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Comparative study between torsional phacoemulsification and longitudinal phacoemulsification in their effect on corneal endothelium using specular microscopy.

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ORIGINAL STUDY

Comparative study between torsional phacoemulsification and longitudinal phacoemulsification in their effect on corneal endothelium using specular microscopy

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Abstract

Background: **The cornea is formed of five layers, endothelium is that most posterior layer which is responsible for keeping cornea dehydrated. Loss of corneal endothelium is a side-effect of many cataract surgeries that may influence postoperative visual outcome of the patients. Our study aims to compare torsional phacoemulsification and longitudinal phacoemulsification in their effect on corneal endothelium using specular microscopy.**

Patients and methods: **We will compare the corneal endothelium parameters (central density of cells and cell loss, alterations in shape and size) afterward torsional phacoemulsification and longitudinal phacoemulsification in this prospective randomized study. Fifty eyes with nuclear cataracts in grades 1 through 3 will be included in our study.**

Results: **The *P* value for the comparison of the percentage of endothelial cell loss between the torsional and longitudinal phacoemulsification groups was 0.09, indicating that there was no statistically significant difference (>0.05) between the two groups.**

Conclusion: **On comparing both categories of phacoemulsification, we have found no statistically significant difference regarding endothelial cell loss and postoperative best-corrected visual acuity, therefore we concluded that both phacoemulsification types are safe, so the type of phacoemulsification to be used is determined according to the preference and experience of the surgeon.**

Keywords: Endothelium, Phacoemulsification, Specular microscopy

1. Introduction

We now have an amazing image of the cornea with great resolution over comparatively wide areas. Thanks to information from electron microscopy. The epithelium, Bowman's membrane, stroma, Descemet's layer, and endothelium are the five layers that make up the cornea [1].

On the posterior aspect of the cornea, a single layer of nearly 400 000 cells made up the corneal endothelial cells. These cells are primarily hexagonal in shape and 20 μm broad when viewed from their posterior surface. Due to the obvious infolding and interdigitation between neighboring cells, their contour at the level of Descemet's membrane is uneven. Some believe that the posterior cell membrane is covered by a viscous material that may be of endothelial origin. Like the huffy coat on the epithelial surface, this coating may lower the lipid membrane's surface tension to increase wettability. Many endothelial cells have only one primary cilium, although its purpose is unknown. The cilium appears to not be mobile and is structurally connected to the centriole of the cell [2].

Below a certain threshold of endothelial cell density (400−700 cells/mm^2), endothelial decompensation takes place, leading to increasing stromal edema and ultimately epithelial edema. Higher cell

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densities can result in stromal edema, which is linked to endothelial pathologic states and is most likely caused by disruption of the paracellular pathways, as in early Fuchs' dystrophy. Endothelial cells may lose their regular hexagonal structure and develop irregular shapes (pleomorphism) and sizes (polymegathism) when they are stressed, particularly when some cells are lost. These changes may occur with aging, following trauma, or in those who have worn touch lenses for a long time. Pleomorphism and polymegathism are of unknown significance, however, there is evidence that a cornea with these abnormalities cannot resist further stress as well as a normal cornea. Soon after inserting a contact lens, people who wear them may experience tiny blebs in the endothelium. These blebs are temporary and are likely brought on by the osmotic effects of lactic acid buildup or low pH [3].

The early specular microscope which was able to give data about the cornea was described in the late sixties. This machine was later modified to allow studying the endothelium *in vivo*. Specular microscopes are either contact or noncontact. The original narrow-field specular microscopes imaged ~20 cells per frame, and this technique could only be proceeded in the center of the cornea. Later, wide-field specular microscopes have been developed, which provide a field of greater than 200 cells per frame and allow studying all regions of the cornea [4].

Using the specular microscope, we can obtain accurate measurements regarding endothelial cell density or count. The clinical specular microscope can also be used to view a number of endothelium features that are obscured by the slit light. It is possible to identify morphological changes in intracellular structures, cell surface characteristics, intercellular borders, and endothelial cell architecture. Although many of these anomalies' natures and significances are still unknown, recognizing them is a first step toward understanding their pathophysiological significance [5]. Wide-field specular microscope photomicrographs are subjected to computer-assisted analysis, which reveals quantitative and qualitative alterations in the corneal endothelium. Numerous studies have demonstrated that analyzing endothelial cell size and morphology rather than just cell measures can give a more reliable indicator of endothelial cell destruction [6].

Changes in the uniformity of size and shape of endothelial cells can be described by measuring certain variables like coefficient of variation in cell size and proportion of hexagonal cells. Size of a cell, the coefficient of variation, which provides a quantitative assessment of cell size variation (polymegathism), is a unit less number (SD of cell area/mean cell area); its value is unrelated to cell density. Below 0.33 is the typical coefficient of variance. Increases in coefficient of variation are a marker of corneal endothelium damage because they show a decline in cell size uniformity [7]. Over 60 % of the cells in the healthy corneal endothelium are hexagonal in form. A decrease in the proportion of hexagons, which measures the degree of cell pleomorphism, denotes some kind of change [7]. The scanning confocal microscope is another instrument that has superior lateral and axial resolution and serial optical sectioning capabilities. This microscope can be used to study all layers of the cornea including the endothelium. It consists of an applanation cone like that one used in specular microscopy, attached to a microscope. Images are transmitted through a videotape system to a computerized image-enhancement and analysis system [7].

In the 1960s, it was thought to be difficult to remove a cataract with a 3 mm incision. The 'impossible' had to be done through resolving inconsistencies, which was accomplished through clever use of new technology. As is now widely known, Dr Charles Kelman was motivated to develop phacoemulsification after having his teeth cleaned with ultrasonic energy during a dental visit. To translate inspiration into reality, however, took a lot of creativity and tenacity. History demonstrates that creativity, biotechnology, and surgical technology came together, making phacoemulsification a practical tool for cataract surgery. Intraocular lenses (IOLs) were not available, and only Kelman performed lens emulsification 35 years ago. Currently, Kelman phacoemulsification is used in around 95 % of cataract procedures in the United States. What to do next [8].

Endothelial cell loss occurs during straightforward procedures with preservation of the posterior capsule as a result of intraoperative mechanical injury to the endothelium brought on by ultrasonic vibration, whirling lens cortical and nuclear fragments, irrigation solutions, air bubbles, and surgical instruments. Nevertheless, the heat produced by the ultrasonic probe's tip remains a substantial source of harm [9]. The power required to emulsify the cataract was reduced by modern phacoemulsification techniques. Due to the risk of endothelial cell damage posed by ultrasonic power, phacoemulsification technology's primary objectives are to lower ultrasound power and boost its effectiveness [10].

The action of longitudinal phacoemulsification is in the direction of the forward stroke, and this longitudinal approach benefits from elevated vacuum to lessen repulsion, which reduces heat production proportional to the amount of phacoemulsification power utilized [11]. Torsional phacoemulsification uses a side-to-side stroke action with a cutting effect in the right and left directions, requiring much less power than longitudinal phacoemulsification with better efficiency and shorter phacoemulsification time. The torsional technique also has better followability, less repulsion, less lens matter dispersion, and less surge than other phacoemulsification methods. Torsional phacoemulsification machines have a shorter mean needle time, less clatter, and better followability than longitudinal machines. Less corneal edema resulted from this [12].

Variable percentages of endothelial cell loss may result from cataract surgeries when novel surgical techniques like torsional phacoemulsification and ophthalmic viscoelastic devices are used. In addition, torsional phacoemulsification reduces corneal endothelial loss by offering less repulsion and less heat energy generation [13].

In a study by Liu and colleagues comparing the effects of torsional and longitudinal phacoemulsification on endothelial loss, it was discovered that torsional phacoemulsification significantly reduced cell loss (12.5 %) compared with a conventional US group (19.1 %) 30 days after surgery. Another study conducted in 2009 by Bozkurt et al. [14] found that although the results were not statistically significant (4.2 ± 5.7 % for the torsional group vs. 6.7 % $\pm$ 3.3 % for the conventional group), the torsional phacoemulsification appeared to result in a decrease in the lost endothelial cells.

No statistically significant difference was found between the longitudinal group (7.1 ± 4.4 %) and the torsional group (7.2 ± 4.6 %) regarding endothelial cell loss after 3 months in the study by Anna et al. [15], which included 148 patients. Seventy eyes with highly dense cataracts were included in a 2013 study by Gonen and colleagues. Thirty-five of the eyes underwent torsional phacoemulsification, and 35 underwent longitudinal phacoemulsification. The percentage of mean endothelial cell loss in both groups ranged from 35.4 to 39.1 %, with no statistically significant difference between the two groups [16]. According to a study by Amrita and colleagues, individuals who had torsional phacoemulsification (8.1 %) experienced considerably less corneal endothelial cell loss than those who underwent longitudinal phacoemulsification (10.78 %). In addition, the results show that the torsional group considerably outperformed the longitudinal group in terms of mean best-corrected visual acuity (BCVA) improvement on postoperative day 30 compared with baseline mean BCVA [17].

This study compared the effects of longitudinal and torsional phacoemulsification on the corneal endothelium using specular microscopy.

2. Patients and methods

2.1. Time frame

Between January 2021 and January 2022, this study was conducted. The Institutional Review Board of our hospital granted approval for the study process. Administrative consent and official permits were sought before data collection. Informed agreement was obtained from study participants under the guarantee of data privacy.

2.2. Study population

This study was proceeded on 50 eligible eyes in 50 consecutive patients who attended the Outpatient Ophthalmology Clinic, Memorial Institute for Ophthalmic Research (MIOR), during the study period.

2.3. Inclusion criteria

(1) Immature and mature senile cataract.
(2) Clear cornea with no evidence of endothelial disease.
(3) Dilatable pupil.
(4) Normal anterior chamber depth.
(5) No local ocular disease or inflammation.

2.4. Exclusion criteria

(1) History of any eye surgeries.
(2) Existence of any type of corneal opacities.
(3) Diseases, scarring, or even dystrophies of endothelium, for example Fuch's dystrophy, cornea guttata.
(4) Glaucomatous patients.
(5) Patients with hypermature age-related cataract.
(6) Pseudoexfoliative material.
(7) Patients having endothelial count fewer than 1900 cells/mm^2.

2.5. Methods

We compared the corneal endothelium changes (central cell density and cell loss) after torsional phacoemulsification with longitudinal phacoemulsification in our prospective randomized trial. In our study, 50 eyes with nuclear cataracts of grades 1 to 3 were included. Patients ranged in age from 50 to 70 years old. Phacoemulsification was performed utilizing a Infiniti, Ozil technology (Infiniti, Ozil Technology, Alcon, Geneva, Switzerland) phacoemulsification machine using the Divide and Conquer technique.

The cases were divided into two groups:

Group A included 25 eyes who underwent cataract surgery using torsional phacoemulsification.

Group B included 25 eyes who underwent cataract surgery using longitudinal phacoemulsification.

2.5.1. Preoperative assessment

(1) Slit lamp examination (Haag Striet slit lamp).
(2) Corneal endothelial cell count (central area) with specular microscopy (Topcon SP − 2000 specular microscope).
(3) Full preoperative assessment including measuring intraocular pressure (applanation tonometer), fundus examination (Volk 90 lens), and calculation of IOL power (SRK-T formula).

2.5.2. Operative procedure

Mydriasis achieved using tropicamide 1 %, cyclopentolate 1 % and phenylephrine 10 %. Peribulbar anesthesia was used with lidocaine 2 % mixed with bupivacaine 0.5 %. The conjunctival sac was washed with povidone−iodine. Clear corneal incision was done at 11 o'clock with keratome 2.2 mm. Sodium hyaluronate 1 % (Healon, Johnson&Johnson, New Bruswick, New Jersey, USA) injected in anterior chamber. Capsulorrhexis was proceeded with a capsulorrhexis forceps. Two side ports were done at 3 o'clock and 9 o'clock. Hydrodissection and hydrodelineation were done with rotation of the nucleus. Phacoemulsification was performed using (Infiniti, Ozil technology; Alcon) phacoemulsification machine, with a Kelman 30° beveled phacoemulsification tip.

In torsional cases, continuous mode was used and the parameters were during sculpting (phacoemulsification 1): 80 % power, 80 cmH_2O bottle height, 24 ml/min. Flow rate and 50 mmHg vacuum. During phacoemulsification (phacoemulsification 2): 60 % power, 100 cmH_2O bottle height, 28 ml/min flow rate and 300 mmHg vacuum.

In longitudinal cases, pulse mode was used and phacoemulsification power decreased to be 60 % during sculpting (phacoemulsification 1) and 40 % during phacoemulsification (phacoemulsification 2) while other parameters kept the same as torsional group.

Divide and Conquer approach was used followed by removing the cortex with bimanual technique and again Healon was injected inside the anterior chamber and capsular bag. The corneal tunnel is enlarged to 3 mm to allow the implantation of a foldable acrylic single-piece IOL (Hexavision) inside the capsular bag. The Healon was aspirated with the bimanual I/A and the corneal tunnel and side ports sealed with stromal hydration. Subconjunctival gentamicin and dexamethasone were injected at end of the surgery. The patients used prednisolone 1 % and ofloxacin 0.3 % eyedrops five times daily postoperatively.

2.5.3. Postoperative follow-up plan

All patients of both groups followed at 1 day,1 week, 1 month, and 3 months after surgery, doing specular microscopy at 3-month postoperative comparing it with the preoperative specular microscopy, in addition to measuring visual acuity.

2.6. Statistical analysis

The Statistical Package for the Social Sciences (IBM Corp., 2011) was used to gather, process, code, tabulate, and analyze data (version 20 of IBM SPSS Statistics for Windows; IBM Corp., Armonk, New York, USA). Numbers and percentages are used to present qualitative data. For quantitative data with a parametric distribution, the mean, SD, and ranges are used; for nonparametric quantitative data, the median and interquartile range are used. The two groups were compared before and after quantification, together with parametric distribution of data, using a paired t test. To compare the two groups, the Wilcoxon rank test with quantification before and after the nonparametric distribution was utilized. The margin of error was estimated to be 5 %, and the confidence interval was set at 95 %. Consequently, a P value which is less than 0.05 is significant.

3. Results

Phacoemulsification was performed on 50 eyes, 25 eyes received torsional phacoemulsification, while the remaining 25 eyes were randomized to receive longitudinal phacoemulsification. Fifty-four percent (27 cases) of the cases were female and 46 % (23 cases) male. The age range was 52−70 years in torsional group with a mean age of 60.6 ± 4.57 years and the age range was 50−70 years in the longitudinal group with a mean age of 61.48 ± 6.12 years. In

Table 1. Comparison among torsional phacoemulsification group between preoperative endothelial count and postoperative endothelial count.

Variable	Groups	Preoperative endothelial count	Postoperative endothelial count	Paired *t* test	*P* value
Torsional phacoemulsification	Mean ± SD	3018.7 ± 639.8	2562.9 ± 553.53	19.67	0.001 HS
	Range	2144–4591	1801–3984		

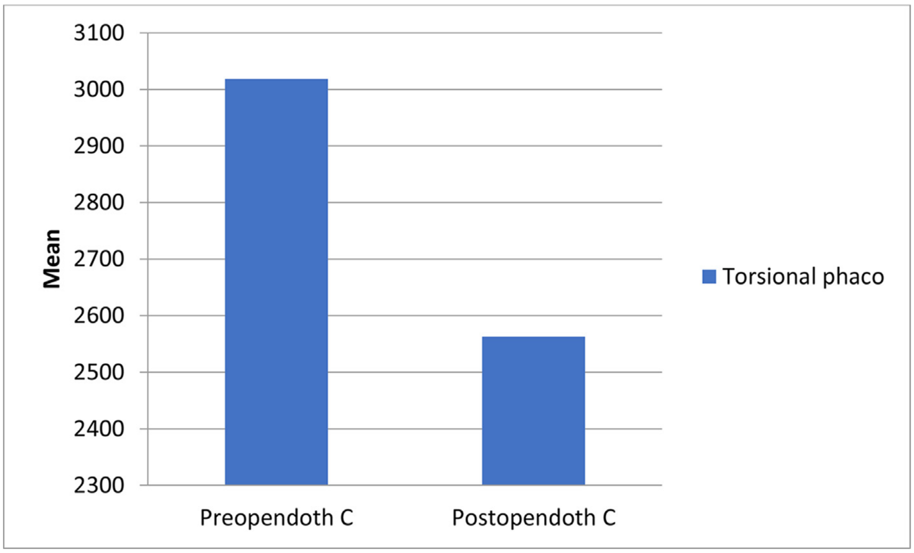

Chart 1. Correlation among torsional phacoemulsification group between preoperative endothelial count and postoperative endothelial count.

the torsional phacoemulsification group we compared the preoperative and postoperative endothelial count (Table 1 and Chart 1).

Also in longitudinal phacoemulsification group we compared preoperative and postoperative endothelial count (Table 2 and Chart 2).

Finally we calculated the percentage of endothelial loss in each group (Table 3 and Chart 3).

The SD of the mean preoperative endothelial cell count in torsional phacoemulsification is 639.8 cells/mm^2, with a mean of 3018.7 cells/mm^2. The mean count was 2562.9 cells/mm^2 with an SD of 553.53 mm^2 at 3 months after surgery. Endothelial cell loss was −15.1 ± 2.49 % of total cells. The *P* value for the difference between the preoperative and postoperative endothelial counts in the torsional phacoemulsification group was 0.001, which is statistically significant (0.05).

In longitudinal phacoemulsification, the mean preoperative endothelial cell count is 2638.2 cells/mm^2, with a SD of 318.44 cells/mm^2. The mean count at 3 months after surgery was 2209.2 cells/mm^2, with an SD of 288.12 cells/mm^2. The loss of endothelial cells was −16.33 ± 2.52 % of the total. The *P* value for the change in endothelial counts between the preoperative and postoperative periods in the longitudinal phacoemulsification group was similarly 0.001, which is statistically significant (0.05).

When comparing the percentage of endothelium loss between the torsional phacoemulsification and longitudinal phacoemulsification groups, the *P* value was 0.09, indicating that there was no statistically significant difference (>0.05) between the two groups.

Figure 1a and b shows endothelial counts of a 55-year-old patient with grade 2 nuclear cataract who

Table 2. Comparison among longitudinal phacoemulsification group between preoperative endothelial count and postoperative endothelial count.

Variable	Groups	Preoperative endothelial count	Postoperative endothelial count	Paired *t* test	*P* value
Longitudinal phacoemulsification	Mean ± SD	2638.2 ± 318.44	2209.2 ± 288.12	28.29	0.001 HS
	Range	2042–3376	1664–2751		

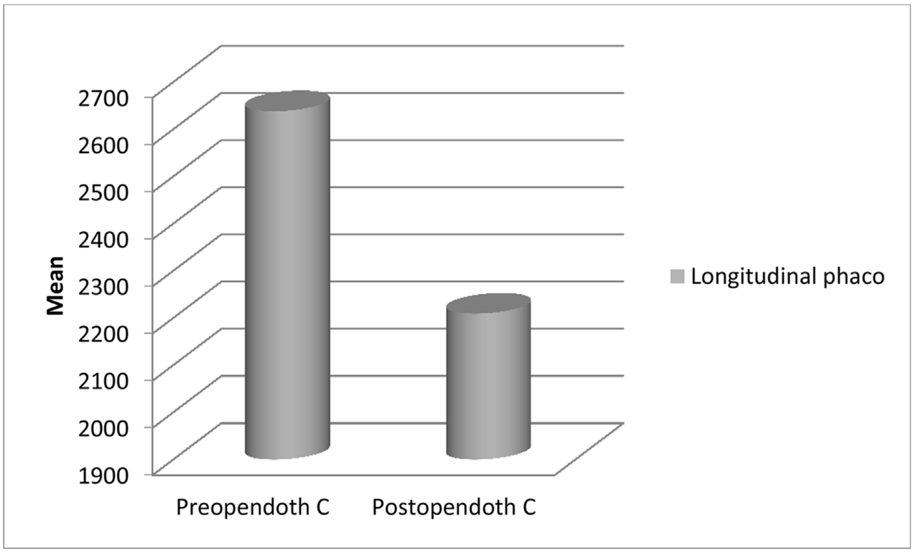

Chart 2. Correlation among longitudinal phacoemulsification group between preoperative endothelial count and postoperative endothelial count.

Table 3. Comparison of longitudinal and torsional phacoemulsification in terms of endothelium loss percentage.

Variable	Groups	Torsional phacoemulsification	Longitudinal phacoemulsification	Student *t* test	*P* value
% of endothelial loss	Mean ± SD	15.1 ± 2.49	16.33 ± 2.52	1,73	0.09 NS
	Range	9.62–20.8	11.51–20.34		

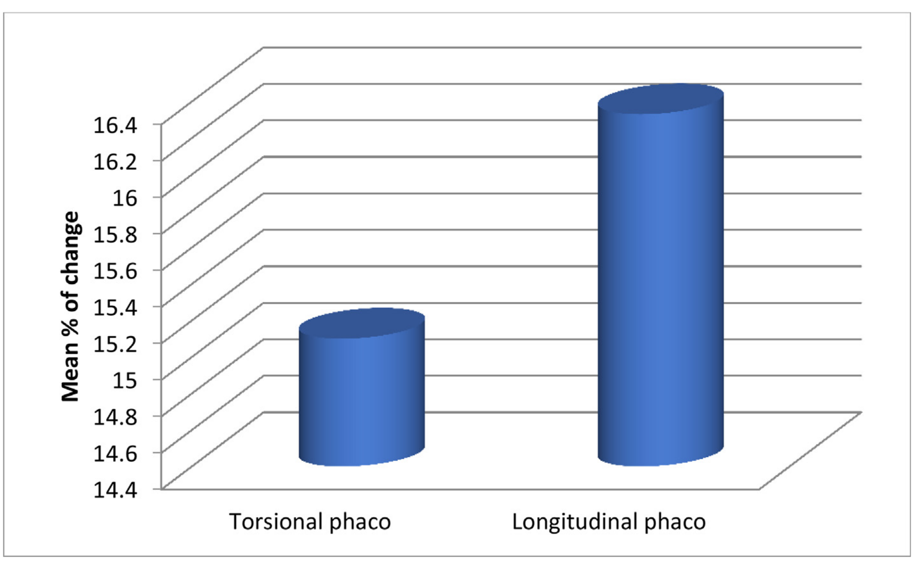

Chart 3. Correlation between longitudinal and torsional phacoemulsification, based on the percentage of endothelium loss.

had torsional phacoemulsification (preoperative and 3-month postoperative).

Figure 2a and b shows endothelial counts of a 59-year-old patient with grade 2 nuclear cataract who had longitudinal phacoemulsification (preoperative and 3-month postoperative).

4. Discussion

Trauma has a profound impact on the shape and sensitivity of corneal endothelial cells, affecting both cell density and morphology. Loss of endothelial cells during surgery impairs the cornea's ability to

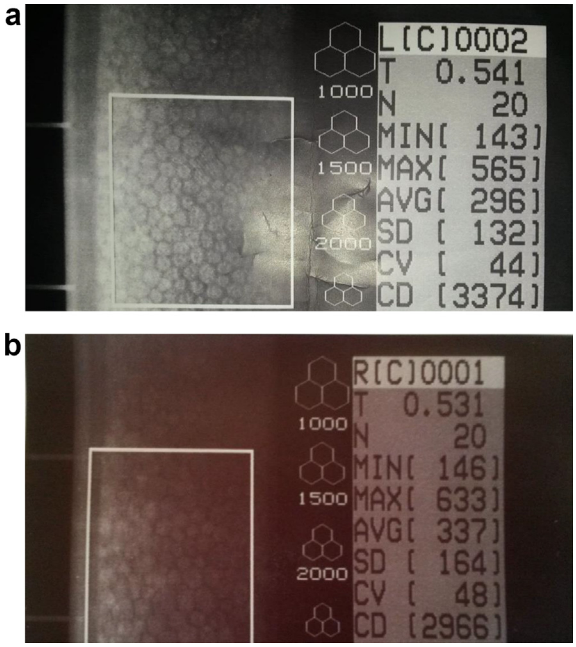

Fig. 1. (a) Preoperative specular microscope of 55-year-old patient. (b) 3-month postoperative specular microscope of same patient in previous figure who had torsional phacoemulsification.

retain transparency, which leads to a decline in vision. The mainstays of postoperative clarity, normal corneal metabolism, and constant dehydration of the corneal tissue, mostly rely on unaltered cell morphology and adequate cell density. In this manner, postoperative corneal endothelial cell density serves as a helpful marker of the harm any surgical treatment has produced [9].

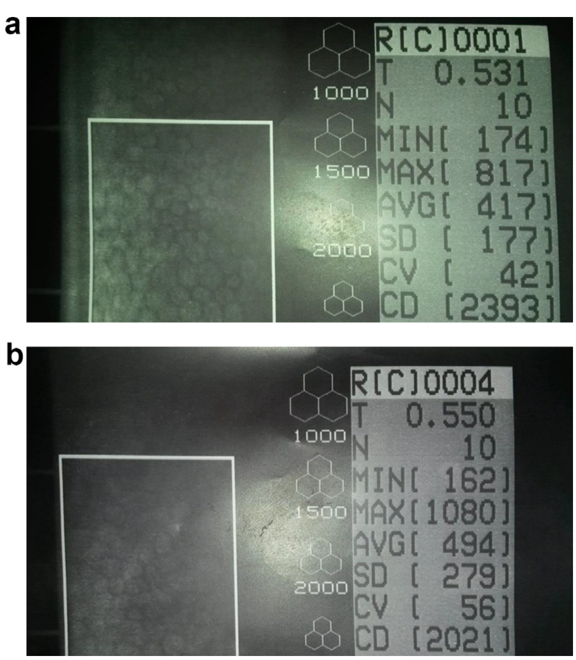

Fig. 2. (a) Preoperative specular microscope of 59-year-old patient. (b) 3-month postoperative specular microscope of same patient in previous figure who had longitudinal phacoemulsification.

Endothelial cell loss is not very significant when using current phacoemulsification procedures. However, it is important to keep in mind that endothelial cells might be damaged or lost during any type of cataract surgery. The most effective cataract surgery method now available is phacoemulsification using a foldable lens [18].

In a 2005 study, George and colleagues compared the surgically induced astigmatism and endothelial cell loss following phacoemulsification, manual small incision, and extracapsular cataract surgery. They discovered that all three groups had a comparable mean endothelial cell loss [19].

Numerous research indicates within 3 months, endothelial cell stability. After 4 weeks, according to Kohlhaas et al.'s [9] study, there was no longer any postoperative endothelial cell loss. The majority of cell loss, according to Price et al. [20], occurred within the first month following surgery.

Based on these findings, we arranged our postoperative checkup, and 3 months later we performed the postoperative endothelial count. In our study, there was no significant difference between the torsional institution and longitudinal institution in terms of relevant lack of endothelial cells, and the results for each group are comparable to those of a study by Bozkurt et al. [14] (4.2 ± 5.7 % for the torsional group; 6.7 ± 3.3 % for the conventional group). Bozkurt and colleagues discovered that the torsional mode seems to cause less endothelial cell loss, although their findings were not statistically significant and were based on the second postoperative month in 100 eyes. Another difference is that Bozkurt et al. [14] used a different technique (stop-and-chop technique) to remove the cataracts in their study. However, these variations might not be the cause of the slightly higher endothelial cell loss in our study [21].

In contrast to our work, which found no significant difference between the two groups, Liu et al.'s study of 525 eyes found a considerably lower rate of cell loss (12.5 %) in the torsional group compared with that in the longitudinal phacoemulsification group (19.1 %). These outcomes also covered a shorter time period than our study's 3-month assessment — 30 days — following surgery. Another distinction is the new cataract removal technique developed by Liu et al. [11]. Instead of using nonchopping procedures, they adopted the quick-chop method. According to Zeng et al. [22], the quick-chop appears to have higher loss in endothelial cells.

In 2013, Gonen and colleagues, conducted a study which involved 70 eyes with highly dense cataract, 35 eyes received torsional phacoemulsification and 35 received longitudinal phacoemulsification. Due to the extremely dense cataract they operated on, the mean endothelial cell loss in both groups ranged from 35.4 to 39.1 % [16], which is higher than our study, but there was no statistically significant difference between the two groups ($P > 0.05$), as was the conclusion of our investigation.

The use of ocular viscoelastic devices, which deepen the anterior chamber, mechanically protect against surgical trauma, absorb the ultrasound energy, and coat the IOLs, is the main factor in our study that reduces endothelial cell loss. In 1997, Ravalico and colleagues conducted a study in Italy comparing hydroxypropyl methylcellulose, Healon 1.0 % and 3.0 %, and chondrotin sulfate 4.0 % (Viscoat) in phacoemulsification. They found no significant differences between the four viscoelastic devices in terms of the postoperative mean endothelial loss of endothelial cells [23].

Finally the results in our study showed that both types of phacoemulsification, torsional and longitudinal, are safe procedures on corneal endothelium and both types showed no statistically significant difference on their effect on endothelial cell density and cell loss postoperatively and also no difference in postoperative BCVA, so the category of phacoemulsification, to be used either torsional or longitudinal is determined by surgeon experience [24].

4.1. Conclusion

Cataract extraction represents the biggest surgical load in ophthalmic units all over the globe. Both longitudinal and torsional phacoemulsification techniques, in the hands of skilled surgeons, produced good visual results. Regarding the loss of postoperative endothelial cells, we compared the two forms of phacoemulsification and found no clinically or statistically significant differences, indicating that both methods of phacoemulsification are equivalent, so each surgeon can determine the preferred type of phacoemulsification According to his own experience but taking into consideration that in longitudinal phacoemulsification the preferred mode is the pulse mode with high vacuum and low power to decrease repulsion and heat production while in torsional phacoemulsification the preferred mode is the continuous mode with medium vacuum which is sufficient to pull the material through, as the repulsion and heat production in torsional phacoemulsification are much less than the longitudinal phacoemulsification.

4.2. Recommendations

Both types of phacoemulsification, torsional and longitudinal, are safe procedures on corneal endothelium so the type of phacoemulsification, to be used is determined by surgeon experience. Multicenter randomized trials should be performed comparing between the two types of phacoemulsification regarding other aspects as vision and corneal thickness.

Conflicts of interest

There are no conflicts of interest.

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