Corneal Endothelial Changes Following Tortional Versus Longitudinal Phacoemulsification

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ABSTRACT

Aim: To study the corneal endothelial changes that occur following tortional phacoemulsification and compare it with that occurring after longitudinal phacoemulsification in cataract surgery.

METHODS: This is prospective randomized study for comparative analysis of corneal endothelial modifications held on 60eyes of 60patients with senile immature cataract with senile cataract of different grades of nuclear hardness for which torsional phacoemulsification surgery was performed to 30eyes and longitudinal phacoemulsification surgery was performed to 30eyes. Cataract extraction using phacoemulsification and IOL implantation was done to all patients.

RESULTS: There was highly statistically significant endothelial cell loss throughout the study in the two groups, With no significant difference between the two groups by the third month (P=0.5). There was statistically significant decrease in the mean endothelial cell count (ECC) in the two groups post-operatively at 1week(P<0.001*), 1month (P<0.001*) and 3 months (P<0.001*), compared to pre-operative mean ECC. The most significant decrease in ECC was at the first visit (1week follow up) in both groups (about 6.5% in tortional group and 6.8% in longitudinal group). After 1month there is small decrease in both groups (2.2% decrease in tortional group and1.6% decrease in longitudinal group compared to 1wk results). After 3months there is slight decrease in both groups (1.1% decrease in tortional group and1.9%decrease in longitudinal group compared to 1mo results (postoperative P is the value that expresses the change between preoperative and endothelial counts P=0.161after one week, P=0.178after one month and P=0.404 after three months).

CONCLUSION: The torsional phacoemulsification mode was more safe than longitudinal phacoemulsification mode as regards the postoperative corneal endothelial cell loss and central corneal thickness changes.

KEYWORDS: Torsional, longitudinal phacoemulsification, Corneal Endothelial Changes, Central corneal thickness, ECC.

INTRODUCTION

cataract is the leading cause of blindness in the world, being particularly common in low-income countries. There are 39 million people reported to be blind worldwide[1]. Age-related cataract is responsible for 51% of world blindness, which represents about 20 million people. cataract is defined as "any definite lens opacity" irrespective of any effect on visual acuity. The human crystalline lens grows continuously through the whole life, because of the addition of new lens fibers[2].

The main objectives of modern phacoemulsification technology are the reduction of ultrasound power and improved efficiency. Interrupted phacoemulsification modes with improved pump systems, chopping techniques, and vacuum-assisted phacoemulsification have reduced the amount of energy needed to remove a cataract and, therefore, the potential associated risk for endothelial cell loss and tissue damage due to associated heat generation. In the longitudinal US mode, the phacoemulsification tip moves forward and backward to break up the lens material, and the US energy comes from longitudinal movement of the tip. The jackhammer effect plays an important part, and the cavitation effect plays a minimal role in longitudinal phacoemulsification[3].

The material is only broken up when the tip goes forward. When it moves backward, it is not cutting anything, just generating more energy and more heat. The longitudinal mode also can produce a repulsion effect, because the phacoemulsification tip pushes the nucleus away when it moves forward[4]. Torsional ultrasound (US) using a torsional hand piece that cuts the lens material through circular oscillations has been recently introduced[5].

When the needle is going side to side, it is not repulsing the lens material and is actually maintaining longer contact with it .This makes these technologies faster and more efficient because they require less energy[6]. Torsional US has a lower resonant frequency and slower needle movement than longitudinal US, which allows for optimized cutting efficiency with reduced heat generation[7].

In the human eye, the endothelial cell density decreases with aging from 4000 cells/mm2 in childhood to ~2500 cells/mm2 at age 80 years[8]. Corneal endothelial cell loss is an inevitable complication after cataract surgery and occur after any cataract technique[9].

When endothelial cell count (ECC) drops below 600-800 cells/mm2, corneal decompensation and corneal edema occur as a result of the compromised pump function. Endothelial cells are non-replicative, and cell loss is compensated by enlargement and migration of residual cells[8].

The ideal procedure is that protects the intraocular tissue from surgical damage particularly the corneal endothelium. We are aware that using the least amount of ultrasonic energy leads to less endothelial damage and minimizes corneal burns[10].

SUBJECTS AND METHODS

Ethical Approval The study protocol was approved by the Committee of Institution Review Board and Medical Research Ethics Committee, Faculty of Medicine, Mansoura University and followed the principles outlined in the Declaration of Helsinki. Written consent was obtained from every patient and they were informed about risks of surgery and consequences of the study.

Patient Enrollment This is a comparative prospective case study on patients with senile immature cataract of different grades of nuclear hardness who attended outpatient clinic of Mansoura Ophthalmology Center (MOC) during the period from October 2017 to March 2019. Cataract extraction using phacoemulsification and IOL implantation was done to all patients. The inclusion criteria were patients with age related nuclear or cortical nuclear cataract with corneal Endothelial Cell Density more than 1500 cells / mm2. The exclusion criteria were previous corneal surgery such as pterygium or refractive surgery, abnormal cornea such as keratoconus or corneal epithelial pathology, ocular surface disease, corneal endothelial cell density less than 1500 cells / mm2, history of ocular inflammation, posterior segment pathology such as macular degeneration and retinopathy, previous retinal surgery with silicone oil injection and zonular dialysis or lens dislocation. Any case with intra operative complications such as tears of posterior capsule or vitreous loss was excluded. Selection of the type of phacoemulsification surgery for patients was based on surgeon's preferences, there was no specific selection criteria.

Preoperatively Every patient had a complete ophthalmic examination which included uncorrected distant visual acuity (UDVA) and corrected distant visual acuity (CDVA), manifest and cycloplegic refractions using Nidek AR-800 autorefractometer, slit lamp biomicroscopic examination, nuclear hardness grading using LOCS lll classification system, endothelial cell count, central corneal thickness using non-contact specular microscopy (Tomey EM 3000), tonometry using Keeler pulsair intellipuff, anterior, fundus examination using binocular Indirect ophthalmoscopy, A-scan ocular ultrasonography for axial length measuring and IOL power calculation, B-scan ocular ultrasonography to evaluate posterior segment .

The study sample were classified into two groups Group 1(30eyes underwent longitudinal phacoemulsification surgery), Group 2(30 eyes underwent torsional phacoemulsification surgery).

Surgical Techniques

The same experienced surgeon performed all procedures under local anesthesia (retrobulbar anesthesia) using 4ml mepivacaine HCL3% after dilatation of the pupil using mydriatic eye drops and adequate sterilization of the eye with povidone–iodine. Two corneal side ports was created at 2 o'clock and 10 o'clock using 20 gauge micro-vitreoretinal blade (MVR), 3.2 mm stepped corneal incision was created by keratome. If needed, Trypan Blue stain was injected into anterior chamber (A.C.) and then washed using balanced salt solution, Sodium hyaluronate 1.0% (Healon) was injected to fill the anterior chamber, anterior Capsulorrhexis was done (5 mm in diameter) by sharp tip capsule forceps. Hydrodissection of lens and hydrodelineation of the nucleus using balanced salt solution, phacoemulsification of the nucleus was carried out by means of Stop & Chop technique.

Healon was injected to fill the anterior chamber, followed by implantation of foldable acrylic IOL, introduced by means of an injector in the capsular bag followed by irrigation & aspiration again to remove any viscoelastic using a bimanual technique, and the main incision with the two side ports were hydrated. No intra cameral antibiotics or adrenaline were used to avoid the adverse effect on corneal endothelium. Patient with any complications during surgery or prolonged phacoemulsification time was excluded.

Postoperative treatment:

Systemic antibiotics cephradine 500mg capsule 3times/day, analgesics if needed, Topical Antibiotic eye drops moxifloxacin 0.5% 5 times/day, Steroids eye drops prednisolone acetate 1% 6times /day gradually tapered and discontinued after 1 month.

Examination visits were scheduled at 1 day post operative at which Complete ophthalmic examination with special focusing on Slit lamp biomicroscopy to observe: Corneal incisions, Any clinically apparent corneal edema, Aqueous flare or cells and IOL position and stability.

Then after 1wk, 1mo and 3mo using the same preoperative clinical parameters and investigation tools.

Assessment of outcome measures was based on a comparison of preoperative and postoperative endothelial cell count and central corneal thickness values.

Statistical Analysis Data were fed to the computer and analyzed using IBM SPSS software package version 20.0**.** **(**Armonk, NY: IBM Corp**)** Qualitative data were described using number and percent. The Kolmogorov-Smirnov test was used to verify the normality of distribution Quantitative data were described using range (minimum and maximum), mean, standard deviation and median. Significance of the obtained results was judged at the 5% level. *P*-values less than 0.05 was considered statistically significant. The Chi-square test, Monte Carlo correction, Student's *t* test, Mann Whitney test and ANOVA with repeated measures were used.

RESULTS

Patient's Characteristics Data were collected and recorded from October 2017 to March 2019. The study included 60 eyes of 59 patients whose ages ranged from 50 to 75 years, 38 (63.3%) males and 22 (36.7%) females (*P*= 0.28). Of 30 eyes underwent longitudinal phacoemulsification surgery, 30 eyes underwent torsional phacoemulsification surgery. All patients completed the follow up duration (Table 1). Comparison between both groups revealed statistically insignificant difference as regard age (60.77 ±6.92y for longitudinal group and 61.80 ±6.46y for torsional group, *P*= 0.55)

Most of the cases were with grade III nuclear cataract *(17 patients in group 1, 18 in group 2*) which represent 58.3% of the whole study group. Comparison between patients of the two groups regarding nuclear grade (P=0.936) revealed *no statistically significant difference*.

Endothelial Cell Count (ECC) in Studied Groups:

There was statistically significant endothelial cell loss throughout the study in the two groups, With no significant difference between the two groups by the third month (P = 0.5). There was statistically significant decrease in the mean ECC in the two groups post-operatively at 1week (P <0.001*), 1month (P <0.001*) and 3months (P <0.001*), compared to pre-operative mean ECC.

The most significant decrease in ECC was at the first visit (1week follow up) in both groups (about 6.5% in tortional group and 6.8% in longitudinal group). After 1month there was small decrease in both groups (about 2.2% decrease in tortional group and 1.6% decrease in longitudinal group over the last follow up). After 3months there was slight decrease in both groups (about 1.1% decrease in tortional group and 1.9% decrease in longitudinal group over the last follow up).

However, on comparing two groups the difference was statistically insignificant (P is the value that expresses the change between preoperative and postoperative endothelial counts P=0.161 after one week, P=0.178 after one month and

P=0.404 after three months).

Central Corneal Thickness (CCT) in Studied Groups:

There was statistically *significant* increase in the mean CCT in the two groups post-operatively, at 1week (P <0.001*), 1month (P<0.001*) and 3months (P <0.006*), compared to pre-operative mean CCT.

1week, the percentage (%) of increase of the mean CCT, was *equal* in both groups (8%), then at 1 month the percentage (%) of increase of the mean CCT was 5.3% in longitudinal group and 3.3% in tortional group.

Also at 3months, the percentage (%) of increase of the mean ECC remains *least* (1.4%) in longitudinal group and 2% in tortional group.

However, difference between the two groups was statistically insignificant (P=0.179 after one week, P=0.325 after one month and P=0.123 after three months).

In current study, CCT after 3 months was 520.0 (493.3 – 547.5) and 528.5 (510.0 – 566.0) microns in Longitudinal group and Tortional group, respectively which is nearly equal to the pre-operative values were (513.0(489.0 – 540.0) and 518.0 (500.8 – 540.3) microns in Longitudinal group and Tortional group, respectively). With no significant difference between studied groups (P = 0.5).

The percentage (%) of decrease of mean ECC, was *least* in tortional group -8.79 (-11.40 – -4.87) then in longitudinal group -10.52 (-14.41 – -6.12).

The percentage (%) of increase of the mean CCT, was *least* in longitudinal group 0.49 (0.37 – 1.66), then in tortional group 0.57(-0.47 – 3.47).

However, difference between the two groups as regard ECC and CCT was statistically *insignificant.*

Table (1): Comparison between the two studied groups according to demographic data

Parameters	G1-Longitudinal (n = 30)		G2-Tortional (n = 30)		*P*
	No.	**%**	**No.**	**%**	
Sex					
Male	21	70.0	17	56.7 70.0	0.284
Female	9	30.0	13	43.3 30.0	
Age					
Min. – Max.	50.0 –74.0		50.0 –75.0		0.552
Mean ± SD.	60.77 ±6.92		61.80 ±6.46		
Median (IQR)	62.0 (53.75 –66.25)		62.0 (55.0 –65.75)		

Table (2): Comparison between the two studied groups according to nuclear grading

Nuclear Grading	G1-Longitudinal (n = 30)		G2-Tortional (n = 30)		χ^2	^{MC}p
	No.	**%**	**No.**	**%**		
I	7	23.3	5	16.7	1.36	0.936
II	6	20.0	6	20.0		
III	17	56.7	18	60.0		
IV	0	0	1	3.3		

Table (3): Comparison between studied groups according to ECC

ECC	Longitudinal (n = 30)	Tortional (n = 30)	T	p
Preoperative				
Min. – Max.	1972.0 –3019.0	1477.0 –3074.0		0.168
Mean ± SD.	2506.6 ±264.7	2397.0 ±339.2	1.395	
Median (IQR)	2516.0 (2349.0 –2727.5)	2430.5 (2236.0 –2599.5)		
1 week post–operative				
Min. – Max.	1612.0 –2984.0	1436.0 –2973.0		0.161
Mean ± SD.	2373.3 ±295.8	2258.3 ±330.5	1.420	
Median (IQR)	2346.0 (2213.8 –2526.5)	2297.0 (2015.5 –2454.8)		
1 month post–operative				
Min. – Max.	1576.0 –2957.0	1420.0 –2934.0		0.178
Mean ± SD.	2320.5 ±300.4	2210.9 ±322.3	1.363	
Median (IQR)	2306.0 (2103.0 –2478.3)	2219.5 (2003.0 –2420.3)		
3 months post–operative				
Min. – Max.	1570.0 –2908.0	1418.0 –2894.0		0.404
Mean ± SD.	2260.0 ±303.1	2192.9 ±314.9	0.841	
Median (IQR)	2258.0 (2089.8 –2410.5)	2195.0 (1996.3 –2397.8)		

Table (4): Comparison between the two studied groups according to CCT

CCT	Longitudinal (n = 30)	Tortional (n = 30)	T	P
Preoperative				
Min. – Max.	401.0 – 579.0	444.0 – 597.0		0.432
Mean ± SD.	513.3 ± 38.10	521.0 ± 37.86	0.792	
Median (IQR)	513.0 (489.0 – 540.0)	518.0 (500.8 – 540.3)		
1 week post–operative				
Min. – Max.	417.0 – 594.0	455.0 – 656.0		0.179
Mean ± SD.	540.4 ± 44.70	556.9 ± 49.29	1.361	
Median (IQR)	555.0 (517.5 – 577.3)	559.5 (523.8 – 591.5)		
1 month post–operative				
Min. – Max.	426.0 – 597.0	449.0 – 613.0		0.325
Mean ± SD.	529.5 ± 42.17	540.7 ± 45.26	0.992	
Median (IQR)	540.5 (501.5 – 562.5)	535.5 (512.3 – 576.5)		
3 month post–operative				
Min. – Max.	410.0 – 580.0	445.0 – 602.0		0.123
Mean ± SD.	516.9 ± 38.64	533.5 ± 43.55	1.565	
Median (IQR)	520.0 (493.3 – 547.5)	528.5 (510.0 – 566.0)		

Table (6): Comparison between the two studied groups according to % of change

% of change	Longitudinal (n = 30)	Tortional (n = 30)	U	P
ECC				
Min. – Max.	-24.81 – 23.20	-22.71 – 23.20		
Mean ± SD.	-9.78 ± 8.70	-8.20 ± 8.06	380.0	0.301
Median (IQR)	-10.52 (-14.41 – -6.12)	-8.79 (-11.40 – -4.87)		
CCT				
Min. – Max.	-5.73 – 12.50	-3.53 – 14.75		
Mean ± SD.	0.75 ± 3.26	2.43 ± 4.99	379.0	0.294
Median (IQR)	0.49 (-0.37 – 1.66)	0.57(-0.47 – 3.47)		

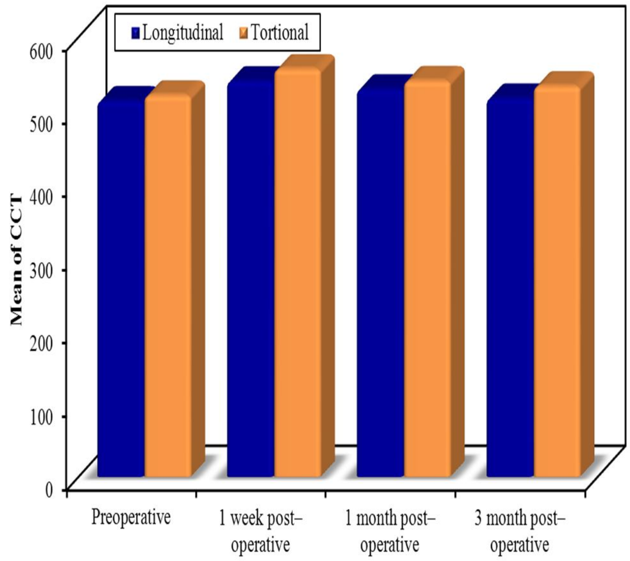

Figure (1): Comparison between the two studied groups according to CCT

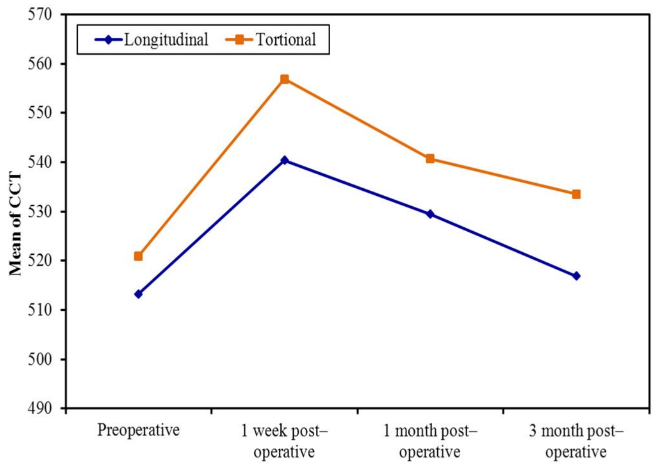

Figure (2): Comparison between the different periods according to CCT in each group

DISCUSSION

It has been more than five decades when Charles D. Kelman stated the new era of cataract surgery by introducing phacoemulsification. But world has changed radically since then and phacoemulsification is not exception. Recently, ophthalmologists found many advantages of newer technologies over older ones, including torsional and longitudinal phacoemulsification devices[11]. Previous studies reported a high endothelial loss following cataract surgery. Sugar et al.1978 found endothelial loss of 33.8% in 70 eyes compared with the fellow unoperated eye. Therefore they came to a conclusion that phacoemulsification cause more damage to endothelium than intracapsular cataract extraction[12].

Storr-Paulsen et al.2008 found from 20% to 30% endothelial loss of after phacoemulsification due to luxation of the nucleus in the anterior chamber. After that, there has been many researches aiming to protect the endothelium during phacoemulsification[13].

This study proved that torsional phacoemulsification is at least equally effective and a safer procedure when compared to conventional longitudinal phacoemulsification. In torsional phacoemulsification the side to side movement has a cutting effect that causes almost no repulsion. The cutting in lateral direction made by torsional phacoemulsification and less repulsive effect compared to longitudinal phacoemulsification make it more efficient despite the lower frequency of torsional phacoemulsification (32 kHz) than longitudinal phacoemulsification (40 kHz)[4].

Our results also matched those of Reuschel et al 2010. in their study on grade III nuclear cataract found that there was statistically insignificant difference in endothelial cell loss between both groups (6.6% in longitudinal group and 6.9% in torsional group; P = 0.34)[14].

Also our results in each group came similar to those in a study by Bozkurt et al.2009 (4.2% ± 5.7%, torsional group; 6.7% ± 3.3%, conventional group). Bozkurt et al.2009 concluded that less damage to corneal endothelial cells is caused by torsional mode, although statistically insignificant[7].

In this study we found that endothelial cell loss in the Longitudinal and Tortional modes was within the same range (no significant difference) as found in the previous studies. So endothelial cells of cornea were affected to the same level in both groups, which may be due to adequate use of viscoelastic material in the AC to protect the corneal endothelium during delivery of the nucleus to the anterior chamber and adequate phacoemulsification parameters also.

This result suggested that torsional mode, when compared to longitudinal mode of phacoemulsification, it is more efficient or equally safe at least in moderate cataracts. However, there was debates about safety and efficacy of torsional mode in hard nuclear cataracts as compared to longitudinal mode[15]. The harshness of phacoemulsification that occur in hard nucleus result in more endothelial injury in both torsional and longitudinal phacoemulsification-modes as well. This may be due to more repulsion, but a large number of comparative studies will be needed to verify the safety of torsional mode and efficiency in hard nuclear cataracts[4].

Considering the cutting pattern of torsional and longitudinal mode (torsional hand piece cuts in both sides, while longitudinal hand piece cuts only in a forward direction), the endothelial loss in torsional phacoemulsification would be theoretically 40% of the value in longitudinal phacoemulsification, as long as phacoemulsification time is the same. This result suggested less endothelial loss in moderate cataracts in torsional mode is more than the longitudinal mode[4].

In the current study, there was no statistically significant difference in endothelial cell loss between the two groups at 1 week or 1 month postoperatively. However, 3 months postoperatively there was difference in endothelial cell loss between the two groups, with the torsional group showing less endothelial cell loss though statistically insignificant. Our study suggested more efficiency for the torsional mode compared with the longitudinal mode, although this study is limited by the small sample size in hard cataract (only one case).

This result came in agreement with earlier reports by Kim et al.[4], and Fakhry and El Shazly (P < 0.001)[14].

Kim et al.2010 found that in patients with moderate cataract the percentage of endothelial cell loss at 1 week postoperatively was 13.18% in longitudinal group and 5.12% in torsional group, which became not significantly different 1 month postoperatively (7.9% in longitudinal group and 3.19%

in torsional group), whereas in hard cataract group the percentage of endothelial cell loss was 13.45% in longitudinal group and 23.52% in torsional group[4].

They reported that the jackhammer effect may be more effective than the shearing effect in hard cataract, because ultrasound power does not act perpendicularly on the nucleus in torsional mode.

Our results matched those of Liu et al. also, who reported that the torsional mode provides more effective lens removal with less endothelial cell loss compared with that of the longitudinal mode at 7 days and 30 days (P < 0.001).

Several authors have noted that all patients retrieved preoperative values of corneal thickness after 4 weeks, while some others have found that increases remained up to 6 months or even 1 year postoperatively[16].

Patil & Melmane (2014) measured endothelial cell loss 40 days after phacoemulsification, it was 7.37%, 9.76%, 12.7% and 13.35%, in nuclear grade 1, 2, 3 and mature cataract, respectively[17].

The clinical corneal edema occurring postoperative were well correlated with corneal thickness measured by the specular microscope. There was marked increase in corneal thickness in both groups during the first week after surgery. And the mean corneal thickness preoperatively was the same nearly like that after 3 months with no significant difference.

Several studies suggested ECD stabilization within 3 months following cataract surgery. A study by Kohlhaas et al. found no more endothelial cell loss occurring after 1 month. Also Price et al. also found that most of endothelial loss occur during the first month after phacoemulsification surgery[18].

Some authors confirmed that the central ECC does not indicate the entire corneal state and that the greatest loss occurs near the incision. Corneal cells migrate to cover this loss, which takes about 3 to 6 months[19].

"Successful cataract surgery is like a chess game, where every move is critically dependent on the previous move" Dr. Rosenfeld said. "When you start the case, you need a good capsulorhexis. If you don't have a smooth intact anterior capsular rim the next steps will be more difficult. And some surgeons would consider the phacoemulsification step to be the most dangerous part, especially when takes longer time."

"The longer you do phacoemulsification, the more power used and the more endothelial cell loss and contribute to postoperative corneal edema," Dr. Rosenfeld said. "This is why the newer technologies are so attractive. We can remove a cataract faster, using less power and with balanced fluidics."

Dr. Devgan concluded that any device you choose, it is very important to understand the optimum settings of the machine to have a safe and effective surgery. "Ophthalmologists are sure that these machines are excellent upgrade from previous technology. They need to understand to customize their settings of power modulation and fluidics to optimize their surgical performance."[17].

Most ophthalmologic surgeons agree that newer refractive surgical platforms represent important advances over older ones. However, comparing two different new platforms can be so difficult, said Dr Wilson Takashi Hida, PhD "Most studies compare new technology from one manufacturer with previous generations of the same technology from the same instrument maker. A lot of studies began around 2010 to compare the torsional and longitudinal technologies, and they reached the same conclusion: It is a better technology. But they were all looking at newer technology so of course it is better than that came before.

However, the learning curve of the torsional phacoemulsification was shorter and more easy. The OZil technology uses a lower energy with less heat generation, and achieves more constant power distribution throughout the surgery. So the anterior chamber become more stable and turbulence of the irrigation fluid become less, therefore protecting the corneal endothelium from thermal and mechanical damage[20].

Conclusion

The torsional phacoemulsification mode was more safe than longitudinal phacoemulsification mode as regards the postoperative corneal endothelial cell loss and central corneal thickness changes.

DATA AVAILABILITY

All data are included in this article.

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None

Conflict of Interest

Authors declare no conflicts of interest.

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Ethics declarations

Conflict of interest

Nouran M. Abd-Allah, Sherief E. El-Khouly, Ehab Hassan Neamat-Allah, Ahmed Rashid AL-lakany all authors have no conflicts of interest that are directly relevant to the content of this review.

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