

## Comparison of transversal versus torsional mode phacoemulsification for removal of hard cataracts

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### ABSTRACT

**Aim:** To compare the efficacy and safety profiles of phacoemulsification machines using transversal and torsional ultrasonic power in hard cataract surgery.

**Methods:** The medical records of patients having NO4-6 grade hard cataract based on the Lens Opacification Classification System III, and thereby, operated by using Whitestar Signature (with transversal ultrasonic power) or Infiniti Ozil IP (with torsional ultrasonic power) phacoemulsification machines were retrospectively reviewed. At baseline, best-corrected visual acuity (BCVA), cataract grade, intraocular pressure (IOP), central corneal thickness (CCT), and biometric parameters such as lens thickness or anterior chamber depth were noted. Intraoperatively, total phaco needle time and total surgery time were recorded. Postoperatively, corneal edema severity, BCVA, IOP, and CCT was examined at first, 7<sup>th</sup> and 30<sup>th</sup> days.

**Results:** Ninety-eight eyes of 98 patients with an average age of 69.5±10.9 (47-88) years and an average follow-up time of 3.0±1.4 (1-6) months were included into the study. Total phaco needle time and surgery time were significantly shorter in the torsional US group compared to the transversal US group (112±46 vs 171±42 seconds and 9.2±3.5 vs 13.4±3.3 minutes, respectively, both  $p<0.001$ ). Severe postoperative corneal edema was more common in patients in the transversal US group compared to the torsional US group.

**Conclusion:** Transversal ultrasonic power is more likely to cause corneal edema in patients with hard cataract possibly due to increased phaco needle time and surgery time, compared to torsional ultrasonic power. Therefore, torsional ultrasonic power-based phacoemulsification machines should be the first option, in patients whose corneas at risk of decompensation.

**Key words:** Corneal edema, hard cataract, phacoemulsification, torsional, transversal, ultrasonic power.

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### Introduction

Phacoemulsification is currently considered as the gold standard surgical option for treatment of cataract [1]. Although most cataract cases can be treated with phacoemulsification, cataracts that are too hard to be emulsified by

phacoemulsification are occasionally needed extracapsular cataract extraction surgery [2]. The cataractous lens fragments are emulsified by the means of ultrasonic power used in phacoemulsification machines. Early cataracts typically tend to be soft, and therefore, can be easily emulsified and aspirated by using minimal ultrasonic power; however, as the cataract hardens, higher ultrasonic power required to emulsify lens fragments. In conventional phacoemulsification machines, the phaco tip vibrates to produce reciprocating motion, called

as longitudinal mode, and emulsify the lens fragments in this way [3]. However, in hard cataracts, the setting the ultrasonic power to higher values generates a driving force, called as chatter, at the phaco tip, which forces the lens fragments forward from the needle tip. Chatter leads to break occlusion during phacoemulsification and reduces the contact of the lens fragments with the needle tip. This considerably prolongs the effective phacoemulsification time (EPT), and thus results in excessive use of ultrasonic power.

In recent decades, researchers have been in search of a new ultrasonic mode, which can emulsify and aspirate lens fragments by using low ultrasonic power, because high-level and long-term use of ultrasonic power during the cataract surgery may lead to intraoperative corneal burn, postoperative prolonged corneal edema, and even the development of bullous keratopathy. Accordingly, transversal and torsional modes have been introduced in recent years [4, 5]. The main difference of these contemporary modes from the conventional (longitudinal) mode is the variability of the vibration directions at the needle tip during the phacoemulsification. In transversal mode, needle tip vibrating at 38 kHz not only moves reciprocally, but also moves side-to-side, aiming to hold the lens fragments at the needle tip more stable during the emulsification [6]. In torsional mode, needle tip vibrating at 32 kHz generates side-to-side and rotational movements [7]. Chatter does not occur in the torsional mode, as no back-and-forth movements are generated. These two modern modes aim to emulsify cataractous lens using as little ultrasonic power as possible to harness ultrasonic power most effectively during the cataract surgery. Studies on the comparative evaluation of transversal and torsional phacoemulsification machines are mostly experimental [8, 9]. A limited number of

clinical studies have evaluated the efficacy of torsional and transversal modes in hard cataract surgery [10, 11].

Herein, we aimed to compare the intraoperative and postoperative outcomes of patients who underwent phacoemulsification with transversal or torsional mode for the treatment of hard cataract.

### **Materials and methods**

This retrospective comparative study was approved by the Ahi Evran University Ethical Committee and Review Board (Approval no: 2022-07/71), and was conducted in accordance with the declaration of Helsinki.

### **Patients**

Preoperatively, all cataracts were clinically classified according to the Lens Opacities Classification System III [12]. Hard cataract was defined as a NO4, NO5 or NO6 grade nuclear sclerosis based on LOCS III. Consecutive patients with hard cataract who underwent phacoemulsification surgery from September 2021 to February 2022 were retrospectively analyzed. At baseline visit, all patients had a comprehensive ophthalmic examination including visual acuity test, air-puff tonometer, slit-lap biomicroscopic examination, indirect funduscopy, biometry (Lenstar LS 900, Haag-Streit AG/Alcon Laboratories), and optical coherence tomography (Heidelberg Engineering, Germany). Best-corrected visual acuity (BCVA), intraocular pressure (IOP), central corneal thickness (CCT), central foveal thickness (CFT) and biometric parameters including axial length, anterior chamber depth, and lens thickness were noted. Intraoperatively, total surgery time was recorded. Patients with prior history of any ocular surgery or trauma, soft cataract (NO1, NO2, and NO3 grades), any ocular disorder other than cataract, any intraoperative complication, and a follow-up less than one month were

excluded from the study. Postoperative corneal edema was graded as follows: grade 1 (trace), minimal loss of transparency, only epithelial involvement; grade 2 (mild), dull glass appearance, partial stromal involvement; grade 3 (moderate), total stromal involvement, visible endothelium; grade 4 (severe), whitish cornea, invisible endothelium.

All procedures were performed by a single-ophthalmic surgeon (A.Y.Ü.). All patients were operated by using the phacoemulsification machine with transversal mode (WhiteStar Signature Pro, Abbott Medical Optics, Inc., USA) or torsional mode (Infiniti-OZil-IP, Alcon Laboratories, Inc., Fort Worth, TX, USA). Written and oral informed consent were obtained from all participants. Patients were separated into two groups based on the type of ultrasound (US) mode used in phacoemulsification step as follows: The transversal US group and the torsional US group.

#### ***Phacoemulsification machine settings***

The patients were randomly operated by using WhiteStar Signature Pro (transversal mode, peristaltic pump) or Infiniti OZil IP (torsional mode, peristaltic pump) phacoemulsification machines. Chopping parameters were adjusted for WhiteStar Signature Pro as follows: aspiration, 40 cc/min linear; vacuum, 400 mm Hg linear; phaco power, pulse mode 30-50% fixed (duty cycle ON time: 6 milliseconds (ms), OFF time 6 ms); bottle height, 90-110 cm. These parameters were also adjusted for Infiniti OZil IP as follows: aspiration, 40 cc/min linear; vacuum, 600 mm Hg linear; phaco power, longitudinal 0% and torsional 40-70% fixed; bottle height, 90-110 cm.

#### ***Surgical Technique***

All procedures performed under topical anesthesia. Proparacaine eye drop (Alcaine 0.5%, Alcon) was used for topical anesthesia. Briefly, general surgical steps for cataract

surgery were as follows: 1) Temporal and nasal ports were created 23 G microvitrectomy blade. 2) Anterior chamber was filled up with a dispersive ophthalmic viscoelastic material (OVM) consisting of sodium hyaluronate 3.0% and chondroitin sulfate 4.0% (Viscoat, Alcon Laboratories). 3) Main clear corneal incision was formed by 2.8 mm microblade. 4) A continuous curvilinear capsulorhexis of 5-6 mm in diameter was created by using vitreous forceps and hydro dissection was then performed to mobilize lens. 5) Nucleus was broken into pieces by phaco-chop technique. 6) Lens fragments were emulsified by using phacoemulsification machine. 7) Cortex materials were removed by bimanual irrigation/aspiration. 8) Anterior chamber was filled with a cohesive VEM consisting of sodium hyaluronate 1.0%. 9) A monofocal posterior chamber intraocular lens (SN60AT, Alcon Laboratories, and USA) was implanted in the bag. 10) VEM was removed by bimanual irrigation/aspiration. 11) Ophthalmic cefuroxime solution (Aprokam) was injected into the AC. 12). At the end of the procedure, corneal wounds were hydrated to stabilize anterior chamber.

#### ***Statistical Analysis***

Before the statistical comparisons, the powers of the analyses to be used in this study were calculated by using Gpower software, as between 0.926 and 0.957. Afterwards, SPSS Statistics version 22.0 software (IBM Corporation, Armonk, NY, USA) was used to analyze the data from this study. Kolmogorov-Smirnov test was used to evaluate the distribution of continuous variables. Numeric data was presented as mean  $\pm$  standard deviation and categorical data as number of cases and percentages. The differences of baseline demographic and clinical characteristics, and clinical outcomes between the two surgical groups were evaluated by Independent samples *T* test or Chi-Square test, where appropriate. Split-plot ANOVA test was

used to compare changes in CCT between the two groups. A *p* value less than 0.05 was considered as statistically significant.

## Results

Ninety-eight eyes of 98 patients with an average age of 69.5±10.9 (47-88) years and an average follow-up time of 3.0±1.4 (1-6) months were included into the study. Overall, female ratio was 50.0%. The mean baseline BCVA was 1.3±0.5 log MAR and the mean baseline IOP was 15.3±4.1 mm Hg. Out of 98 patients, 36 (37%) had NO4-grade cataract, 33 (34%) had NO5-grade cataract, and 29 (29%) had NO6-grade cataract according to LOCS III classification system. The baseline clinical and demographic

torsional US group compared to the transversal US group (112±46 vs 171±42 seconds, respectively, *p*<0.001). Similarly, total surgery time was markedly shorter in the torsional US group compared to the transversal US group (9.2±3.5 vs 13.4±3.3 minutes, respectively, *p*<0.001). At final visit, BCVA, IOP, CCT, and CFT were similar in both groups. Table 2 shows the detailed surgical outcomes in both groups. On postoperative day 1, moderate-to-severe corneal edema was more commonly observed in the transversal US group compared to the torsional US group. Patients in the torsional US group exhibited slighter corneal edema than those in the transversal US group (*p*<0.001). Similarly, on postoperative day 7, mild-to-

**Table 1.** Baseline clinical and demographic characteristics of the patients.

| Parameters                  | Transversal Mode (n:47) | Torsional Mode (n:51) | Total (n:98) | <i>p</i>           |
|-----------------------------|-------------------------|-----------------------|--------------|--------------------|
| Mean age (year)             | 70.4±11.7               | 68.8±10.1             | 69.5±10.9    | 0.670 <sup>a</sup> |
| Mean follow-up time (month) | 2.8±1.3                 | 3.2±1.4               | 3.0±1.4      | 0.180 <sup>a</sup> |
| Female (n, %)               | 24 (51.1%)              | 25 (49.0%)            | 49 (50.0%)   | 0.840 <sup>b</sup> |
| Mean BCVA (log MAR)         | 1.2±0.4                 | 1.4±0.5               | 1.3±0.5      | 0.449 <sup>a</sup> |
| Mean baseline IOP (mm Hg)   | 15.1±4.1                | 15.4±4.2              | 15.3±4.1     | 0.974 <sup>a</sup> |
| Mean baseline CCT (µm)      | 532.1±25.3              | 539.0±26.2            | 535.7±25.9   | 0.188 <sup>a</sup> |
| Mean LT (mm)                | 4.38±0.28               | 4.34±0.23             | 4.35±0.27    | 0.577 <sup>a</sup> |
| Mean ACD (mm)               | 3.54±0.44               | 3.72±0.54             | 3.63±0.50    | 0.065 <sup>a</sup> |
| Mean baseline CFT (µm)      | 165.4±7.6               | 168.5±8.8             | 167.1±8.3    | 0.063 <sup>a</sup> |
| Cataract grade (n)          |                         |                       |              | 0.841 <sup>b</sup> |
| NO4                         | 16 (34%)                | 20 (39%)              | 36 (37%)     |                    |
| NO5                         | 16 (34%)                | 17 (33%)              | 33 (34%)     |                    |
| NO6                         | 15 (32%)                | 14 (28%)              | 29 (29%)     |                    |

<sup>a</sup>Independent samples *T* test; <sup>b</sup>Chi-Square test; BCVA: best-corrected visual acuity; IOP: intraocular pressure; CCT: central corneal thickness; LT: lens thickness; ACD: anterior chamber depth; CFT: central foveal thickness.

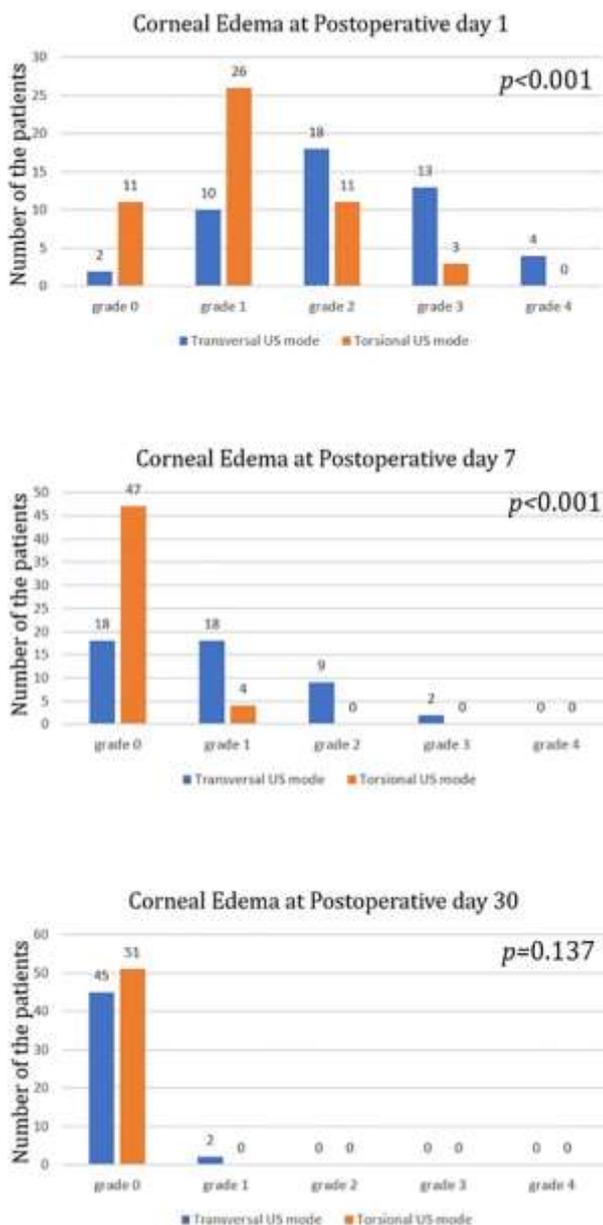
data were similar in both groups (Table 1). When it comes to final outcomes, total phaco needle time was significantly shorter in the

moderate corneal edema was more commonly observed in the transversal US group compared to the torsional US group (*p*<0.001). On

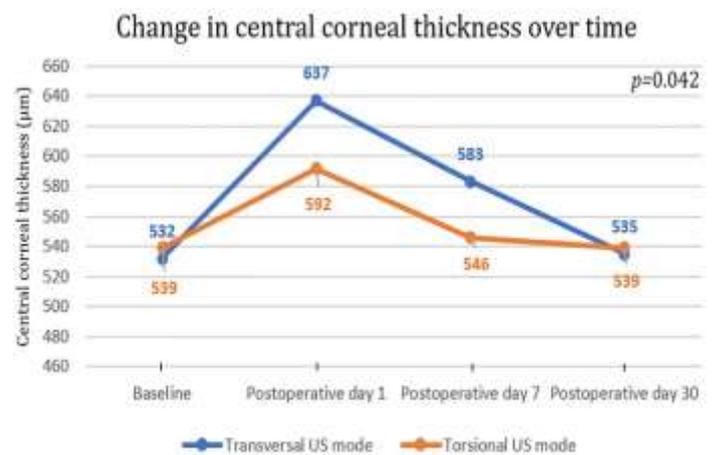
**Table 2.** Final clinical outcomes of the patients.

| Parameters                             | Transversal Mode (n:47) | Torsional Mode (n:51) | Total (n:98) | <i>p</i>            |
|--|-------------------------|-----------------------|--------------|---------------------|
| Total phaco needle time (second)       | 171±42                  | 112±46                | 140±44       | <0.001 <sup>a</sup> |
| Total surgical procedure time (minute) | 13.4±3.3                | 9.2±3.5               | 11.2±3.9     | <0.001 <sup>a</sup> |
| Final BCVA (Log MAR)                   | -0.12±0.15              | -0.16±0.12            | -0.14±0.13   | 0.633 <sup>a</sup>  |
| Final IOP (mm Hg)                      | 13.1±3.5                | 13.4±3.6              | 13.2±3.6     | 0.694 <sup>a</sup>  |
| Final CCT (µm)                         | 535.0±27.5              | 539.4±25.8            | 537.3±26.6   | 0.426 <sup>a</sup>  |
| Final CFT (µm)                         | 167.1±9.2               | 169.7±9.3             | 168.4±9.3    | 0.164 <sup>a</sup>  |

<sup>a</sup> Independent samples *T* test. BCVA, best-corrected visual acuity; IOP, intraocular pressure; CCT, central corneal thickness; CFT, central foveal thickness. Bold values indicate statistical significance.



**Figure 1.** Change in postoperative corneal edema over time between two different phaco machines.



**Figure 2.** Change in central corneal thickness over time between two different phaco machines.

postoperative day 30, all but two patients had a clear cornea. These two patients were treated with 5% sodium chloride four times a day for four weeks. Corneal oedema persisted until the end of postoperative second month in two patients in the transversal US group. Figure 1 shows the distribution of postoperative corneal edema in both groups. In postoperative period, CCT witnessed a more significant increase in the transversal US group compared to the torsional US group; however, it returned to preoperative levels at the postoperative day 30 in both groups (*p*=0.042, Figure 2).

When it comes to the complications, one patient (2%) in the transversal US group and one patient (2%) in the torsional US group experienced

intraoperative posterior capsular rupture, and thus were excluded from the study.

## Discussion

The main expectation of patients after cataract surgery is the rapid recovery of preoperative visual impairment. In relatively soft cataracts such as posterior subcapsular, cortical, or early-grade nuclear cataracts, postoperative visual recovery is rapid, as minimal ultrasonic power is used during phacoemulsification. However, as the grade of nuclear component of cataract increases, the higher amount of ultrasonic power used to emulsify lens is needed. It is well-known that an increase in the amount of ultrasonic power used can cause corneal endothelial loss and dysfunction [13]. This reflects clinically significant corneal edema, visual impairment in the early postoperative period. Furthermore, patients with limited endothelial number, who are more sensitive to ultrasonic power, may develop permanent corneal edema due to endothelial loss, and in such cases, endothelial keratoplasty is required to treat corneal edema [14].

Patient-related factors affecting the development of postoperative corneal edema after cataract surgery include presence of hard cataract, narrow anterior chamber, small pupil, floppy iris, endothelial dystrophy, glaucoma, and chronic ocular inflammation [15]. These factors cannot be modified before or during the surgery. Phaco machine-related factors affecting the development of postoperative corneal edema include excessive use of ultrasonic power, increased chatter, poor followability, poor stabilization, high bottle height [16]. Longitudinal mode is usually used in conventional phaco machines. Transversal and torsional mode phaco machines have been recently introduced because longitudinal mode uses too much ultrasonic power especially in

hard cataracts that are difficult to emulsify. Although Whitestar Signature phaco machine is called only transversal, it uses both transversal and longitudinal ultrasonic powers simultaneously, and thereby, it is not possible to turn off the longitudinal mode completely. On the contrary, in Infiniti Ozil IP using torsional ultrasonic power, longitudinal mode can be turned off and thus phacoemulsification can be completed with using only torsional ultrasonic power.

Previous studies comparing the efficacy and safety of Whitestar Signature using transversal ultrasonic power and Infiniti Ozil IP using torsional ultrasonic power reported controversial results [10, 11, 17]. Ataş et al. [10] evaluated the corneal endothelial cell density and morphology of cataract patients operated with Infiniti Ozil IP and Whitestar Signature phacoemulsification machines and found no significant difference between them. Similarly, Assaf et al. [11] retrospectively analyzed the outcomes of cataract surgeries where Infiniti Ozil IP and Whitestar Signature used, and reported that both devices were similarly effective and safe. On the contrary, Christakis et al. [17] reported that Infiniti using torsional ultrasonic power caused less postoperative corneal edema and had a shorter phaco needle time compared to Whitestar Signature using transversal ultrasonic power. They also reported that Infiniti Ozil IP had better followability and caused less chatter. Both soft and hard cataracts were included in the aforementioned studies. However, it would be inappropriate to include patients with soft cataracts in a study evaluating the efficacy and safety of phaco machines using different ultrasonic power modes because of the minimal or even no need for ultrasonic power in soft cataracts.

This study has an advantage of inclusion of purely hard cataracts, which enable the efficacy

and safety of phaco machines with different ultrasonic modes to be more clearly evaluated. According to this study, total phaco needle time and total surgery time are significantly higher in cases of hard cataract operated with Whitestar Signature. These findings may explain why patients operated with the Whitestar Signature exhibited more frequent and severe postoperative corneal edema. As the torsional phaco machine does not use longitudinal ultrasonic power, it produces no chatter and has strong followability due to absence of repulsion. These two important factors shorten the surgical time and provide the use of ultrasonic power more effectively.

The limitations of this study include retrospective design, lack of the corneal endothelium analysis. Furthermore, we could not evaluate the parameters directly related to ultrasonic power used, such as effective phaco time or total dissipated US energy due to the different algorithms used by the two phaco machines. Other limitations include a relatively small number of patients reviewed and short-term outcomes reported in this study.

In conclusion, postoperative long-term visual outcomes were found similar in patients operated with both phaco machines; however, visual recovery in the early postoperative period was faster with torsional phaco mode. In patients with hard cataracts, who have limited endothelial cell count, endothelial dystrophy, or risk of floppy iris, torsional phaco machines should be preferred. Our study is encouraging; however, further prospective large-scale studies are needed to support these outcomes.

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**Ethical Statement:** *Kırşehir Ahi Evran University local ethics committee and institutional review board approved the study protocol (Approval no: 2022-07/71).*

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