
Total	40	100.00	40	100.00	
CATARACT GRADE					
NO Gr-II	15	37.50	14	35.00	
NO Gr-III	17	42.50	17	42.50	
NO Gr-IV	8	20.00	9	22.50	
Total	40	100.00	40	100.00	
p-value					0.954**

*significant; **non-significant

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

Table 2: Comparison of Cumulative Dissipated Energy (CDE) and Ultrasound Time (UST) Between the 2 Groups

	CDE (% secs)	UST (secs)
TPKE (mean±SD)	8.93±1.99	47.93±8.27
LPKE (mean±SD)	12.31±2.31	56.14±5.43
p-value	<0.001*	<0.001*

*significant; **non-significant

Table 3: Comparison of Endothelial Cell Loss (ECL) and CCT between Groups

	ECD (cells/mm$^{2)}$	ECD (cells/mm$^{2)}$	ECL (%)	p-value

	Pre-op	POD-28	Overall	
TPKE (mean±SD)	2644.55±281.33	2580.50±273.09	2.42%	>0.05**
LPKE (mean±SD)	2625.85±308.64	2547.90±316.38	2.96%	>0.05**
	CCT (µm)	CCT (µm)	CCT change (%)	p-value
	Pre-op	POD-28	Overall	
TPKE (mean±SD)	519.60±14.56	529.70±15.89	1.94%	>0.05**
LPKE (mean±SD)	520.08±16.19	530.78±17.33	2.05%	>0.05**

*significant; **non-significant

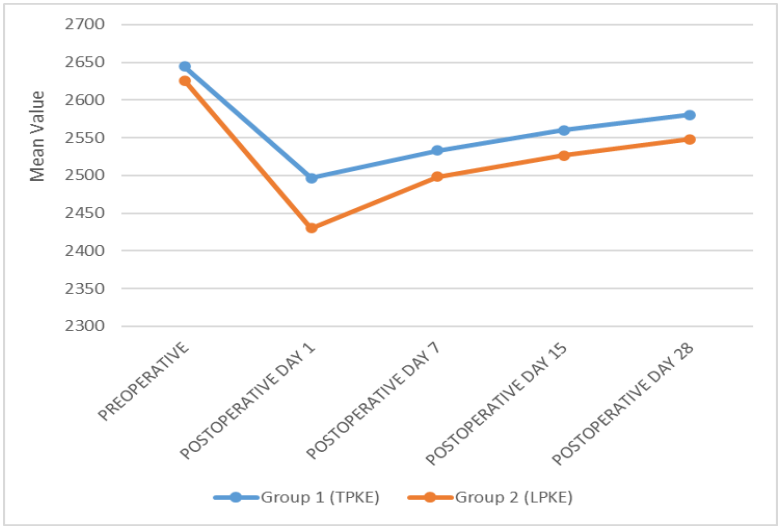

Figure 1: Graph Depicting Comparison of Mean Endothelial Cell Density (Ecd) In Per Sq. Mm between Group 1 and Group 2 (Preoperatively and Postoperatively On the 1st Day, 7th Day, 15th Day, and 28th Day)

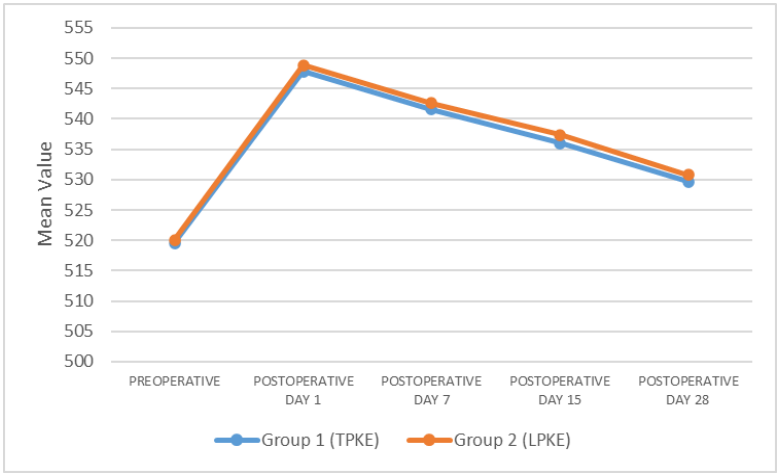

Figure 2: Graph Depicting Comparison Of Mean Central Corneal Thickness (Cct) In µ between Group 1 and Group 2 (Preoperatively and Postoperatively At Day 1, Day 7, Day 15, and Day 28)

DISCUSSION

In our study, we compared different clinical outcomes for torsional versus longitudinal phacoemulsification mode using the same machine having gravity fluidics and an intrepid balanced tip attached to the *OZil*® phaco probe in different cataract densities.

The results of our study demonstrate that torsional phacoemulsification produces a safe and more efficient mode of phacoemulsification than longitudinal mode with reduced mean UST and CDE in all grades of nucleus densities. This indicates that the total energy dissipated in the Torsional mode is much less than that in the Longitudinal mode of phacoemulsification; thus, the efficiency of the torsional mode increased by nearly one-third.

A similar observation was made by previous authors in different grades of NO, using gravity fluidics and Kelman tip also [9, 10 & 13], Our study results were also supported by results obtained by*Yizhi Liu et al* [4]. Energy saving (as determined by CDE) was significant in nucleus Grade-1 and Grade-4 following torsional phacoemulsification. This was

indicated by the absence or traces of corneal edema in most patients on day 1 and only a few patients with mild or moderate corneal edema that resolved within one week of adequate treatment following torsional phacoemulsification.

The mean BCVA at postoperative day 1 was better in the torsional group (Group 1) which was attributable to less corneal edema secondary to less UST and CDE. However, at postoperative day 28, the mean BCVA was nearly the same in both groups with no statistically significant differences. This indicates that torsional phacoemulsification has better visual outcomes in the early postoperative period.

CDE is the total energy dissipated at the incision site, which includes a combination of both torsional and longitudinal ultrasound energies. The calculation of CDE is based on the average ultrasound power multiplied by the total ultrasound time. When using torsional phacoemulsification, the CDE is multiplied by a coefficient of 0.4 as there is an 80% reduction in the frequency of the phacoemulsification tip, and the stroke length is also reduced by half [6].

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 [5, 6 & 7]

Chen et al. [14], found in their study that CDE varies with the experience of the surgeon and the phaco-technique used, which corresponds to the results of *Bozkurt et al.'s* study [11], which included three surgeons and showed an insignificant difference in these metrics between the two modes.

In this study, the overall mean percentage of ECL from the baseline was found to be comparable between TPKE and LPKE modes (2.42% vs 2.96%). However, the percentage of ECL was found to be less in the former; this indicates faster endothelial cell 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.

Kim DH et al [13]. 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 the nucleus, different PKE techniques, the 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 [15, 16 & 17]. In our study, other than modes, we tried our best to avoid the bias arising from all these factors.

Surgical damage to the corneal endothelium leads to a transient postoperative increase in CCT [17]. 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 a greater 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.* [13], and *Maalej et al.* [10], reported that CCT-change at early follow-up was significantly less in the early postoperative period, but on combining both the modes altogether, grade-2 (striae; n = 18) and grade-3 (folds; n = 2) edema was much more on POD 1. With different machines, *Christakis PG et al.* [17], found significantly less corneal edema in TPKE mode ($P < 0.05$) as compared to LPKE, corresponding to a smaller increase in the mean CCT.

BCVA is one of the best outcome parameters to evaluate the quality and efficacy of a surgical technique. Our study showed no statistically significant difference ($P > 0.05$) in this regard between the two modes at any of the follow-up visits. However, TPKE mode seems to have a marginal advantage of faster visual recovery in the early as well as late follow-up period as compared to LPKE mode. These observations were consistent with other studies as well [10, 14]. We speculate, faster visual recovery in this group was attributed to faster recovery from corneal injury.

The validity of our study was increased by the fact that all the surgeries were 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 a relatively small study population and the short course of follow-up. Another limitation of our study was not considering 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

Although the Torsional mode of Phacoemulsification is found to be better than the Longitudinal mode in terms of intraoperative UST and CDE, ECD, CCT, early postoperative UCVA, and BCVA they may not necessarily alter the visual outcome significantly as we found in our study.

But as we saw in our study longitudinal mode caused more corneal insult as compared to torsional mode due to the observation that the endothelial cell loss was more in longitudinal which can lead to problems later in the future (like pseudophakic bullous keratopathy (PBK), pseudophakic corneal edema (PCE), etc to name a few), especially in young patients.

So, keeping this in mind, we concluded from our study that either a combination of both Torsional and Longitudinal modes should be used with their percentage varying according to the cataract grade instead of pure longitudinal mode.

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