· Original article ·

Comparison of 21G curved and straight phacotips designs in transversal microcoaxial phacoemulsification

Süleyman Demircan[1], Mustafa Ataş[1], Emre Göktaş[1], Burhan Başkan[1], Gökmen Zararsiz[2]

[1]Eye Clinic, Kayseri Training and Research Hospital, Kayseri 38010, Turkey
[2]Department of Biostatistics, Erciyes University, Kayseri 38010, Turkey
Correspondence to: Süleyman Demircan. Eye Clinic, Kayseri Training and Research Hospital, Kayseri 38010, Turkey. dr.s.demircan@hotmail.com
Received: 2015-01-15 Accepted: 2015-07-28

比较21G弯头和直头在横向劈核微切口同轴超声乳化手术中的应用

Süleyman Demircan[1], Mustafa Ataş[1], Emre Göktaş[1], Burhan Başkan[1], Gökmen Zararsiz[2]
(作者单位:[1]土耳其,开塞利 38010,开塞利培训与研究医院眼科门诊;[2]土耳其,开塞利 38010,埃尔吉耶斯大学,生物统计学系)
通讯作者:Süleyman Demircan. dr.s.demircan@hotmail.com

摘要

目的:比较在微切口同轴扭动超声乳化使用直头和弯头的术中表现和术后结果。

方法:白内障患者行2.2mm横向劈核微切口同轴超声乳化术中使用30°直头或弯头进行治疗。术中检查分析包括平均超声功率,总超声乳化时间,有效的超声乳化时间。使用非接触镜显微镜评估术前和术后1d, 7d和30d的中央内皮细胞密度和角膜中央厚度。

结果:此研究共纳入白内障患者190例190眼,95眼为弯头组,95眼为直头组。术中检查显示弯头组总超声乳化时间和有效的超声乳化时间较直头组显著降低($P<0.05$)。弯头组总超声乳化时间和有效的超声乳化时间中位数分别为25.9(13.5-45.0)s(四分位间距)和18.0(9.0-30.0)s,直头组分别为38.8(16.5-73.5)s和26.0(11.0-49.0)s。

结论:横向劈核微切口同轴超声乳化术中,相比较直头,使用弯头可以更加有效的摘除晶体,在所有阶段中除了第四阶段,总超声乳化时间和有效的超声乳化时间更短。

关键词:横向劈核微切口同轴超声乳化;弯头;直头;微切口同轴超声乳化

引用:Demircan S, Ataş M, Göktaş E, Başkan B, Zararsiz G. 比较21G弯头和直头在横向劈核微切口同轴超声乳化手术中的应用. 国际眼科杂志 2015;15(12):2029-2035

Abstract

• AIM: To compare the intraoperative performance and postoperative outcomes after microcoaxial torsional phacoemulsification using the straight and the curved phacotip configurations.

• METHODS: Cataracts were treated using 2.2mm microcoaxial transversal phacoemulsification with either a 30° straight or 30° curved phaco tip. Intraoperative measurements analyzed included the average ultrasound (U/S) power, the total phacoemulsification time, and the effective phacoemulsification time (EPT). The central endothelial cell density (ECD) and the central corneal thickness (CCT) were evaluated preoperatively and postoperatively at 1, 7 and 30d after surgery using noncontact specular microscopy.

• RESULTS: The study enrolled a total of 190 eyes (190 patients), 95 eyes in the curved tip group and 95 eyes in straight tip group. Intraoperative measurements showed significantly reduced total phacoemulsification time, and EPT in the curved-tip group, compared to the straight-tip group ($P<0.05$). The median total phacoemulsification time and the EPT were 25.9 (13.5 - 45.0) s (1^{st} - 3^{rd} quartiles) and 18.0 (9.0-30.0)s in curved-tip group, and 38.8 (16.5-73.5)s and 26.0 (11.0-49.0)s in the straight-tip group, respectively.

• CONCLUSION: Transversal phacoemulsification performed with a curved tip provided more effective lens removal with a less total UST and EPT in all grades, except for grades IV, compared to a straight tip.

• KEYWORDS: transversal phacoemulsification; curved phaco tip; straight phaco tip; microcoaxial phacoemulsification

DOI:10.3980/j.issn.1672-5123.2015.12.02

Citation: Demircan S, Ataş M, Göktaş E, Başkan B, Zararsiz G. Comparison of 21G curved and straight phacotips designs in transversal microcoaxial phacoemulsification. *Guoji Yanke Zazhi* (*Int Eye Sci*) 2015;15(12):2029-2035

INTRODUCTION

The recent developments in current phacoemulsification technology have focused on reducing incision size, phacoemulsification energy, and endothelial cell loss, while increasing ultrasound (U/S) efficiency phacoemulsification[1-4].

In 2007, the relatively new cataract removal modality of transversal Ellips phaco technology (Abbott Medical Optics, Inc.) was released. The technology is based on tip movement in an elliptical path, thus combining a side - to - side movement and a longitudinal stroke[5-8]. In 2010, the new FX version of the Ellips handpiece was introduced to the market to improve performance. The Signature Ellips - FX uses transversal phacoemulsification technology, in which a straight or curved needle tip vibrating at 38 kHz can be used to generate side-to-side, as well as longitudinal, movement and has both peristaltic and venturi fluidics[9].

The geometric configuration of the phaco tip is also expected to be an important factor in the procedure's efficiency and surgery outcomes[10,11]. There has not been sufficient availability of straight tips for a prospective comparative study, which is required in order to prove the similar performance of straight and curved tips in transversal phacoemulsification.

We designed a study to compare the intraoperative performance and postoperative outcomes after microcoaxial transversal phacoemulsification using either 30° curved or straight - tip configurations because, theoretically, as for torsional phacoemulsification, the efficiency of transversal phacoemulsification is influenced by the tip design.

SUBJECTS AND METHODS

This prospective randomized comparative study was performed at Kayseri Training and Research Hospital Eye Clinic, Kayseri, Turkey, from May to July 2014. The study protocol was approved by the institutional review board and performed according to the Declaration of Helsinki. Patients who applied to the clinic with the diagnosis of age related-cataract were enrolled in the study. Exclusion criteria were previous ocular trauma or intraocular surgery, intraocular inflammation, preoperative anterior chamber depth less than 2.5 mm centrally, preoperative pupil dilation less than 4 mm after dilation, any corneal pathology, any condition that impeded corneal evaulation by specular microscopy and pachymetry or follow-up. Patients were randomly assigned to surgery groups after they provided informed consent. All patients underwent a complete ophthalmic examination. The Lens Opacities Classification System II scale was used for nucleus grading. Equal numbers of eyes were allocated to the groups for each nucleus density grade. Phacoemulsification was performed by the quick chop technique using the Abbott Whitestar Signature system and 21G 20° bent 30° bevel curved phaco tip or 21G 30° bevel straight phaco tip. The two tips have a similar bevel angle at the aperture of the tips, except for the bend configuration. The outer diameter and inner diameter of the phaco tips was 0.80 mm and 0.54 mm, respectively (Figure 1). The same energy and fluid settings were used to compare the intraoperative performance and postoperative outcomes after microcoaxial transversal phacoemulsification in both phaco tip groups.

For the quick-chop technique, transverse mode was adjusted as follows: fixed power 40% pulse mode 20 pps, vaccum limit 500 mm Hg linear, aspiration flow rate 32 mL/min fixed with and bottle height at 105 cm. All surgery was performed under topical anesthesia (Proparacaine hydrochloride 0.5%) by the same experienced surgeon (Demircan S). A clear corneal incision was made on the steep axis with 2.2 mm Intrepid Clearcut 2.2 mm dual bevel metal keratome (Alcon Surgical, Inc.). Viscoat (Sodium hyaluronate 3.0%, Chondroitin sulfate 4.0%) was used to reform and stabilize the anterior chamber and protect the corneal endothelium. Trypan blue 0.4% was used to improve visualization of the capsule in eyes with dense cataract. A 5.0 to 5.5 mm cotinuous curvilinear capsulorhexis was made using an ultrata capsulorhexis forceps (Katena, USA). All intraocular lenses (Acrysof SA60AT, Alcon) were inserted into a capsular bag using the same injector system (MonarchIII D - Catridge). Sodium hyaluronate (1.0%, Provisc, Alcon) was used for intraocular insertion. The ocular viscoelastic device (OVD) was removed from the anterior chamber and the capsular bag using the I/A system. For endophthalmitis prophylaxis, 0.1mL moxifloxacin ophthalmic solution (0.5% Vigamox) was injected into the anterior chamber after closure of the port incisions by stromal hydration using a balanced salt solution. After surgery, all patients used topical prednisolone acetate (1.0%) and moxifloxacin (0.5%) 6 times daily for 4wk. Intraocular pressure (IOP) was measured using a noncontact applanation tonometer (NT-510, Nidek).

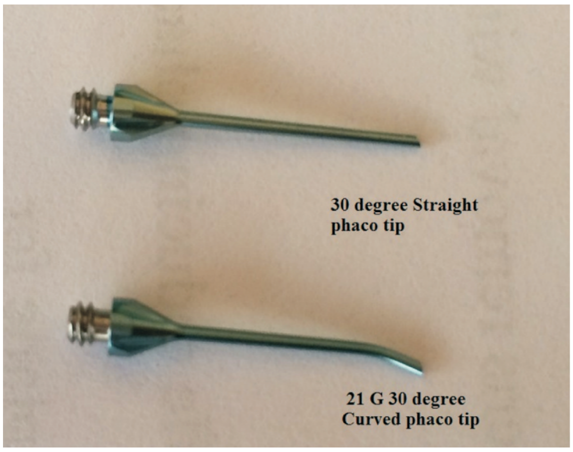

Figure 1 A photographs of 21G 30 degree straight and curved phaco tip.

The central corneal thickness (CCT) and the central endothelial cell density (ECD), polymegathism [coefficient of variation (CV)], and pleomorphism (percentage of hexagonal cells), were evaluated preoperatively and postoperatively at 1, 7 and 30d after surgery using noncontact specular microscopy (SP 3000P, Topcon). More than 75 endothelial cells per eye were used to calculate the ECD, CV, and percentage of hexagonalty using the IMAGEnet i-base imaging system (version 3.5.6, Topcon). During each visit, 3 photographs of each cornea were taken and analyzed indepedently by another ophthalmologist. The mean of the 3 readings was calculated and used as the final reading for each visit. The percentage change in ECT and CCT at each visit were calculated as follows: [(preoperative value-postoperative value)/preoperative value]×100.

Intraoperative parameters of the average U/S power, the total phacoemulsification time, and the effective phacoemulsification time (EPT) were automatically calculated and displayed on the monitor of the Whitestar Signature Ellips,

Table1 Comparison of patients' characteristics (n, $\bar{x}\pm s$)

Variable	Phaco tip groups		P
	Curved (n=95)	Straight (n=95)	
Age (a)	68.39±13.40	66.50±11.52	0.297
Gender(M/F)	52/43 (54.7/45.3)	49/46 (51.6/48.4)	0.532
Eye (R/L)	45/45 (50.0/50.0)	48/47 (50.5/49.5)	0.716
Pupil size	7.26±1.07	7.39±0.92	0.614
ACD	3.20±0.34	3.12±0.37	0.336

ACD: Anterior chamber depth.

Table 2 Comparison of intraoperative parameters in LOC Ⅱ subgroups

Variable	Phaco tip groups		P
	Curved (n=95)	Straight (n=95)	
Total (n=190)			
EPT	18.0 (9.0-30.0)	26.0 (11.0-49.0)	0.013
UST	25.9 (13.5-45.0)	38.8 (16.5-73.5)	0.008
Average UST	13.0 (13.0-13.0)	13.0 (13.0-13.0)	0.480
Grade 1 (n=50)			
EPT	3.0 (0.0-10.5)	8.0 (2.5-14.0)	0.032
UST	4.3(0.0-13.2)	11.8 (3.6-21.4)	0.022
Average UST	13.0 (0.0-13.0)	13.0 (13.0-13.0)	0.882
Grade 2 (n=78)			
EPT	17.0 (11.0-24.0)	24.0 (11.0-36.0)	0.030
UST	23.9 (15.5-33.4)	36.3 (16.0-54.7)	0.021
Average UST	13.0 (13.0-13.0)	13.0 (13.0-13.0)	0.472
Grade 3 (n=44)			
EPT	33.5 (24.8-42.5)	58.5 (43.8-72.5)	<0.001
UST	49.3 (36.6-63.7)	87.9 (65.3-108.4)	<0.001
Average UST	13.0(13.0-13.0)	13.0 (13.0-13.0)	0.317
Grade 4 (n=18)			
EPT	69.0 (55.5-113.5)	113.0 (47.5-127.5)	0.508
UST	103.4 (82.8-147.7)	169.8 (71.0-188.6)	0.387
Average UST	13.0 (13.0-13.0)	13.0 (13.0-13.0)	0.317

Values are expressed as median(1^{st}-3^{rd} quartiles). LOC Ⅱ: Lens opacities classification system Ⅱ; EPT: Effective phacoemulsification time; UST: Ultrasound time; Average UST: Average ultrasound time.

Abbott Medical Optics, Inc. phacoemulsification system.

Statistical Analysis Shapiro-Wilk's test and q-q plots were examined to assess the univariate data normality. The Levene test was applied to test the homogeneity of variances. Pearson's Chi-square test and Fisher's exact tests were used to compare the differences for categorical variables. A two-way independent samples t-test or Mann-Whitney U tests were used to compare the differences for continuous variables. Analysis were conducted using R 3.1.0 (www.r-project.org) software and $P<0.05$ was considered as statistically significant.

RESULTS

We enrolled 190 eyes (190 patients) and assigned half to the straight group and half to the curved group. We used the 21G 30° curved tip on the former and the 21G 30° straight tip on the latter. Table 1 shows the patients' characteristics and intraoperative parameters. There were no statistically significant differences in age, gender, pupil size, or ACD between the groups. Intraoperative measurements showed significantly reduced total median phacoemulsification time and EPT in the curved group than in the straight group ($P<0.05$). The respective values were 25.9 (13.5-45.0)s (1^{st}-3^{rd} quartiles) and 18.0 (9.0-30.0)s in curved-tip group, and 38.8 (16.5-73.5)s and 26.0 (11.0-49.0)s in the straight tip group, respectively. Average U/S time was similar in both groups ($P>0.05$). Table 2 shows the nucleus density grades in each group. The median total U/S time, and EPT were significantly lower in the curved group than in the straight group for all grades, except for grade Ⅳ (Figure 2). The mean ECD loss was 10.8% in the curved group and 11.9% in the straight group 30d after surgery. The percent change in ECD and CCT were similar in both groups throughout the follow up period ($P>0.05$; Table 3). Clear ECD measurements could not be obtained in 2 patients from each group 1d postoperatively. There was a relative decrease in ECD at 1 and 7d postoperative, which can be related to the

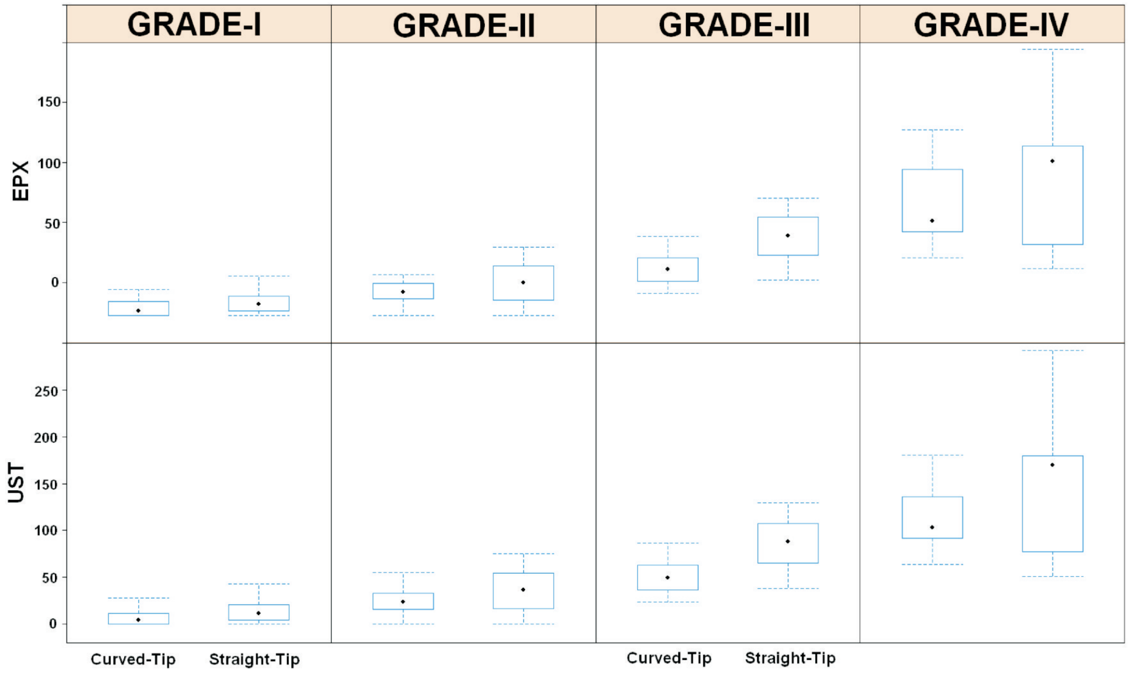

Figure 2　Comparison of intraoperative parameters in LOC Ⅱ grades　LOC Ⅱ: Lens opacities classification system Ⅱ; EPT (EFX): Effective phacoemulsification time; UST: Ultrasound time.

Table 3　Comparison of CCT, ECD, andpercentage differences in CCT and ECD between groups over time　$\bar{x}\pm s$

Variable	Phaco tip groups		*P*
	Curved(*n*=95)	Straight(*n*=95)	
CCT			
Preoperative	501.24±32.67	508.87±34.15	0.117
Postoperative 1d	546.42±50.34	551.89±48.50	0.517
Postoperative 7d	525.14±47.08	528.42±41.18	0.729
Postoperative 30d	506.25±30.41	509.70±35.22	0.709
Δ0-1	0.09±0.07	0.08±0.07	0.348
Δ0-7	0.05±0.06	0.04±0.06	0.642
Δ0-30	0.01±0.02	0.01±0.04	0.709
ECD			
Preoperative	2375.03±398.54	2382.53±354.05	0.891
Postoperative 1d	2161.82±430.04	2212.62±447.62	0.499
Postoperative 7d	2121.24±467.36	2101.18±485.60	0.837
Postoperative 30d	2118.24±414.07	2075.24±412.51	0.718
Δ0-1	-0.08±0.14	-0.08±0.13	0.986
Δ0-7	-0.10±0.14	-0.12±0.14	0.603
Δ0-30	-0.11±0.15	-0.12±0.13	0.811

CCT: Central corneal thickness; ECD: Endothelial cell density.

difficulty in measuring ECD caused by greater corneal edema in both groups. No patient suffered intraoperative complications or postoperatively complications, such as synechiae, fibrin formation, or endophthalmitis.

DISCUSSION

To our knowledge, this is the first study conducted to compare 21G curved and straight phaco tips designs in transversal microcoaxial phacoemulsification. There has, until now, not been sufficient availability of straight tips for a prospective comparative study, which is needed to prove that straight tips are as effective as curved tips in transversal phacoemulsification.

The nonlongitudinal U/S is the major modality used in phacoemulsification today. Each of these U/S modalities has resulted in improved ultrasonic efficiency and, most important, can use smaller gauge phaco tips to effectively emulsify nuclear material[12]. We used to test 21G a straight or curved phaco tips *via* 2.2 mm microcoaxial phacoemulsification. Microcoaxial phacoemulsification requires an incision of less than or equal to 2.2 mm and accommodates a sleeve over the tip. This allows aspiration and irrigation through the same incision coaxially and allows implantation of an IOL without enlarging the incision[13].

To increase the efficiency and safety of phacoemulsification, 2 forms of nonlongitudinal U/S motion have been introduced as alternative approaches to the classic longitudinal motion of the phaco tip[12,14]. One system (Infiniti Ozil, Alcon Surgical Inc.) uses an U/S action that causes the needle tip to move in a horizontal motion and that can also be combined with a longitudinal U/S component. In the other system (Whitestar Signature Ellips, Abbott Medical Optics, Inc.), the tip subtends an ellipsoid shape so that there is some degree of inherent longitudinal motion[5-8]. Heat generation by the elliptical mode was significantly lower than that by the longitudinal mode at the high U/S power setting. Because the elliptical vibration is a combination of horizontal and longitudinal movements, the suppressed heat generation seems to be due to a reduction in the longitudinal vibration[15].

The choice of phaco tip depends on surgeon preference, which is mainly surgical technique dependent (*i. e.*, chop or nucleofractis). Many ophthalmologists prefer a straight tip to the curved tip in longitudinal phacoemulsification. Unlike torsional phacoemulsification, the motion can be created with a straight phaco needle. As a result, the surgeon does not have to modify his or her preferred technique or embrace new tip designs.

The transversal phaco modality can be used with either a straight or curved phaco tip, although some bend in the needle shaft does increase the amplitude of the motion. This increased amplitude should increase overall efficiency. The working frequency is 28 kHz, and the transversal-to-longitudinal movement ratio is 3:1. In transversal mode, cavitation is generated in the region around the tip, including the sides, rather than only at the front, as with longitudinal phaco. The transversal technology was further improved with the introduction of the Ellips FX system in 2009. The Ellips FX technology features three main modifications compared with the preceding version: 1) the working frequency is increased by 45% to 38 kHz; 2) the stroke length of the transversal tip movement is intensified by three-fold; and 3) the transversal-to-longitudinal ratio is modified from 3:1 to 1:1.

We compared the intraoperative efficiency and postoperative outcomes of curved and straight phaco tips. The tip selection is important for the efficiency of nonlinear phacoemulsification. Theoretically, there are two ways to enhance the cutting efficiency of a tip[10,11,16]. The first is the stroke length, the 22-degree curved tip cuts longer than the 12-degree curved tip. The second is the angulation or bevel, the higher the degree (up to 45°), the better the cutting efficiency. A curved tip oscillates with greater motion, giving it greater cutting power to break up the nucleus. The side-to-side motion of a torsional handpiece, or the elliptical motion of the previous generation of the manufacturer's system, required a curved phaco tip. However, it is claimed that the new transversal technology is so effective that it is not necessary to change the surgeon's technique. We found that the safety and efficiency of transversal phacoemulsification were increased by the use of the curved-design phaco tip in all cataract grades, except for grade Ⅳ. Davidson[17] compared the surgeon-generated tip travel and surgical time of longitudinal and torsional phacoemulsification with straight and angled tips. Davidson[17] found that for removal of all four quadrants, there was a 36.1% and 44.3% reduction in tip travel in the angled tip/longitudinal phacoemulsification and angled tip/torsional phacoemulsification, respectively, compared with straight tip/longitudinal phacoemulsification. We found that the reduction in the total phacoemulsification time was 65.8% in the curved-tip group, compared with straight tip group in transversal phacoemulsification. This reduction can be explained by the bend in the needle shaft increasing the amplitude of the motion. This increased amplitude should increase the overall efficiency in transversal phacoemulsification. However, the data generated in this study show that there were no diffrences in EPT and total UST in hard cataracts (grade 4) between both phaco tip groups.

Aspiration flow rates, vacuum levels, and phaco tip movement are the 3 main factors influencing cataract extraction efficiency, which is defined as the inverse of the amount of time required to remove nuclear material[18]. Efficiency is reduced by microchatter and macrochatter events during phacoemulsification. Chatter results from inadequate hold as counteracted by the tip action's repulsive force at the phaco tip and leads to decreased efficiency and an increased risk for complications[1,17,19]. Previous studies have shown that reduced repulsion from the phaco tip improved followability and reduced chatter [16]. This result may be explained by the fact that the 21G curved phaco tip does not form as strong a hold to a hard cataracts fragments in order to show shearing effect on lens fragments, resulting in higher chatter and less efficiency. This issue may be solved with venturi system. Therefore the venturi system might cause a decrease in chatter and efficiency given its uniqueability to maintain constant vacuum at the tip. Another possible explanation for this is that Gupta *et al*[20] studied phacoemulsification efficiency with a radiused phaco tip. They concluded that the shearing effect of phaco tip is more efficient if the its edge is sharp in torsional phacoemulsification. However, transversal and conventional longitudinal motion of phaco tip do not require edge sharpness because of nature of jackhammer effect compared with shearing effect. Farukhi *et al*[21] found that the 0.7 mm tip was highly statistically significantly less efficient than a 0.9mm tip. Transversal phacoemulsification statistically significantly increased chatter events in the 0.7 mm tip group compared with the 1.1 mm tip group and the 0.9 mm tip group. Only transversal phacoemulsification showed a significant difference in chatter between the different tip sizes. Kim *et al*[22] reported the intraoperative energy used and ocular damage can be decreased in MICS with the pulse and burst modes compared with the continuous mode for hard cataract. In addition, Park *et al*[23] found that the phaco-chop technique can be more effective for lens removal, with less corneal endothelial damage, than the divide-and-conquer and stop-and-chop techniques in eyes with hard cataract having coaxial MICS. In the light of their findings, in order to enhance efficiency and minimize the surgical variations, all surgeries were performed by the same experienced surgeon using the same techniques and settings (*i. e.*, vertical choping technique with pulse mode, similar nuclear gradings, and same catridge system for IOL implantation, as well as same OVD and BSS-plus for irrigating solution).

The same parameters were also used in both groups, so as to maintain focus on the efficiency of the tips. We adjusted the transverse mode setting parameters as follows: fixed power 40%, pulse mode 20 pps, vaccum limit 500 mm Hg linear, aspiration flow rate 32 mL/min fixed, with and bottle height at 105 cm. The fixed power 40% setting was chosen because DeMill *et al*[6] suggested that setting high phaco powers on the Signature Whitestar machine yields few advantages. When the settings were optimized to 50% power and 550 mm Hg vacuum, Ellips-FX chatter was minimal and significantly improved. Higher vacuum generally improved efficiency and chatter, while additional power often increased both. Amplitude had a variable effect depending on the power level.

The stroke of the Signature Whitestar Ellips FX system tends to a plateau for phaco powers exceeding 40%. The jackhammer repulsion effect depends, at least partially, on the mechanical punching of the forward stroke on the lens material. The lens is emulsified by both a shearing and a longitudinal jackhammer effect. The use of curved phaco tips is indicated for both lens-fragmentation strategies and even required for the Infiniti Ozil. The curved tip allows magnification of the side-to-side movement because of the bent tip edge. DeMill *et al*[6] analyzed the curved tip movement on the x-axis and found that the Signature Whitestar with Ellips FX hand-piece had a different behavior; that is, the curve tended to reach a plateau at more than 30% phaco power. The shape of the ellipse generated by the Ellips FX handpiece was primarily determined by the side-to-side movement on the x-axis at lower phaco powers and mainly on the y-axis at higher phaco powers. The crossover point was at approximately 37% of phaco power. The stroke generated by the Signature Whitestar Ellips FX system had a predominantly jackhammer effect, rather that shearing effect, at higher powers, even though a relevant x component (shearing effect) was present at all phaco powers. From 40 to 70% of phaco power, the elliptical shape of the stroke tended to form a circle; the x and y values were roughly similar even though the longitudinal component prevailed. The theoretic advantage of the new Ellips FX handpiece is that the simultaneous jackhammer and shearing fragmentation strategy may compensate for the reduced longitudinal elongation of the tip. This may reduce chattering caused by a minor jackhammer effect, leading to better followability and phaco efficiency.

ECD and CCT changes, and biomicroscopic evaluation of postoperative anterior chamber reactions, were used to measure the safety of the surgeries. The mean ECD loss was 10.8% in the curved group and 11.9% in the straight group 30d after surgery. Our results are similar to those in the literature evaluating ECD loss[24,25]. The percent change in ECD and CCT were similar in the two groups throughout the follow-up period (P>0.05; Table 3), eventhough this might have been influenced by many factors, such as techniques, fluid energy settings, and proximity of emulsification to the cornea during surgery. Therefore, EPT, which was used to show the efficiency of the procedures, is also a meaningful intraoperative parameter for indicating postoperative morbidity regarding the corneal endothelium.

Efficiency and chatter are significantly affected by the parameters used[6]. The operations were performed more efficiently with the enhanced cutting effect of the 30° aperture curved tips.

In conclusion, our study found that efficiency of transversal phacoemulsification were increased by the use of the curved-design phaco tip in all cataract grades, except for grade Ⅳ. A deep knowledge of each phaco tip allows a customized parameter setting according to clinical needs and surgeon preferences.

REFERENCES

1 Liu Y, Zeng M, Liu X, Luo L, Yuan Z, Xia Y, Zeng Y. Torsional mode versus conventional ultrasound mode phacoemulsification; randomized comparative clinical study. *J Cataract Refract Surg* 2007;33(2):287-292

2 Christakis PG, Braga-Mele RM. Intraoperative performance and postoperative outcome comparison of longitudinal, torsional, and transversal phacoemulsification machines. *J Cataract Refract Surg* 2012;38(2):234-241

3 Tsuneko H, Shiba T, Takahashi Y. Feasibility of ultrasound cataract surgery with a 1.4 mm incision. *J Cataract Refract Surg* 2001;27(6):934-940

4 Zeng M, Liu X, Liu Y, Xia Y, Luo L, Yuan Z, Zeng Y, Liu Y. Torsional ultrasound modality for hard nucleus phacoemulsification cataract extraction. *Br J Ophthalmol* 2008;92(8):1092-1096

5 Tognetto D, Cecchini P, Leon P, Nicola MD, Ravalico G. Sroke dynamics and frequency of 3 phacoemulsification machines. *J Cataract Refract Surg* 2012;38(2):333-342

6 DeMill DL, Zaugg BE, Pettey JH, Jensen JD, Jardine GJ, Wong G, Olson RJ. Objective comparison of 4 nonlongitudinal ultrrasound modalities regarding efficiency and chatter. *J Cataract Refract Surg* 2012;38(6):1065-1071

7 Schmutz JS, Olson RJ. Thermal comparison of Infiniti OZil and Signature Ellips phacoemulsification systems. *Am J Ophthalmol* 2010;149(5):762-767. e1

8 Oakey ZB, Jensen JD, Zaugg BE, Radmall BR, Pettey JH, Olson RJ. Porcine lens nuclei as a model for comparison of 3 ultrasound modalities regarding efficiency and chatter. *J Cataract Refract Surg* 2013;39(8):1248-1253

9 Patrício MS, Almeida AC, Rodrigues MP, Guedes ME, Ferreira TB. Correlation between cataract grading by Scheimpflug imaging and phaco time in phacoemulsification using peristaltic and venturi pumps. *Eur J Ophthalmol* 2013;23(6):789-792

10 Helvacioglu F, Sencan S, Yeter C, Tunc Z, Uyar OM. Outcomes of torsional microcoaxial phacoemulsification using tips with 30-degree and 45-degree apertura angles. *J Cataract Refract Surg* 2014;40(3):362-368

11 Helvacioglu F, Yeter C, Sencan S, Tunc Z, Uyar OM. Comparison of two different ultrasound methods of phacoemulsification. *Am J Ophthalmol* 2014;158(2):221-226

12 Dewey S, Beiko G, Braga-Mele R, Nixon DR, MD, Raviv T, Rosenthal K; ASCRS Cataract Clinical Committee, Instrumentation and IOLs Subcommittee. Microincisions in cataract surgery. *J Cataract Refract Surg* 2014;40(9):1549-1557

13 Vasavada V, Vasavada V, Raj SM, Vasavada AR. Intraoperative performance and postoperative outcomes of microcoaxial phacoemulsification: Observational study. *J Cataract Refract Surg* 2007;33(6):1019-1024

14 Atas M, Demircan S, Karatepe Hashas AS, Gulhan A, Zararsiz G. Comparison of corneal endothelial changes following phacoemulsification with transversal and torsional phacoemulsification machines. *Int J Ophthalmol* 2014;7(5):822-827

15 Suzuki H, Oki K, Igarashi T, Shiwa T, Takahashi H. Temperature in the anterior chamber during phacoemulsification. *J Cataract Refract Surg* 2014;40(5):805-810

16 Kim EK, Jo JK, Joo CK. Comparison of tips in coaxial microincision cataract surgery with the bevel-down technique. *J Cataract Refract Surg* 2011;37(11):2028-2033

17 Davidson JA. Cumulative tip travel and implied followability of longitudinal and torsional phacoemulsification. *J Cataract Refract Surg* 2008;34(6):986-990

18 Watanabe A. New phacoemulsification tip with a grooved, threaded-tip construction. *J Cataract Refract Surg* 2011;37(7):1329-1332

19 Miyoshi T, Yoshida H. Ultra-high-speed digital video images of vibrations of an ultrasonic tip and phacoemulsification. *J Cataract Refract Surg* 2008;34 (6):1024-1028

20 Gupta I, Zaugg B, Stagg BC, Barlow WR Jr, Pettey JH, Jensen JD, Kirk KR, Olson RJ. Phacoemulsification efficiency with a radiused phaco tip. *J Cataract Refract Surg* 2014;40(5):818-821

21 Farukhi AM, Stagg BC, Ronquillo C Jr, Barlow WR Jr, Pettey JH, Olson JD. Effect of phaco tip diameter on efficiency and chatter. *J Cataract Refract Surg* 2014;40(5):811-817

22 Kim EC, Byun YS, Kim MS. Microincision versus small-incision coaxial cataract surgery using different power modes for hard nuclear cataract. *J Cataract Refract Surg* 2011;37(10):1799-1805

23 Park J, Yum HR, Kim MS, Harrison AR, Kim EC. Comparison of phaco-chop, divide-and-conquer, and stop-and-chop phaco techniques in microincision coaxial cataract surgery. *J Cataract Refract Surg* 2013;39(10) :1463-1469

24 Mennuci R, Ponchietti C, Virgil G, Giansanti F, Menchini U. Corneal endothelial damage after cataract surgery: microincision versus standart technique. *J Cataract Refract Surg* 2006;32(8):1351-1354

25 Oshika T, Bissen-Miyajima H, Fujita Y, Hayashi K, Mano T, Miyata K, Sugita T, Taira Y. Prospective randomized comparison of DisCoVisc and Healon 5 in phacoemulsification and intraocular lens implantation. *Eye(Lond)* 2010;24(8):1376-1381