

Research Article

Comparative Study of Stop and Chop versus Phaco Chop Nucleotomy Techniques in Phacoemulsification

Sherief E. El-Khouly*, Mohammad H. Shosha, Ayman E. Abd EL-Ghafar, Ahmad S. El-weheedy and Adel E. EL-Layeh

Department of Medicine, Mansoura Ophthalmic Center, Mansoura University, Mansoura, Egypt

Abstract

Aim: To compare Phaco-chop versus stop-and-chop Nucleotomy for phacoemulsification, as regard operative ultrasound power used, time of the operation and operative complications also post-operative best corrected visual acuity.

Setting: Mansoura Ophthalmic Center, Mansoura University Egypt.

Design: comparative prospective study.

Methods: Sixty patients were evaluated prospectively in 2 groups. The stop-and-chop technique was performed in Group 1 (20 eyes) and Phaco-chop Nucleotomy technique in Group 2 (40 eyes) divided into 2 subgroups, group 2a (horizontal chopping 20 cases), group 2b vertical chopping 20 cases). The mean Phaco time, Phaco power, effective Phaco time, in addition to outcome parameters (visual acuity, Endothelial cell losses and pachymetry) in both groups were statistically compared.

Results: The effective Phaco time was 10.32 seconds \pm 2.85 seconds in group 1 and 9.71 seconds \pm 3.05 seconds, 9.6 seconds \pm 1.65 seconds in group 2a and group 2b respectively. The post operative pachymetry values in group 1 one week, one month, 3 months and 6 months were 542.06 microns \pm 37.54 microns, 528.16 microns \pm 45.06 microns, 520.61 microns \pm 46.59 microns and 519.18 microns \pm 35.99 microns respectively. The postoperative pachymetry values in group 2a one week, one month, 3 months and 6 months, were 548.37 microns \pm 38.07 microns, 535.36 microns \pm 35.09 microns, 528.51 microns \pm 36.59 microns, and 524.04 microns \pm 36.85 microns respectively. The post operative pachymetry values in group 2b one week, one month, 3 months and 6 months, were 535.53 microns \pm 29.31 microns, 522.22 microns \pm 35.34 microns, 515.77 microns \pm 40.44 microns and 513.85 microns \pm 38.60 microns respectively. The post operative endothelial cell count in group 1 one week, one month, 3 months and 6 months were 2314.25 cells/mm² \pm 296.47 cells/mm², 2294.18 cells/mm² \pm 290.57 cells/mm², 2293.35 cells/mm² \pm 291.35 cells/mm², 2289.13 cells/mm² \pm 295.14 cells/mm² respectively. the post operative endothelial cell count in group 2a one week, one month, 3 months and 6 months were 2321.4 cells/mm² \pm 324.44 cells/mm², 2303.35 cells/mm² \pm 373.55 cells/mm², 2291.5 cells/mm² \pm 370.71 cells/mm², 2287.28 cells/mm² \pm 70.13 cells/mm² respectively. The post operative endothelial cell count in group 2b one week, one month, 3 months and 6 months were 2318.8 cells/mm² \pm 319.95 cells/mm², 2299.6 cells/mm² \pm 302.51 cells/mm², 2293.4 cells/mm² \pm 300.91 cells/mm², 2289.17 cells/mm² \pm 281.33 cells/mm² respectively.

Conclusions: Phaco-chop techniques had fewer negative effects on the corneal endothelium as less ultrasonic energy was used. This accelerates the functional healing process and the return to preoperative physiologic values.

Keywords: Phacoemulsification; Stop and chop; Phaco chop; Nucleotomy

Introduction

Ultrasonic phacoemulsification was first introduced by Kelman in 1967 [1] aiming to find a safer and more effective way of cataractous lens removal, however, US power required for traditional or longitudinal Phaco continues to be a risk factor for endothelial cell loss and tissue damage.

Corneal endothelial cell loss is an inevitable complication

Citation: El-Khouly SE, Shosha MH, EL-Ghafar AEA, El-weheedy AS, EL-Layeh AE. Comparative Study of Stop and Chop versus Phaco Chop Nucleotomy Techniques in Phacoemulsification. Clin Ophthalmol J. 2019; 1(1): 1001.

Copyright: © 2019 Sherief E. El-Khouly

Publisher Name: Medtext Publications LLC

Manuscript compiled: Nov 27th, 2019

***Corresponding author:** Sherief E. El-Khouly, Department of Medicine, Mansoura Ophthalmic Center, Mansoura University, Elgomhoriastreet, Mansoura, Egypt, Tel: 002-050-2202064; Fax: 002-050-2203043; E-mail: elkhouly_eye_clinics@yahoo.com

following cataract surgery and occurs after any cataract technique [2].

The corneal endothelium is vital for the maintenance of corneal transparency. This is accomplished by its effectiveness in keeping the corneal stroma in a state of continuous dehydration through two main actions - active fluid pump and barrier function. Any compromise in these activities has a direct effect on corneal clarity.

Cataract extraction with phacoemulsification is one of the most common surgical procedures performed today [3].

The normal corneal thickness and transparency are maintained by corneal endothelium. Endothelial alterations are considered important parameters of surgical trauma and also essential for estimating the safety of surgical techniques. Endothelial cell density decreases at a greater rate after cataract surgery than it does in healthy; previously un-operated corneas [4].

Divide-and-conquer technique, described by Gimbel, was the first nucleofractis cracking technique developed [5,6]. It provided safer surgery with less endothelial cell loss [7]. In 1993, the Phaco-chop technique for nucleus cracking was described by Nagahara. The main purpose of this technique was to mechanically break the nucleus into

smaller fragments, to decrease the use of ultrasonic power and limit Endothelial Cell Loss (ECL) [8].

Patients and Methods

This prospective study included 60 eyes of 60 patients attending the outpatient clinic of Mansoura Ophthalmic Center. They presented with immature senile cataract during the period from January 2014 to January 2016.

Ethical approval: The study was carried according to the Declaration of Helsinki with approval of IRB.

Inclusion criteria

Patients \geq 50 years old with senile cataract with moderate nuclear firmness (nuclear grades from 2-4) are included in this study.

Exclusion criteria

The following criteria were excluded during patient selection:

Patient age less than 50 years, Eyes with very soft or very hard nuclei (grade 1 or 5). Eyes with sunken globes and prominent supra orbital ridges, poorly dilated pupil. Eyes with ocular pathology such as corneal opacities, pseudoexfoliation syndrome, uveitis, glaucoma, ocular hypertension, posterior segment pathology as diabetic retinopathy or endothelial cell density less than 1500 cells/mm². Eyes with previous intraocular surgery. Eyes with previous ocular trauma.

Patients were randomly assigned to one of the 3 groups:

Group I (20 eyes): In which phacoemulsification was performed using the stop and chop technique.

Group 2a (20 eyes): In which phacoemulsification was performed using the horizontal chopping technique.

Group 2b (20 eyes): In which phacoemulsification was performed using the vertical chopping technique.

The following was performed for every patient:

History taking, It included onset, course and duration of vision diminution, history of previous ocular trauma or surgery, review of systemic diseases, detailed ophthalmic examination; including: visual acuity assessment using Landolt's broken rings chart. Refraction: using Topcon automated refractometer or retinoscopy. Measurement of the Best Corrected Visual Acuity (BCVA). Slit lamp examination to assess corneal clarity, anterior chamber depth, state of pupil dilatation, lens morphology and nuclear grading. Fundus examination; using non-contact Volk 90 lens, and indirect ophthalmoscopy. Measuring ocular tension using the Goldman applanation tonometer.

Anesthesia was achieved locally by peribulbar injection of 3 ml of Mepivacaine Hydrochloride 3%. All patients were operated on by the same surgeon using the Oertli CataRhex machine with a Phaco tip 30 degree. The surgical technique was similar in all cases except for the method of nucleus fracturing as following;

Application of wire speculum. Conjunctival sac washing with povidone iodine (betadine) 5%. Two clear corneal side port incisions were done using 20-gauge MVR knife 90 degrees from the main incision. A superior or superior temporal self-sealing clear corneal incision was done using 2.8 disposable metal keratome. The keratome was first passed for 2 mm inside the corneal stroma parallel to the iris plane before penetrating the descemet's membrane and entering the anterior chamber.

Ophthalmic Viscosurgical Device (OVD), sodium hyaluronate 1.4% was injected to fill the Anterior Chamber (AC). Capsulorhexis was initiated by a bent 27 gauge needle and then completed by a capsulorhexis forceps.

Hydro dissection followed by hydro delineation was done using 25 gauge cannula. Hydroxypropylmethyl cellulose was injected to fill AC.

Nuclear phacoemulsification; nuclear fracturing technique was different for each group.

Irrigation/Aspiration (I/A) of the cortical matter was then done using bimanual I/A system. Sodium hyaluronate was injected into the AC to inflate the capsular bag. Implantation of a foldable hydrophilic acrylic Intra Ocular Lens (IOL). (eyecryluv foldable IOL with holder folder).

Aspiration of the OVD by the bimanual I/A system. Wound closure was done by stromal hydration of corneal incision and side ports edges by balanced salt solution. Fracturing technique was different for each group as following:

Group 1(stop and chop): In the stop and chop group two memory programs were used.

Memory 1 was used for sculpting (maximum 60% ultrasound (US) power, vacuum 20 mm Hg, flow rate 20 cc/min - 25 cc/min and bottle height 90 cm). Memory 2 was used for quadrant removal (maximum 50% pulsed mode US power, maximum vacuum 350 mm Hg, flow rate 25 cc/min - 30 cc/min and bottle height 90 cm - 110 cm).

Group 2a (horizontal chopping): The memory 1 program was bypassed and only the pulse-mode program, memory 2 was used.

After the superficial cortex and epinucleus were aspirated, the Phaco tip was buried in the center of the endonucleus at a high vacuum setting (100 mmHg to 120 mmHg). Then the Nagahara Phaco chopper was brought through the side-port incision and the equator of endonucleus was engaged by the chopper under the lower edge of the capsulorhexis. The chopper was moved toward the Phaco probe to initiate nuclear cracking. Both instruments were moved in opposite directions, dividing the nucleus into halves. The nucleus was then rotated through 90 degrees, the Phaco tip impaled in the inferior hemi section of the nucleus, and the chopper used to break this half into 2 smaller fragments, which were then emulsified. The procedure was repeated on the superior nucleus.

Group 2b (vertical chopping): After the superficial cortex and epinucleus were aspirated, the Phaco tip was buried in the center of the endonucleus at a high vacuum setting (100 mmHg to 120 mmHg). Then the sharp chopper was brought through the side-port incision using the centrally impaled Phaco tip must completely immobilize the nucleus against the incoming sharp chopper tip in order to generate enough shearing force to fracture it. Dividing the nucleus into halves, the nucleus was then rotated through 90 degrees, the Phaco tip impaled in the inferior hemi section of the nucleus, and the chopper used to break this half into 2 smaller fragments, which were then emulsified. The procedure was repeated on the superior nucleus.

The following were reported during surgery:

The mean Phaco power (%). The absolute Phaco time, APT was calculated by multiplying the Phaco time (seconds) by the mean Phaco power (%).

Postoperative follow up

The following were done for every patient in each postoperative visit: Unaided visual acuity, refraction, BCVA, Slit lamp examination to assess: State of the cornea for edema, clarity and ulcers. State of the main incision. Aqueous flare or cells in the anterior chamber. Shape of the pupil and its reaction, any iris abnormality, IOL regarding its position and any deposits on its surface, clarity of the posterior capsule, Fundus examination, measurement of the ocular tension and corneal pachymetry to measure Central Corneal Thickness (CCT).

Statistical Analysis

IBM's SPSS program version 24.0 (2016) for windows was used for data tabulation and data analysis. Normality of data was tested using Shapiro-Wilk test. The three groups were compared with one-way ANOVA test for both parametric and non-parametric data. For intra group comparisons, dependent student t test (parametric data) and Mann-Whitney test (non-parametric data) were used. Statistical differences showing P (probability) value ≤ 0.05 was considered significant and if ≤ 0.01 it was considered highly significant.

Results

Demographic data and clinical characteristics

The data were collected during the period from January 2014 to January 2016. The study included sixty eyes of sixty patients, 32 cases were males (53.3%) 28 cases were females (46.7%). Average age in group 1 was 63.15 ± 5.41 years and 66.0 ± 7.18 years 64.3 ± 4.92 years in group 2a and group 2b respectively. Visual Acuity values were represented in decimal, Group 1 with visual acuity 0.06 ± 0.05 and 0.04 ± 0.03, 0.08 ± 0.12 in group 2a and group 2b respectively (Table 1). The stop-and-chop technique was performed in Group 1 (20 eyes) and Phaco-chop Nucleotomy technique in Group 2 (40 eyes) divided into 2 subgroups (horizontal chopping 20 cases group 2a, vertical chopping 20 cases group 2b).

Table 1: Sex and age distribution of the studied groups.

	Group 2a	Group 1	Group 2b	P	P ₁	P ₂	P ₃
Age	66.0 ± 7.18	63.15 ± 5.41	64.3 ± 4.92	0.31	0.1	0.36	0.54
Sex	Male 6 30%	Male 10 50%	Male 12 60%	0.15	0.2	0.06	0.52
	Female 14 70%	Female 10 50%	Female 8 40%				

-Data are expressed as mean± standard deviation or number (percentage).

-P is the significance value between three groups using one-way ANOVA, P₁ is the significance vale between group H and group S, P₂ is the significance vale between group H and group V, P₃ is the significance vale between group S and group V. P₁, P₂, P₃ were generated using LSD post Hoc multiple comparisons.

-P value is statistically significant when ≤ 0.05 and highly significant when ≤ 0.001.

Nuclear grades

According to Lens Opacity Classification system III LOCS III classification system, nuclear firmness was classified into three grades; grade 1, grade 2 and grade 3 (Table 2 and 3).

Absolute Phaco time

The effective Phaco time was 10.32 seconds ± 2.85 seconds in Group 1 and 9.71 seconds ± 3.05 seconds, 9.6 seconds ± 1.65 seconds, in Group 2a and group 2b respectively.

Volume of fluid

In our study in Group 1 the mean volume was 212.95 mm³ ± 36.42 mm³, in Group 2a was 213.8 mm³ ± 27.16 mm³, and in Group 2b was 202.9 mm³ ± 27.34 mm³ (Table 4).

Table 2: Grade of nuclear cataract of patients in this study.

Grade II	18 (30%)
Grade III	41 (68.3%)
Grade IV	1 (1.7%)

Data are expressed as number (percentage).

Table 3: Grade of nuclear cataract of patients in studied groups.

	Group 2a	Group 1	Group 2b	P	P ₁	P ₂	P ₃
Grade II	5(25%)	6 (30%)	7 (35%)	0.76	0.93	0.52	0.52
Grade III	15 (75%)	13 (65%)	13 (65%)				
		IV: 1 (5%)					

-Data are expressed as number (percentage).

-P is the significance value between the three groups using one-way ANOVA test, P₁ is the significance vale between group H and group S, P₂ is the significance vale between group H and group V, P₃ is the significance vale between group S and group V. P₁, P₂, P₃ were generated using LSD post Hoc multiple comparison test.

-P value is statistically significant when ≤ 0.05 and highly significant when ≤ 0.001

Table 4: Pintra-operative absolute Phaco time and volume of irrigation fluid used in studied groups.

	Group 2a	Group 1	Group 2b	P	P ₁	P ₂	P ₃
Phaco time (seconds)	9.71 ± 3.05	10.32 ± 2.85	9.6 ± 1.65	0.63	0.45	0.89	0.38
volume of fluid (ml)	213.8 ± 27.16	212.95 ± 36.42	202.9 ± 27.34	0.46	0.93	0.26	0.3

-Data are expressed as mean± standard deviation.

-P is the significance value between three groups using one-way ANOVA, P₁ is the significance vale between group H and group S, P₂ is the significance vale between group H and group V, P₃ is the significance vale between group S and group V. P₁, P₂, P₃ were generated using LSD post Hoc multiple comparisons.

-P value is statistically significant when ≤ 0.05 and highly significant when ≤ 0.001.

Pachymetry

The post operative pachymetry values in group1 one week, one month, 3 months and 6months 542.06 microns ± 37.54 microns, 528.16 microns ± 45.06 microns, and 520.61 microns ± 46.59 microns and 519.18 microns ± 35.99 microns respectively. The post operative pachymetry values in group 2a one week, one month , 3 months and 6 months, 548.37 microns ± 38.07 microns, 535.36 microns ± 35.09 microns , 528.51 microns ± 36.59 microns and 524.04 microns ± 36.85 microns respectively. The post operative pachymetry values in group 2b one week, one month, 3 months and 6 months, 535.53 microns ± 29.31 microns, 522.22 microns ± 35.34 microns, 515.77 microns ± 40.44 microns and 513.85 microns ± 38.60 microns (Table 5).

Endothelial cell count

The post operative endothelial cell count in group 1 one week, one month, 3 months and 6months 2314.25 cells/mm² ± 296.47 cells/mm², 2294.18 cells/mm² ± 290.57 cells/mm², 2293.35 cells/mm² ± 291.35 cells/mm², 2289.13 cells/mm² ± 295.14 cells/mm², respectively. the post operative endothelial cell count in group 2a one week, one month, 3 months and 6 months 2321.4 cells/mm² ± 324.44 cells/mm², 2303.35 cells/mm² ± 373.55 cells/mm², 2291.5 cells/mm² ± 370.71 cells/mm², 2287.28 cells/mm² ± 370.13 cells/mm², respectively. the post operative endothelial cell count in group 2b one week, one month, 3 months and 6 months 2318.8 cells/mm² ± 319.95 cells/mm², 2299.6 cells/mm² ± 302.51 cells/mm², 2293.4 cells/mm² ± 300.91 cells/mm², 2289.17 cells/mm² ± 281.33 cells/mm², respectively (Table 6).

Table 5: Pre-operative pachymetry and its post-operative follow up in studied groups.

Pachymetry	Group 2a	Group 1	Group 2b	P	P ₁	P ₂	P ₃
Basal	520.1 ± 32.74	517.7 ± 35.24	513.4 ± 44.60	0.85	0.84	0.57	0.72
One week	548.37 ± 38.07	542.06 ± 37.54	535.53 ± 29.31	0.51	0.57	0.25	0.56
One month	535.36 ± 35.09	528.16 ± 45.06	522.22 ± 35.34	0.56	0.56	0.28	0.63
Three months	528.51 ± 36.59	520.61 ± 46.59	515.77 ± 40.44	0.62	0.54	0.33	0.71
Six months	524.04 ± 36.85	519.18 ± 35.99	513.85 ± 38.60	0.68	0.68	0.39	0.65

-Data are expressed as mean± standard deviation.

-P is the significance value between three groups using one-way ANOVA, P₁ is the significance vale between group H and group S, P₂ is the significance vale between group H and group V, P₃ is the significance vale between group S and group V. P₁, P₂, P₃ were generated using LSD post Hoc multiple comparisons.

-P value is statistically significant when ≤ 0.05 and highly significant when ≤ 0.001.

Table 6: Pre-operative corneal endothelial count and its post-operative follow up and corneal cell loss in studied groups.

Count	Group 2a	Group 1	Group 2b	P	P ₁	P ₂	P ₃
Basal	2467.25 ± 205.41	2453.61 ± 303	2448.1 ± 282.56	0.97	0.87	0.82	0.95
One week	2321.4 ± 324.44 (Cell loss 5.49%)	2314.25 ± 296.47 (Cell loss 4.29%)	2318.8 ± 319.95 (Cell loss 4.25%)	0.99	0.94	0.97	0.96
One month	2303.35 ± 373.55 (Cell loss 6.5%)	2294.18 ± 290.57 (Cell loss 5.1%)	2299.6 ± 302.51 (Cell loss 5%)	0.99	0.93	0.97	0.96
Three months	2291.5 ± 370.71 (Cell loss 7%)	2293.35 ± 291.35 (Cell loss 5.3%)	2293.4 ± 300.91 (Cell loss 5.3%)	0.99	0.98	0.98	1
Six months	2287.28 ± 370.13 (Cell loss 7.2%)	2289.13 ± 295.14 (Cell loss 5.4%)	2289.17 ± 281.33 (Cell loss 5.4%)	0.99	0.98	0.98	1

-Data are expressed as mean± standard deviation.

-P is the significance value between three groups using one-way ANOVA, P₁ is the significance vale between group H and group S, P₂ is the significance vale between group H and group V, P₃ is the significance vale between group S and group V. P₁, P₂, P₃ were generated using LSD post Hoc multiple comparisons.

-P value is statistically significant when ≤ 0.05 and highly significant when ≤ 0.001.

Visual acuity

The post operative visual acuity in group 1 one week, one month, 3 months and 6months 0.547 ± 0.101, 0.547 ± 0.101, 0.547 ± 0.101, 0.547 ± 0.101, The post operative visual acuity in group 2a one week, one month, 3 months and 6 months, 0.598 ± 0.17, 0.598 ± 0.17, 0.598 ± 0.17, 0.598 ± 0.17. The post operative visual acuity in group 2b one week, one month, 3 months and 6 months were 0.644 ± 0.22, 0.644 ± 0.22, 0.644 ± 0.22, 0.644 ± 0.22 (Table 7).

Table 7: Pre-operative visual acuity and its post-operative follow up in studied groups.

Acuity	Group 2a	Group 1	Group 2b	P	P ₁	P ₂	P ₃
Basal	0.04 ± 0.03	0.06 ± 0.05	0.08 ± 0.12	0.32	0.52	0.13	0.39
One week	0.598 ± 0.17	0.547 ± 0.101	0.644 ± 0.22	0.19	0.34	0.39	0.74
One month	0.598 ± 0.17	0.547 ± 0.101	0.644 ± 0.22	0.19	0.34	0.39	0.74
Three months	0.598 ± 0.17	0.547 ± 0.101	0.644 ± 0.22	0.19	0.34	0.39	0.74
Six months	0.598 ± 0.17	0.547 ± 0.101	0.644 ± 0.22	0.19	0.34	0.39	0.74

-Data are expressed as mean± standard deviation.

-P is the significance value between three groups using one-way ANOVA, P₁ is the significance vale between group H and group S, P₂ is the significance vale between group H and group V, P₃ is the significance vale between group S and group V. P₁, P₂, P₃ were generated using LSD post Hoc multiple comparisons.

-P value is statistically significant when ≤ 0.05 and highly significant when ≤ 0.001.

Discussion

In our study, Phaco-chop techniques were superior to the stop and-chop technique as it decreased the Phaco parameters and shortened the postoperative healing period. Studies comparing the 2 techniques are rare. In a study by Vajpayee et al., with 20 patients in each group, there were no significant differences between the Phaco-chop and stop-and-chop groups in effective Phaco time and endothelial loss; there were no data showing rehabilitation time. In a study of the divide- and-conquer and Phaco-chop techniques by Wong and coauthors, there were significant between-group differences in

Phaco time and power in favor of the Phaco- chop group. The authors stated there was no difference in- complications, but there were no data showing with which technique visual rehabilitation was faster.

Human Corneal Endothelial Cells (CEC) recovery mechanism has been studied mostly *in vitro* or *ex vivo* because human *in vivo*

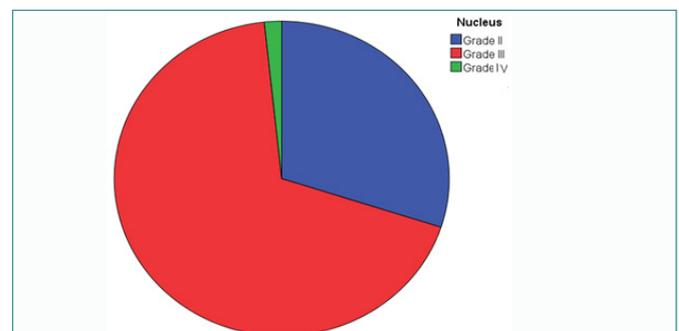


Figure 1: Grade of nuclear cataract of patients in this study.

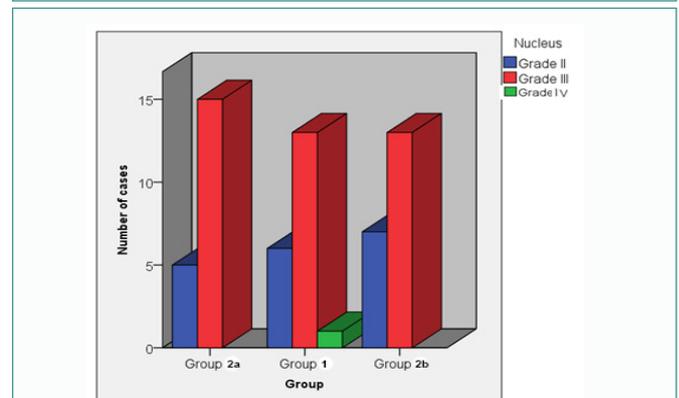


Figure 2: Grade of nuclear cataract of patients in studied groups.

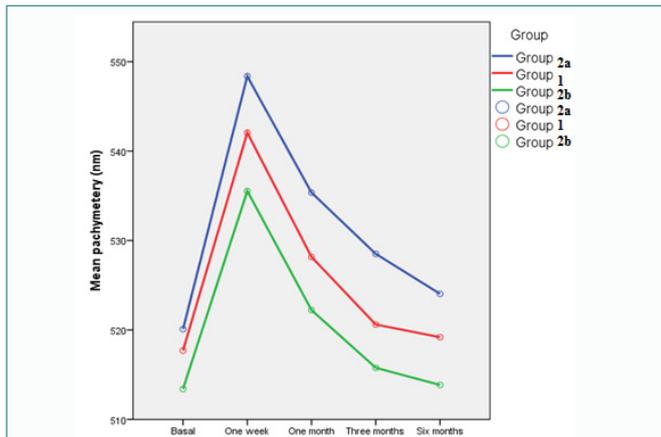


Figure 3: Pre-operative pachymetry and its post-operative follow up in studied groups.

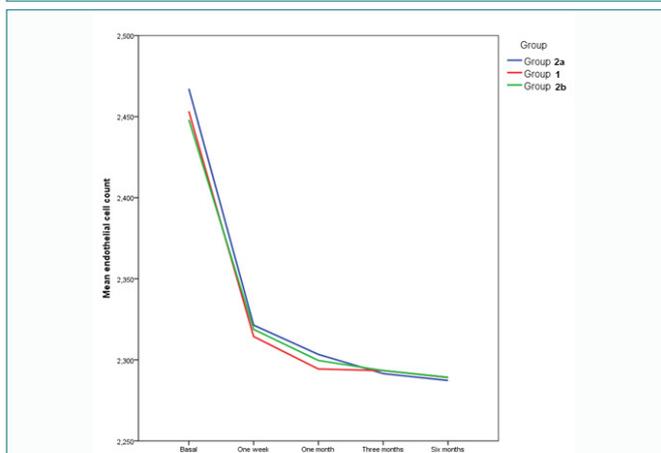


Figure 4: Pre-operative corneal endothelial count and its post-operative follow up in studied groups.

study is very difficult to perform. Human *in vivo* studies about CEC recovery mechanism following endothelial damage were rare. Hughes et al. showed the rise in central Endothelial Cells Density (ECD) increase after toxic endothelial injury which might represent cellular migration from less affected area [9].

In our study APT in stop and chop technique was 10.32 ± 2.85 seconds, The studies by Can et al. and Storr-Paulsen et al. [10,11] showed APT means: 14.9 and 12.79, respectively. In Phaco chop technique as regard horizontal chopping in our study absolute Phaco time was 9.71 ± 3.05 seconds, in vertical chopping was 9.60 ± 1.65 seconds. Higher means were documented by Vajpayee et al. [12] as 28 seconds, while other studies reported much lower APT after Phaco chop technique: less than 10 in the study by Suzuki et al. [13] and 3.98 in the study by Storr-Paulsen et al. [11].

The discrepancy between the result of the present study and other studies can be attributed to variations of surgeon's experiences and using different Phaco machines.

Wong et al. [14] revealed that horizontal-chop technique involved a significant shorter Phaco time and lower absolute Phaco power than the divide-and-conquer technique, leading to less Endothelial Cells Loss (ECL). They postulated that less total energy leads to less ECL. This hypothesis was confirmed by O'Brien et al. [15] whereas the present study and the study by Storr-Paulsen et al. [11] showed that there was no positive correlation between the total US energy and ECL.

Volume of fluid

Studies report that the use of larger infusion volumes during surgery increases the risk of damage to the corneal endothelium. According to Centurion et al. [16] the fluid dynamics required for maintaining anterior chamber volume, removing emulsified fragments, and cooling the titanium tip account for the increased consumption of solution. In our study in stop and chop technique the volume was $212.95 \text{ mm}^3 \pm 36.42 \text{ mm}^3$, in horizontal group was $213.8 \text{ mm}^3 \pm 27.16 \text{ mm}^3$, and in vertical chopping was $202.90 \text{ mm}^3 \pm 27.34 \text{ mm}^3$. There is correlation between volume used and endothelium cell loss.

Pachymetry: The results of our study confirm the findings of other authors like Kohlhaas et al. [17] that endothelial cell numerical density within the physiological range is not correlated with central corneal thickness.

Our data further reveal that central corneal thickness returns to preoperative values after 6 months, irrespective of the severity of endothelial cell loss. This finding supports the data published by Cheng et al. and Amon et al. [18,19].

Precise measurements of corneal thickness may therefore serve as a parameter for assessing overall endothelial function in corneas with a diseased endothelium or with borderline low endothelial cell counts. In corneas which have incurred moderate reductions in the number of otherwise healthy endothelial cells, the corneal thickness does not increase. A healthy endothelium is thus able to maintain corneal dehydration over a large range of endothelial cell counts. In order to evaluate the degree of surgical trauma and endothelial status, morphological criteria are more accurate. This is because the functional capacity of the endothelium is substantial and corneal cell depletion is not reflected in corneal thickness measurements until there has been substantial loss of corneal endothelial cells.

The persistent increases in central corneal thickness reported by Kohlhaas et al. [17] 6 and 12 months, respectively, following surgery could be attributed to the imprecision of the ultrasonic pachymetry measurements ($3 \mu\text{m} - 65 \mu\text{m}$ deviation from true values) or to pre-existing abnormalities in endothelial cell morphology.

Endothelial cell count: ECL following phacoemulsification was the main concern of many investigators since Irvine et al. [20] till Park et al., Cho et al. [21,22]. The reported average losses after phacoemulsification vary between 4% and 25% according to Walkow et al. [23]. Some studies showed low ECL after phacoemulsification as in Poyales-Galan and Pirazzoli, studies that reported ECL of 5.9% at 3 months postoperatively [24].

In our study average ECL in group 1 and group 2b was 5.4% but it was slightly higher in group 2a 7.2% with better results in vertical chopping may be due to better experience of the surgeon in this technique and less disturbance of the anterior chamber. Most operated eyes (83.3%) in Crema et al. [25] study had soft nuclei (grade 1 and 2) which may explain such low ECL. However, results of mentioned studies cannot be compared to that of the present study for 3 reasons. First, some authors did not mention their technique used during surgery. Second, other investigators used more than one technique for the same patient group. Third, some studies used techniques other than those used in the current study.

Phacoemulsification has additional potential risks for corneal endothelial cell damage related with to ultrasonic power in

comparison with extra capsular cataract extraction. These factors are mechanical damage caused by turbulence, air bubble, release of free radicals; greater irrigation fluid volume; and direct trauma from surgical instruments, lens fragments, and the IOL according to Dick et al. [26].

Patil & Melmane 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 [27].

Baradaran-Rafii et al. [28] measured the amount of reduction in ECL in relation to vacuum settings, and it was $9.6\% \pm 4.6\%$ in high vacuum group and $9.0\% \pm 4.0\%$ in low vacuum group at 12 weeks.

Several studies compared between divide and conquer versus Phaco chop techniques regarding their efficacy and safety. Other studies, Can et al. and Park et al. [10,21]. Were done to compare between Phaco chop versus stop-and-chop techniques. Mierzejewski et al. and Davison et al. [29,30] compared divide and conquer versus stop and chop techniques. There was no study has been found comparing all these three techniques simultaneously.

Visual acuity

Several studies; Poyales-Galan and Pirazzoli, Park et al. [24.21] showed BCVA means comparable to those of the present study.

Conclusion

Phaco-chop techniques had fewer negative effects on the corneal endothelium as less ultrasonic energy was used. This accelerated the functional healing process and the return to preoperative physiologic values.

References

- Vargas LG, Holzer MP, Solomon KD, Sandoval HP, Auffarth GU, Apple DJ. Endothelial cell integrity after phacoemulsification with 2 different handpieces. *J Cataract Refract Surg.* 2004;30(2):478-82.
- Gogate P, Ambardekar P, Kulkarni S, Deshpande R, Joshi S, Deshpande M. Comparison of endothelial cell loss after cataract surgery: phacoemulsification versus manual small-incision cataract surgery: six-week results of a randomized control trial. *J Cataract Refract Surg.* 2010;36(2):247-53.
- Sahu PK, Das GK, Agrawal S, Kumar S. Comparative evaluation of corneal endothelium in patients with diabetes undergoing phacoemulsification. *Middle East Afr J Ophthalmol.* 2017;24(2):74-80.
- Mencucci R, Ponchietti C, Virgili G, Giansanti F, Menchini U. Corneal endothelial damage after cataract surgery: microincision versus standard technique. *J Cataract Refract Surg.* 2006;32(8):1351-4.
- Shepherd JR. In situ fracture. *J Cataract Refract Surg.* 1990;16(4):436-40.
- Gimbel HV. Principles of nuclear phacoemulsification. In: Gimbel HV. Trough and crater divide and conquer nucleofractis techniques. *Eur J Implant Ref Surg.* 1991c;3:123-26.
- Hayashi K, Nakao F, Hayashi F. Corneal endothelial cell loss after phacoemulsification using nuclear cracking procedures. *J Cataract Refract Surg.* 1994;20(1):44-7.
- Díaz-Valle D, Benítez del Castillo Sánchez JM, Castillo A, Sayagués O, Moriche M. Endothelial damage with cataract surgery techniques. *J Cataract Refract Surg.* 1998;24(7):951-5.
- Joko T, Shiraishi A, Akune Y, Tokumaru S, Kobayashi T, Miyata K, et al. Involvement of P38MAPK in human corneal endothelial cell migration induced by TGF- β (2). *Exp Eye Res.* 2013;108:23-32.
- Can I, Takmaz T, Cakici F, Ozgöl M. Comparison of Nagaharaphaco-chop and stop-and-chop phacoemulsification nucleotomy techniques. *J Cataract Refract Surg.* 2004;30(3):663-8.
- Storr-Paulsen A, Norregaard JC, Ahmed S, Storr-Paulsen T, Pedersen TH. Endothelial cell damage after cataract surgery: divide-and-conquer versus phaco-chop technique. *J Cataract Refract Surg.* 2008;34(6):996-1000.
- Vajpayee RB, Kumar A, Dada T, Titiyal JS, Sharma N, Dada VK. Phaco-chop versus stop-and-chop nucleotomy for phacoemulsification. *J Cataract Refract Surg.* 2000;26(11):1638-41.
- Suzuki H, Takahashi H, Hori J, Hiraoka M, Igarashi T, Shiwa T. Phacoemulsification associated corneal damage evaluated by corneal volume. *Am J Ophthalmol.* 2006;142(3):525-8.
- Wong T, Hingorani M, Lee V. Phacoemulsification time and power requirements in phaco chop and divide and conquer nucleofractis techniques. *J Cataract Refract Surg.* 2000;26(9):1374-8.
- O'Brien PD, Fitzpatrick P, Kilmartin DJ, Beatty S. Risk factors for endothelial cell loss after phacoemulsification surgery by a junior resident. *J Cataract Refract Surg.* 2004;30(4):839-43.
- Centurion V. *Faco Total*, 2nd ed. Rio de Janeiro, Cultura Me´ dica. 2000.
- Kohlhaas M, Stahlhut O, Tholuck J, Richard G. [Changes in corneal thickness and endothelial cell density after cataract extraction using phacoemulsification]. *Ophthalmologie.* 1997;94(7):515-8.
- Cheng H, Bates AK, Wood L, McPherson K. Positive correlation of corneal thickness and endothelial cell loss. Serial measurements after cataract surgery. *Arch Ophthalmol.* 1988;106(7):920-2.
- Amon M, Menapace R, Radax U, Papapanos P. Endothelial cell density and corneal pachometry after no-stitch, small-incision cataract surgery. *Doc Ophthalmol.* 1992;81(3):301-7.
- Irvine AR, Kratz RP, O'Donnell JJ. Endothelial damage with phacoemulsification and intraocular lens implantation. *Arch Ophthalmol.* 1978;96(6):1023-6.
- Park JH, Lee SM, Kwon JW, Kim MK, Hyon JY, Wee WR, et al. Ultrasound energy in phacoemulsification: a comparative analysis of phaco-chop and stop-and-chop techniques according to the degree of nuclear density. *Ophthalmic Surg Lasers Imaging.* 2010;41(2):236-41.
- Cho YK, Chang HS, Kimm MS. Risk factors for endothelial cell loss after phacoemulsification: comparison in different anterior chamber depth groups. *Korean J Ophthalmol.* 2010;24(1):10-5.
- Walkow T, Anders N, Klebe S. Endothelial cell loss after phacoemulsification: relation to preoperative and intraoperative parameters. *J Cataract Refract Surg.* 2000;26(5):727-32.
- Poyales-Galan F, Pirazzoli G. Clinical evaluation of endothelial cell decrease with VisThesia in phacoemulsification surgery. *J Cataract Refract Surg.* 2005;31(11):2157-61.
- Crema AS, Walsh A, Yamane Y, Nos W. Comparative study of coaxial phacoemulsification and microincision cataract surgery One-year follow-up. *J Cataract Refract Surg.* 2007;33(6):1014-8.
- Dick HB, Kohnen T, Jacobi FK, Jacobi KW. Longterm endothelial cell loss following phacoemulsification through a temporal clear corneal incision. *J Cataract Refract Surg.* 1996;22(1):63-71.
- Patil S, Melmane S. Effect of power used in phacoemulsification surgery on corneal endothelium in various types of cataract. *International J of Healthcare and Biomedical Research.* 2014;2(4):164-7.
- Baradaran-Rafii A, Rahmati-Kamel M, Eslani M, Kiavash V, Karimian F. Effect of hydrodynamic parameters on corneal endothelial cell loss after phacoemulsification. *J Cataract Refract Surg.* 2009;35(4):732-7.
- Mierzejewski A, Kalluzny JJ, Kalluzny B, Elik I. [Cataract phacoemulsification techniques: "divide and conquer" versus "stop and chop"--comparative evaluation of operation course and early results]. *Klin Oczna.* 2004;106(4-5):612-7.
- Davison JA, Cionni RJ, Snowdon JR, Swartz K, Wears S, Simmons S, et al. Simultaneous surgeon and side-view video analysis comparing in situ fracture and stop and chop phacoemulsification. *J Cataract Refract Surg.* 2005;31(2):274-9.