·Meta-Analysis·

An evaluation of intraoperative and postoperative outcomes of torsional mode versus longitudinal ultrasound mode phacoemulsification: a Meta-analysis

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Abstract

• **AIM: To evaluate and compare the intraoperative parameters and postoperative outcomes of torsional mode and longitudinal mode of phacoemulsification.**

• **METHODS: Pertinent studies were identified by a computerized MEDLINE search from January 2002 to September 2013. The Meta-analysis is composed of two parts. In the first part the intraoperative parameters were considered: ultrasound time (UST) and cumulative dissipated energy (CDE). The intraoperative values were also distinctly considered for two categories (moderate and hard cataract group) depending on the nuclear opacity grade. In the second part of the study the postoperative outcomes as the best corrected visual acuity (BCVA) and the endothelial cell loss (ECL) were taken in consideration.**

• **RESULTS: The UST and CDE values proved statistically significant in support of torsional mode for both moderate and hard cataract group. The analysis of BCVA did not present statistically significant difference between the two surgical modalities. The ECL count was statistically significant in support of torsional mode (P<0.001).**

• **CONCLUSION: The Meta-analysis shows the superiority of the torsional mode for intraoperative parameters (UST, CDE) and postoperative ECL outcomes.**

• **KEYWORDS:** conventional (longitudinal) phacoemulsification; phacoemulsification; torsional phacoemulsification
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INTRODUCTION

Phacoemulsification is the gold standard treatment for patients affected by cataract disease. There has been a recent introduction in significant technological improvements[1-4].

The latest generation of phacoemulsification machine provides an efficient and safe treatment due to a variety of options such as the sophisticated modulation of ultrasonic (US) energy and improved fluidic control [5-6]. The aim of cataract surgery is to minimize iatrogenic side effects on ocular structures as cornea. US energy used during phacoemulsification represents a significant threat to the endothelial cell integrity especially in patients affected with hard cataracts[7-12].

In the conventional (longitudinal) mode, the phaco tip moves forward and backward and the US energy is derived from a longitudinal movement of the tip. The forward high frequency movement of the tip creates a repulsion effect that pushes the nucleus away when it moves forward[13-14]. In order to decrease the US energy, several power modulation modes (pulse, burst, hyperpulse) have been developed [15]. In 2006 torsional US mode (OZiL, Infiniti Vision System-Alcon Laboratories, Fort Worth, TX, USA) was proposed [16]. This new mode is based on rotary oscillations of the phacoemulsification tip. The side-to-side movement reduces the repulsion of the lens fragments minimizing side effects of the procedure[17-19].

In this study we conducted a Meta-analysis of published randomized controlled trials (RCTs) to evaluate and compare for the first time in literature the intraoperative parameters and postoperative outcomes of conventional and torsional phacoemulsification.

MATERIALS AND METHODS

The Meta-analysis was performed accordance with the ethical standards of the institutional committee on human experimentation and with the Declaration of Helsinki[20-22].

Search Strategy Articles limited to RCTs were identified using a computerized MEDLINE search from 2002 to September 2013 using the following key words: "longitudinal phacoemulsification", "torsional phacoemulsification", "longitudinal torsional phacoemulsification" and "conventional torsional phacoemulsification".

Inclusion Criteria Two investigators (Leon P, Umari I) independently viewed the titles and abstracts. Afterwards, the eligible full text articles were reviewed. Studies that did not meet eligibility criteria in the opinion of just one of the reviewers were excluded.

Articles were considered for inclusion if they met the following criteria: RCTs that compared longitudinal and torsional phacoemulsification, they reported at least one of the intraoperative surgical parameters or postoperative outcomes measures, only studies performed with human subjects were included. Language restrictions were imposed; only studies published in English were considered.

The exclusion criteria were previous significant ophthalmic disease or complications during surgery or postoperatively. Studies that considered mixed torsional and longitudinal phacoemulsification modes were excluded.

Data Extraction Two investigators (Leon P, Umari I) independently selected the studies that fulfilled the inclusion criteria. The following parameters were taken into consideration: ultrasound time (UST), cumulative dissipated energy (CDE) for intraoperative parameters and best corrected visual acuity (BCVA), endothelial cell loss (ECL) for postoperative outcomes.

The UST represents the time in seconds, in which the footpedal remains in the third position. The mean CDE power indicates the mean percentage of power spent during the UST. The CDE is calculated in accordance with the guidelines of the phaco unit manufacturer and by researching previous studies [1,23]. In longitudinal phaco-mode the CDE was calculated as follows: CDE=mean US power×UST. In torsional mode the CDE was calculated as follows: torsional amplitude× torsional time×0.4[1].

The coefficient of 0.4 was used because torsional phaco differs from the conventional mode in two ways: the frequency of the phaco tip in torsional mode (32 kHz) is 80% of that in the conventional phaco (40 kHz) and the stroke length of the phaco tip in torsional mode (40 μm) is 50% of that in standard mode (80 μm)[24].

The UST and CDE values in torsional and phaco modes were automatically calculated by the device and displayed on the monitor of the phaco system[1].

Intraoperative parameters were extracted from five of seven studies. In the first analysis, UST and CDE were analyzed separately for all surgeries performed.

Considering intraoperative parameters (UST, CDE), there was another, extra analysis performed concerning the nuclear opalescence (NO) grade. We grouped all the samples on the basis of nuclear density according to the 3 lens nucleus density grading systems used: lens opacities classification system II (LOCS II)[25], lens opacities classification system III (LOCS III)[26] and the Oxford clinical cataract classification and grading system (OCCCGS)[27]. In particular, in three[1,16,24] of the five studies, LOCS II was used, in one [14] was adopted LOCS III grading and finally Reuschel *et al* [28] used the OCCCGS. We distinguished a "moderate cataract" group including ≥NOI (Grade-1), ≤NOIII (Grade-3) for LOCSII and ≥NOI (Grade-1), ≤NOIV (Grade-4) for LOCSIII and "hard cataract" group including ≥NOIV (Grade-4) for LOCSII and ≥NOV (Grade-5) for LOCSIII [14]. In the Reuschel *et al* [28] study the data of UST and CDE for each grade of OCCCGS was not provided, so all the samples were included in both "moderate" and "hard" cataract groups.

Postoperative outcome measures were the mean visual acuity expressed in the LogMAR scale (BCVA) after 1d and 1mo[1,14,29] and mean ECL after 1wk, 1 and 3mo [1,14,19,28]. ECL was calculated as ECL=(preoperative cell count-postoperative cell count)/preoperative cell count×100%[14].

Data from three of the seven studies were taken into consideration to evaluate the visual acuity after 1d and 1mo. Five studies were included to evaluate the ECL: three for the analysis of the ECL after 1 and 2wk for the analysis after 1 and 3mo.

The data extracted from each study were title, first author, year of publication, type of the study, location of trial, number of patients, patient's age and sex, outcomes considered, surgical technique, phacoemulsification machine, grading of nuclear density. Numerical discrepancies for each of the above were resolved by an independent investigator (Mangogna A).

Quality Assessment The quality of each trial was assessed using the Jadad *et al* [30] scale. The assessment criteria were as follows: 1) random assignment; 2) appropriateness of randomization; 3) double blind; 4) appropriateness of double blind; 5) clear description and discussion of withdrawals and dropouts. The total score ranged from 0 to 5. Studies scoring less than 3 points were considered to be of low quality.

Statistical Analysis The statistical analysis was performed using "comprehensive meta analysis" software ver. 2.2 (Biostat® , Englewood, NJ, USA). Forest plots were used to present the results, and the results were expressed as standardized mean difference (SMD) and 95% confidence interval (CI). The center of each circle indicated the SMD. The horizontal line bisecting each circle represented the 95% CI for the SMD. Heterogeneity among studies was tested using the Chi-squared statistic. If the significant evidence of statistical heterogeneity or clinical diversity was not found (P>0.10), fixed-effects model was used[31]. However, for the result showing significant heterogeneity (P<0.10), we used random-effects model to account for inter-study heterogeneity and tested for statistically significant difference between the estimates with respect to the torsional and longitudinal modes of phacoemulsification. Funnel plot was used to observe the included studies' publication bias. To explore the steadiness of our results, sensitivity analysis investigating the influence of each individual study on the overall Meta-analysis summary estimates was carried out to identify potential outliners [20,31]. All statistical tests were two-sided.

RESULTS

Literature Search Figure 1 shows the selection process.

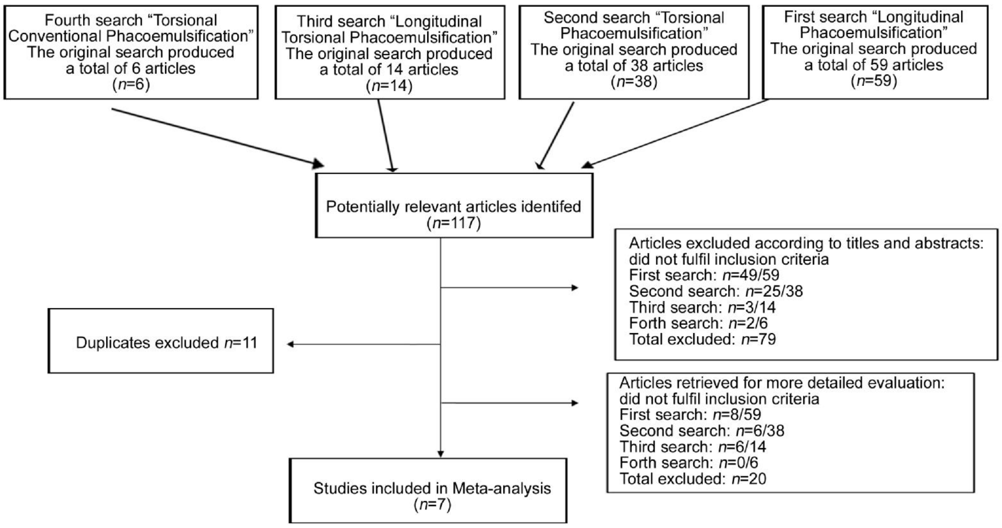

Figure 1 Flow chart of literature search and study selection.

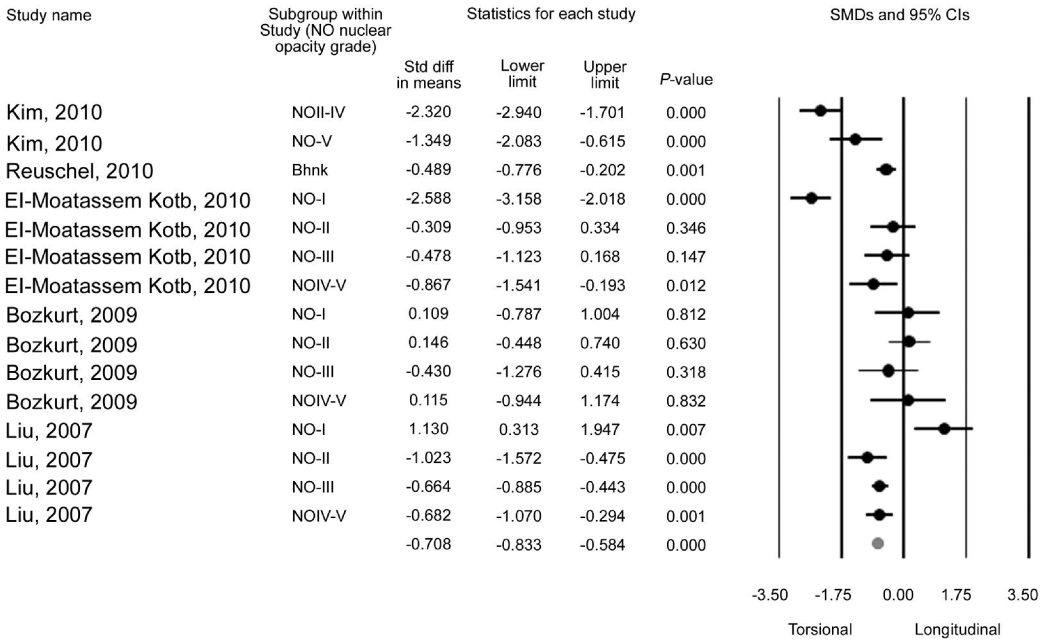

Figure 2 Forest plot comparison of mean UST Subgroup based on nuclear opacity grade (NO).

Overall there were 117 articles retrieved. Seventy-nine articles were excluded after title and abstract evaluation. Twenty articles did not fulfill the inclusion criteria. Eleven trials were duplicate citations so they were excluded. Seven studies published between 2002 and 2013 were included in this Meta-analysis[1,14,16,19,24,28-29].

Characteristics and Quality of Eligible Studies A total of 1765 patients and 1759 eyes (870 treated with longitudinal phaco-mode, 889 with torsional phaco-mode) were included in this Meta-analysis. The seven selected studies were performed in seven different countries: three in Asia (Korea, India, and China), three in Europe (Germany, Poland and Turkey) and one in Africa (Egypt). Both men and women were included. Table 1 summarizes characteristics of RCTs included in the Meta-analysis.

Intraoperative parameters (UST, CDE) were examined in five of the seven studies. Postoperative outcomes were evaluated as follows: BCVA was evaluated after 1, 30d in three of the seven studies, and ECL was evaluated after 1wk, 1 and 3mo in five of the seven studies.

Intraoperative Results Five of the seven studies were included in the evaluation of intraoperative parameters for a total of 1119 eyes.

Ultrasound Time Five studies reported UST [1,14,16,24,28]. Examination of the forest plot showed that the mean UST was shorter in the torsional group than in the longitudinal group. Analysis of these data showed that the SMD in UST (Figure 2) was statistically significant (SMD=-0.708; 95% CI, -0.833 to -0.584, P=0.00).

Cumulative Dissipated Energy Five studies reported the data for mean CDE during cataract surgery [1,14,16,24,28]. Examination of the forest plot showed that the mean CDE was lower in the torsional group in all studies considered. Analysis of these data showed that the SMD in CDE (Figure 3) was statistically significant (SMD=-0.533; 95% CI, -0.656 to -0.409, P=0.00).

Table 1 Characteristics of included studies in the Meta-analysis

Author, year	Cataract density grading system	Eyes; longitudinal[a]; torsional[b]	Intraoperative parameters			Postoperative outcomes (1wk or 1mo follow-up)		
			Longitudinal mode	Torsional mode	P	Longitudinal mode	Torsional mode	P
Kim *et al*[14], 2010	85 (66.0±9.8) LOCSIII NO≤2, N≤4 NO<4, NO≤5	102 51[a] 51[b]	n=34 CDE: 5.3±1.65 UST (s): 61.3±10.0 n= 17 CDE: 30.2±5.1 UST (s): 89.0±13.0	n=33 CDE: 2.4±0.64 UST (s): 39.1±9.1 n=18 CDE: 27.9±9.0 UST (s): 48.3±40.1	 0.014 0.023 0.324 0.249	n=34 ECL (%): 13.18±11.25 (1wk) 7.92±7.24 (1mo) n=17 ECL (%): 19.38±16.21 (1wk) 13.45±16.22 (1wk) n=51 BCVA (logMAR): 0.1453 (1mo)	n=33 ECL (%): 5.12±4.48 (1wk) 3.19±3.62 (1mo) n= 18 ECL (%): 24.02±20.24 (1wk) 23.52±22.16 (1wk) n=51 BCVA (logMAR): 0.2411 (1mo)	 0.037 0.128 0.227 0.251 0.273
Reuschel *et al*[28], 2010	OCCCGS	192 94[a] 98[b]	n=94 CDE: 15.18±7.52 UST (s): 75.13±29.92	n=98 CDE: 9.73±6.70 UST (s): 60.11±31.43	 <0.001 <0.001	n=76 ECL (%): 7.1±4.4 (3mo)	n=72 ECL (%): 7.2±4.6 (3mo)	 0.906
El-Moatassem *et al*[16], 2010	LOCSII	200 100[a] 100[b]	n=100 CDE: grade1: 1.35±0.1 grade2: 5.12±1.1 grade3: 10.61±3.2 grade4: 27.571±6.6 UST (s): grade1: 10.12±3.8 grade2: 23.22±11.3 grade3: 35.14±15.5 grade4: 71.24±11.8	n=100 CDE: grade1: 0.65±0.2 grade2: 4.16±2.2 grade3: 9.33±11.8 grade4: 22.02±9.7 UST (s): grade1: 3.25±0.4 grade2: 20.43±5.3 grade3: 28.41±12.7 grade4: 53.19±27.3	 <0.01 >0,05 >0.05 <0.05 <0.01 >0.05 >0.05 <0.01	N.A.	N.A.	-
Rekas *et al*[29], 2009	LOCSII	400 196[a] 204[b]	n=196 CDE: grade1: 5.16±0.17 grade2: 6.43±0.12 grade3: 7.67±0.27 grade4: 7.92±0.28	n=204 CDE: grade1: 1.58±0.13 grade2: 3.01±0.14 grade3: 5.83±0.28 grade4: 7.11±0.63	 <0.000001 <0.000001 0.000002 0.246796	BCVA (logMAR): 0.21±0.09 (1wk) 0.07±0.06 (1mo)	BCVA (logMAR): 0.19±0.10 (1wk) 0.06±0.05 (1mo)	 >0.05 >0.05
Vasavada *et al*[19], 2010	Emery's Classification 1-5 ([c]Legacy Everest, Alcon Laboratories)	360 120[a] (120[c]) 120[b]	n=120 surgical time (min): 6.65±2.48 n=120[c] surgical time (min): 7.05±3.38	n=120 surgical time (min): 4.40±1.37 n=120 surgical time (min): 4.40±1.37	 <0.05 <0.05	n=120 ECL (%) 5.6±2.5 (3mo) n=120[c] 5.8±2.6 (3mo)	n=120 ECL (%) 3.3±0.8 (3mo) n=120 3.3±0.8 (3mo)	 <0.001 <0.001
Bozkurt *et al*[24], 2009	LOCSII	100 47[a] 53[b]	n=47 CDE: 29.9±16.9 USTT (min): 1.62±1.06	n=53 CDE: 25.2±19.1 USTT (min): 1.49±0.98	 0.20 0.55	ECL (%) 6.7±3.3 (1wk)	ECL (%) 4.2±5.7 (1wk)	0.56
Liu *et al*[1], 2007	LOCSII	525 262[a] 263[b]	n=262 CDE: grade1: 1.25±0.5 grade2: 4.18±1.2 grade3: 8.59±6.5 grade4: 16.51±9.6 UST (s): grade1: 10.25±7.4 grade2: 25.14±5.5 grade3: 36.45±8.3 grade4: 61.44±17.8	n=263 CDE: grade1: 0.94±0.3 grade2: 3.13±2.7 grade3: 7.47±12.6 grade4: 14.08±8.3 UST (s): grade1: 8.32±6.8 grade2: 18.45±7.2 grade3: 29.48±12.4 grade4: 48.39±20.3	 <0.05 <0.05 <0.05 <0.05 <0.05 <0.05 <0.05 <0.05	BCVA (logMAR) 0.00±0.10 (1wk) -0.10±0.07 (1mo) ECL (%) 435±472 (1wk) 567±513 (1mo)	BCVA (logMAR) -0.08±0.05 (1wk) -0.12±0.06 (1mo) ECL (%) 320±378 (1wk) 467±523 (1mo)	 <0.001 >0.01 <0.05 <0.05

Ultrasound Time and Cumulated Dissipated Energy for Moderate and Hard Cataract Groups Patients were also divided into two groups according to the lens nucleus density grade: moderate and hard cataract. A total of 1119 eyes, five of seven studies [1,14,16,24,28], were divided as follow: the moderate cataract group was composed of 925 eyes and the hard cataract group was made up of 194 eyes.

The UST and CDE values were found to be statistically significant in support of the torsional mode for both moderate and hard cataract group. The SMD for moderate cataracts were of -0.657 (95% CI, -0.834 to -0.560; P=0.000) and -0.586 (95% CI, -0.724 to -0.449, P=0.000) for UST and CDE respectively (Figure 4). Advanced cataract presented a SMD of -0.623 (95% CI, -0.828 to -0.417, P=0.000) for UST and of -0.527 (95% CI, -0.731 to -0.323, P=0.000) for CDE (Figure 5).

Postoperative Outcomes Visual Acuity Three studies for a total of 1027 eyes reported BCVA (logMAR expressed) at 1 and 30d postoperatively[1,14,29]. Analysis of these data revealed that the SMD in BCVA were not statistically significant at 1d (P=0.87) and 1mo (P=0.69).

Endothelial Cell Loss Five studies for a total of 1279 eyes were used for the evaluation of the ECL after surgery[1,14,19,24,28]. Three studies were included for analysis at 1wk, two for analysis at 1, 3mo (Figure 6). The mean preoperative endothelial cell count (ECC) reported was not statistically different among the studies. The analysis with results in all cases (1wk, 1 and 3mo of follow-up) showed that the SMD were statistically different in favour of torsional mode (P<0.01).

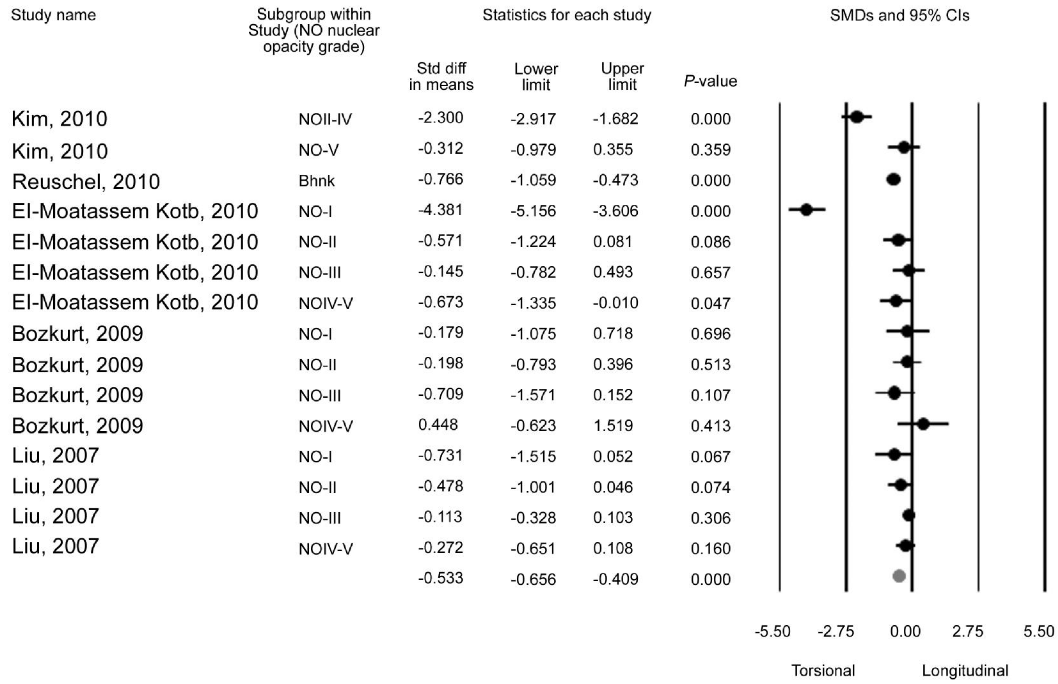

Figure 3 Forest plot comparison of mean CDE Subgroup based on nuclear opacity (NO) grade.

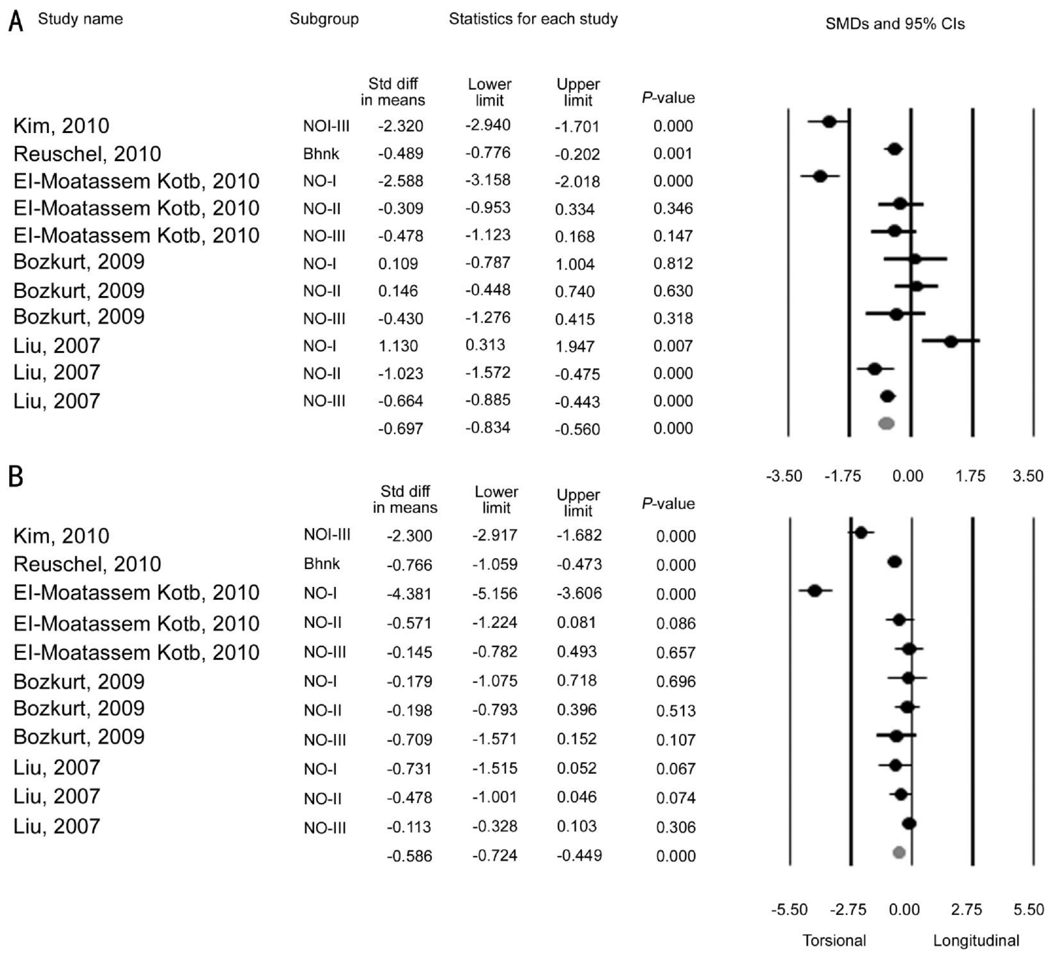

Figure 4 Forest plot comparison of mean UST and mean CDE for moderate cataract group A: Forest plot comparison of mean UST for moderate cataract group; B: Forest plot comparison of mean CDE for moderate cataract group. Subgroup based on nuclear opacity (NO) grade.

Heterogeneity The test of heterogeneity is used to determine whether there are genuine differences underlying the results of the studies (heterogeneity) or whether the variation in findings is compatible with chance alone (homogeneity).

In the present Meta-analysis, a statistical heterogeneity was detected in some outcome measures(P<0.10). Heterogeneity

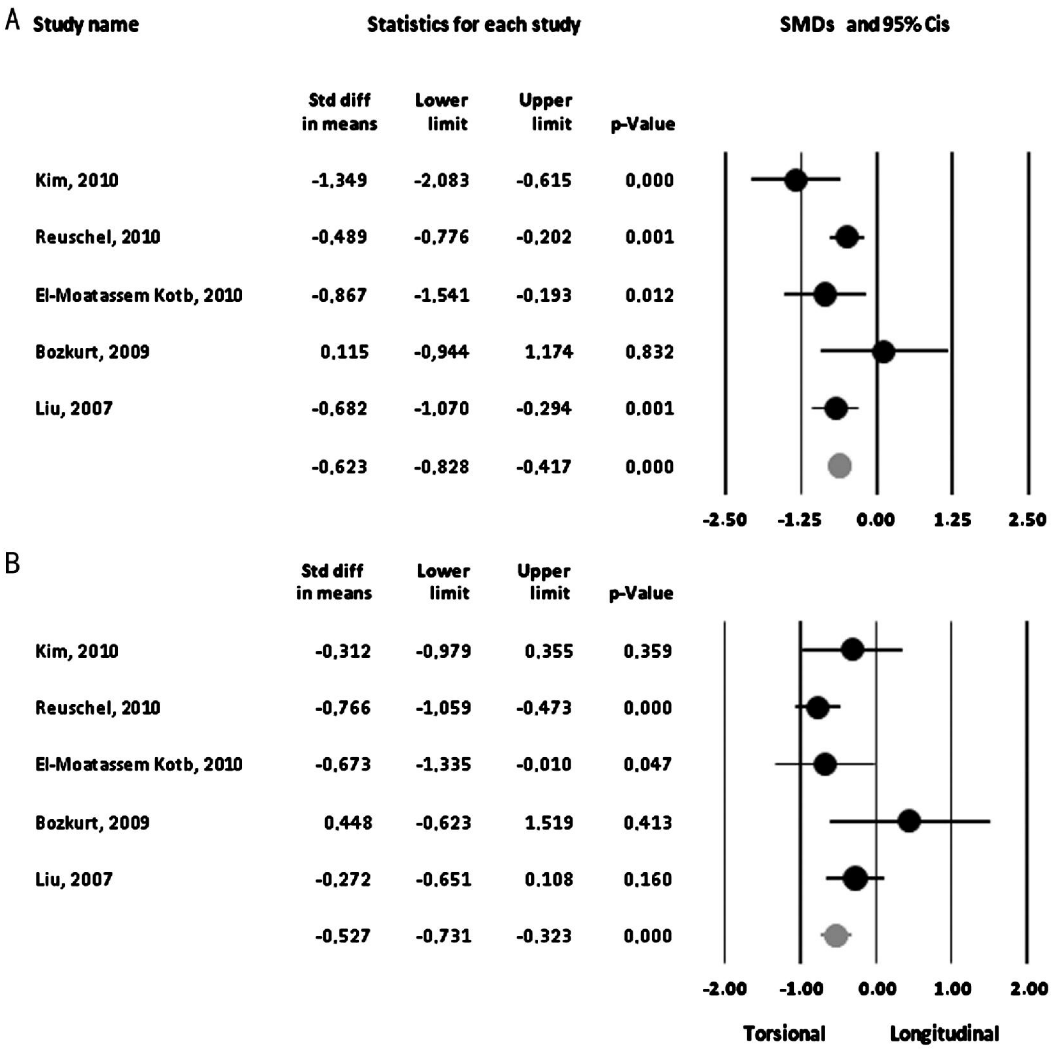

Figure 5 Forest plot comparison of mean UST and mean CDE for hard cataract group A: Forest plot comparison of mean UST for hard cataract group; B: Forest plot comparison of mean CDE for hard cataract group.

may be explained by the variability in the participants (*i.e.* patient characteristics, sample size) or interventions (*i.e.* make and model of the phacoemulsification machine, surgical skills).

Publication Bias The funnel plot showed no correlation between study size and effect.

DISCUSSION

Reviewing the data from seven RCTs this Meta-analysis provides evidence that there was a significant difference between torsional and longitudinal phacoemulsification in intraoperative parameters for all five of the studies considered and secondary for both moderate and hard cataract subgroups. To our knowledge there are no other meta-analysis studies published that compare these two phaco techniques. From our analysis, UST was shorter and CDE was lower in torsional modality. There was also significant difference in ECL in favour of torsional mode. There were no reported significant intraoperative or postoperative complications in any studies. BCVA was not statistically significant between the two groups.

We systematically compared the efficiency of the techniques by analysing the UST and the CDE. Increasing the effectiveness of phacoemulsification reduces the total ultrasound power delivered to the anterior segment, which leads to less surgical tissue damage and less corneal edema[32-33]. US power is considered a risk factor for ECL [7], and the use of high US energy is associated with heat generation damage to the endothelium [8]. This Meta-analysis showed that the mean UST was statistically significantly shorter (P=0.00) and the mean CDE was statistically significantly lower (P=0.00) in the torsional group than in the longitudinal group. In this Meta-analysis we also compared the efficacy of torsional mode with longitudinal phacoemulsification in different grades of nucleus densities. The UST and CDE values proved statistically significant in support of the torsional mode for both the moderate and hard cataract groups (P=0.000 in all groups). Our results demonstrate that torsional phacoemulsification produces an efficient mode of phacoemulsification with reduced mean UST and CDE in all grades of nucleus densities especially in hard cataracts (Grade 4 for LOCSII and Grade 5 for LOCS III). Our results are supported by those findings obtained by all studies included. This was reflected in the absence or traces of corneal edema but this parameter was not analyzed because

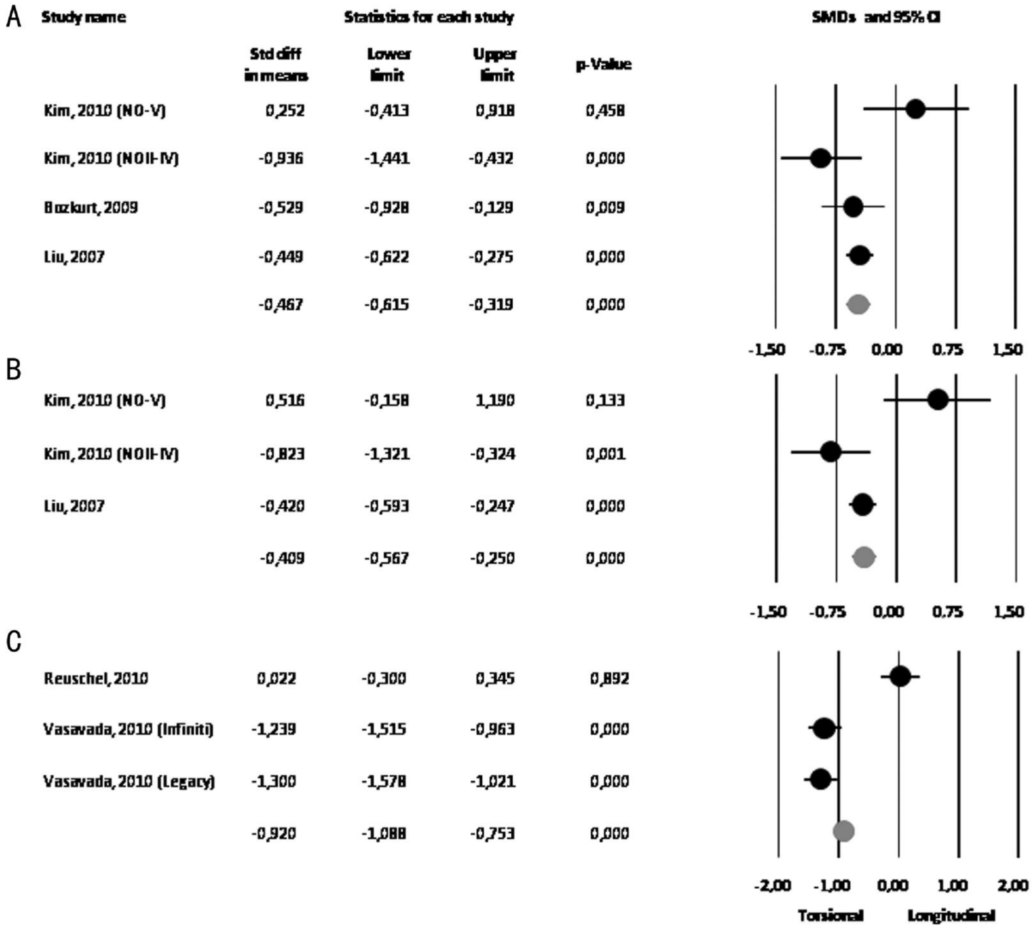

Figure 6 Forest plot comparison of ECL A: After 1wk; B: 1mo; C: 3mo.

the data were not provided in all studies and the corneal ECC was more preserved in the torsional group. In fact, comparing the two phacoemulsification modalities, longitudinal demonstrated a higher value of intraoperative parameters and a greater level of ECL.

Several preoperative and intraoperative parameters (nucleus grade, UST, CDE) can affect ECL after phacoemulsification[7,34]. There was a significant difference in ECL postoperatively after 1wk, 1 and 3mo (P<0.01). The mean preoperative ECC reported was not statistically different among the studies (P<0.01).

Good, fast, and stable visual rehabilitation is the goal of cataract surgery, and BCVA is one of the best parameters to evaluate the quality and efficiency of a surgical technique[35]. Our Meta-analysis showed no statistically differences in BCVA at 1d and 1mo in torsional and longitudinal group and both had better BCVA postoperatively. Liu *et al*[1] report that although the BCVA at 1d and 7d was significantly better in the torsional group, this advantage did not remain at 30d. This suggests that the torsional mode has a better visual outcome in the early postoperative phase. This pattern of visual rehabilitation after surgery is probably attributable to the corneal injury and its recovery[1].

Complications which occurred during cataract surgery such as capsular tears, leaking corneal incision, posterior capsular rupture were not considered in our Meta-analysis due to a lack of data. The limitations of this Meta-analysis stem from the design of the individual trials and the methods of a Meta-analysis. First, a limitation of this Meta-analysis is that only published studies searched on Medline were included. Although multiple databases and websites were explored, unfortunately, it is possible that we may have failed to include some papers, especially those published in other languages. A specific limitation of this analysis is that many trials lacked adequate allocation concealment, blinding, different nuclear opacity grading systems and sample size assessment, which may leave them vulnerable to bias and misestimation of the beneficial effects of one surgical technique. Finally, the pooled data of longitudinal and torsional phacoemulsification modalities are based on only seven papers. Therefore, more research is still needed on the available guidance derived from the current literature.

Our Meta-analysis and other clinical evidences suggests that the torsional and longitudinal phacoemulsification are both safe methods of removing uncomplicated senile cataract but torsional mode is an improved ultrasound phacoemulsification modality with increased efficacy and safety that provides intraoperative time savings and good postoperative outcomes in regard to ECL and corneal condition when compared to the traditional modulated longitudinal ultrasound.

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Conflicts of Interest: Leon P, None; **Umari I,** None; **Mangogna A,** None; **Zanei A,** None; **Tognetto D,** None.

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