Original Article

Effect of Pulse Mode Phacoemulsification on Corneal Endothelium Using Different Frequencies

Shahram Bamdad[1], Ali Reza Eslampoor[2], Hamed Tabesh[3]
Soheyla Jafarpour[4], Mehrnoosh Maalhagh[5], Akbar Derakhshan[6]
[1,5]*Poostchi Ophthalmology Research Center, Shiraz University of Medical Science, Medical school, Shiraz, Iran,*
[2,3,4,6]*Khatam-Al-Anbia Hospital, Mashhad University of Medical Sciences, Mashhad, Iran*

ABSTRACT

Purpose: To determine a safer mode using two different frequencies (10 and 60 pulses per second) in pulse mode phacoemulsification in moderate to severe cataract.

Study Design: Quasi experimental study.

Place and Duration of Study: Khatam-Al-Anbia Hospital, Mashhad, Iran, from 2017 to 2018.

Methods: We enrolled 145 patients with moderate and severe cataracts according to lens opacities classification system III (LOCS III). They were allocated to two different groups with different frequencies of pulse mode (10 PPS and 60 PPS) phacoemulsification. Post-operative parameters, including best-corrected visual acuity, corneal edema, endothelial cell density, central corneal thickness, and effective phaco time, were compared between the groups.

Results: Patients who had undergone surgery using 10 PPS pulse mode had better vision than those in the 60 PPS pulse mode group. Pulse mode with 10 PPS caused 0.112 reductions in log MAR in best-corrected visual acuity compared with the 60 PPS pulse mode group (p value = 0.001). The difference in corneal edema was significant between 10 and 60 PPS groups on the first and seventh days post-operatively (p-value < 0.0001). One month after surgery, corneal thickness increased in both groups and statistically more in 60 PPS group (p-value < 0.0001).

Conclusion: Pulse mode with lower frequency in moderate and hard cataracts preserves endothelial cells from damage. The mean effective phaco time is less with ten pulses per second pulse mode.

Key Words: Phacoemulsification, Cataract, Pulse Mode, Endothelium, Cornea.

How to Cite this Article: Bamdad S, Eslampoor AR, Tabesh H, Jafarpour S, Maalhagh M, Derakhshan A. Effect of Pulse Mode Phacoemulsification on Corneal Endothelium Using Different Frequencies. Pak J Ophthalmol. 2023, **39 (1):** 3-8.

Doi: 10.36351/pjo.v39i1.1488

Correspondence: Akbar Derakhshan
Khatam-Al-Anbia Hospital, Mashhad University of Medical Sciences, Mashhad, Iran
Email: psorc@yahoo.ac.ir

Received: August 13, 2022
Accepted: November 28, 2022

INTRODUCTION

Ultrasound Phacoemulsification has been the cornerstone of cataract surgery since 1980s.[1] There have been different modifications in phacoemulsification technique to reduce damage to endothelial cells and improve visual acuity after surgery.[2] Two modes apply for phacoemulsification, the Pulse mode, in which phaco power is delivered in regular intervals alternating between ON and OFF time. The ON and OFF time sum is called the Duty cycle.[3] The pulse mode is determined by the pulses applied per second (PPS) in the ON time in the duty cycle.[4] In the pulse mode, the surgeon can modulate the intensity of the phaco power of each pulse by a foot pedal in position 3.[5] In Burst Mode, the surgeon has preset the duty cycle, and the applied powers during ON time are equal in amount and length.

Stepping on the foot pedal in position 3 will decrease the OFF time; the phaco power delivers continuously with no rest time.[6]

The effective phaco time (EPT) is another way to compare two different phaco powers. EPT is calculated by multiplying the total phaco time by the average percentage power. In other words, EPT declares the phaco time if 100% power is used in continuous mode.[7] The safety and efficacy of each mode are compared by measuring the consequences of cell damage. Central corneal thickness, corneal edema, and endothelial cell counts can define the number of cell damages.[8] This study aimed to compare the safety and effectiveness of pulse mode in two different frequencies in two groups of patients with moderate and hard density cataracts. One skillful ophthalmic surgeon performed all phacoemulsification surgeries.

METHODS

Two pulse mode phacoemulsification with different pulses per second (PPS) were evaluated in two groups of patients with moderate and severe nuclear sclerosis. The Ethics Committee of Mashhad the University of Medical Sciences approved this study, and each patient filled out informed consent. The study was conducted following the tenets of the Declaration of Helsinki.

The clinical study enrolled 145 patients with cataracts. The cataract was classified based on lens Opacities classification system III (LOCS III). This classification regards four parameters: Nuclear opalescence (NO), Nuclear color (NC), Cortical cataract (C), and Posterior Subcapsular cataract (P).[9] According to LOCS III, the participants with NO and NC 3 or 4, C3, and P4 were considered as moderate cataract groups. Patients with NO and NC 5 or 6, C4 or 5, and P 5 were graded as severe cataract groups.

Inclusion criteria was cataract (grading according to LOCS III system), anterior chamber depth more than 3mm, dilated pupil size more than 6mm, and endothelial cell count of more than 2000 cells in mm^2. Patients with any ocular pathology such as corneal ulcer, herpes keratitis, glaucoma, Pseudo-exfoliation, diabetic retinopathy, uveitis with active inflammation, retinal detachment, or suspected retinal detachment on ocular ultrasonography, traumatic cataract, ocular or systemic diseases that could influence corneal endothelial cell function were excluded. Patients who had complication during surgery, such as floppy iris syndrome, vitreous loss, or using unfoldable intraocular lens, was another exclusion criterion for the study. The included patients were divided into two groups with different frequencies of pulse mode (10 PPS and 60 PPS) by simple random sampling method using a computer-generated list of random numbers.

The sample size (n) was calculated according to the formula: n = (Z_(1-α/2)+Z_(1-β)^2)/d^2 [p_1 (1-p_1) +p_2 (1-p_2)] Where: z = 1.96 for a confidence level (α) of 95%, p = proportion (expressed as a decimal), d = Minimum significant difference between the proportions of two groups. Z_(1-α/2) = 1.96, Z_(1-β) = 0.85. ⟦ p⟧_1 = 0.44, p_2 = 0.37, d = 0.1 and power = 80%. The sample size was equal to 65 for each group.

All 145 patients with eligibility criteria for the study were referred from ophthalmology clinics of Mashhad the University of Medical Sciences from 2017 to 2018. Eleven patients failed to fulfill the inclusion criteria. Seven patients did not come for the post-surgery assessments. Finally, 127 patients were included. Sixty-nine patients with moderate cataracts (54.3%) and 58 patients with severe cataracts (45.7%) were assigned to one of the two groups of 10 and 60 pulses per second (PPS) modes. Sixty-three patients enrolled in the 10 PPS group and 64patients in the 60 PPS group.

All the patients received a ciprofloxacin 0.3% eye drops every 6 hours starting 3 days before surgery. Tropicamide 1% eye drops was applied one hour before surgery for pupil dilation. Tetracaine 0.5% eye drops and intracameral preservative-free Lidocaine 2% were the local anesthetics. Under ZIESS operating microscope, one expert surgeon operated on all patients. After drape placement on the field of operation, one drop of Povidone-iodine 5% was instilled in the eye. The surgeon performed phacoemulsification with the phaco chop technique (Alcon Ozil IP system, 0.9mm mini flared 45-degrees Kelman and Aspiration Bypass System (ABS)).

Phacoemulsification began by making side port incisions 180 degrees apart with a 15-degree knife (Alcon Laboratories). Trypan blue was injected into the anterior chamber and irrigated with balanced salt solution (BSS). Anterior chamber was formed with sodium hyaluronate 1.0% (Provisc, Alcon). A 3.2mm clear corneal incision was made in the temporal side of the cornea by double-beveled trapezoid incision knife (Alcon Laboratories). 6mm continuous curvilinear

Table 1: *Demographics and post-operative parameters evaluation between two groups (*Student t-test, **Chi-square).*

Characteristics			10 PPS group (n = 63), (%)	60 PPS group (n = 64), %	P-Value
Age			64.65 ± 9.63	62.60 ± 7.48	*0.170
Sex	Male		27 (42.9)	29 (51.8)	**0.781
	Female		36 (57.1)	35 (49.3)	
Nucleus Hardness	Moderate		35 (55.6)	35 (54.7)	**0.922
	Severe		28 (44.4)	29 (45.3)	
EPT(sec)	< 20		48 (76.2)	36 (56.3)	0.018
	≥ 20		15 (23.8)	28 (43.8)	
Corneal Edema (Post op day 1)		1+	9 (14.3)	4 (6.3)	**< 0.0001
		2+	30 (47.6)	15 (23.4)	
		3+	24 (38.1)	29 (45.3)	
		4+	0	16 (25)	
Corneal Edema (Post op day 7)		1+	22 (34.9)	6 (9.4)	**< 0.0001
		2+	38 (60.3)	36 (56.3)	
		3+	3 (4.8)	18 (28.1)	
		4+	0	4 (6.3)	
Cell Density (Pre-op)			2443.77 ± 61.40	2423.81 ± 78.75	*0.114
Cell Density (Post-op)			2298.19 ± 85.36	2281.25 ± 80.20	*0.251
Central Corneal Thickness (Pre-op)			540.49 ± 5.15	541.52 ± 3.03	*0.197
Central Corneal Thickness (post op day 30)			549.13 ± 4.14	551.45 ± 2.99	*< 0.0001

capsulorhexis was made using capsulorhexis forceps. The pulse mode with a sixty percent duty cycle was used to remove the quadrants of the lens nucleus. The surgeon used pulse rates of 10 and 60 pulses per second for each study group. An intraocular lens (Acrysof SA 60 AT, Alcon) was implanted, and the ocular viscoelastic device (OVD) was removed from the anterior chamber using the irrigation/aspiration (I/A) system with BSS. Diluted Cefazolin (Daana Pharma Co.) was injected into the inferior conjunctival fornix.

All patients were treated with Ciprofloxacin eye drops 0.3%, Prednisolone Acetate 1% eye drops (Sina Daru, Tehran, Iran) for four weeks.

Corneal edema was assessed on the first day and first week after surgery according to the corneal edema grading (1+ to 4+) as mentioned in Table 1.

One month postoperatively, central corneal thickness (CCT) was evaluated by ultrasound pachymetry (Tomey bM-3000, Japan). The device probe was placed on the cornea of the patient perpendicularly. An average of ten measurements was reported.

The Specular microscopy device (Tomey EM-3000, Japan) evaluated endothelial cell properties one month after surgery. The capturing time was only 1.2 seconds; a series of 15 images were instantly captured, and endothelial cell density was recorded.

The Effective phaco time (EPT) calculates as if the total phaco power is in continuous phaco mode. EPT is higher in the hard nucleus. It is a phacodynamic parameter to assess the safety of the phacoemulsification technique. Endothelial cell density is the most important parameter in evaluating the safety and efficacy of EPT.

The minimum angle of resolution (LogMAR) scale determined the best-corrected visual acuity (BCVA) 3days after surgery.

The statistical analyses were carried out using Statistical Package for the Social Sciences (version 23; IBM SPSS Inc. Chicago, IL, USA). Descriptive statistics were calculated for all measures, including mean, median, ranges, and standard deviations for continuous measures and frequencies and proportions for categorical data. The Chi-square test, t-test, and Fischer test were used for comparing and $P < 0.05$ was considered statistically significant.

RESULTS

Mean age of the patients was 64.65 ± 9.63 years in the 10 PPS group and 62.60 ± 7.49 years in the 60 PPS group, with no significant difference (p-value: 0.170). Regarding nuclear hardness and pulse frequency of phacoemulsification, 35 patients (55.6%) with moderate cataracts were enrolled in the 10 PPS group and other 35 patients (54.7%) with the same nuclear hardness in the 60 PPS group. Out of hard nucleus, 28 and 29 patients (44.4% and 45.3%) were enrolled in 10 PPS and 60 PPS groups, respectively.

In terms of BCVA, based on the log MAR

(minimum angle of resolution), patients with moderate cataracts gained better vision than the group with severe cataracts. Patients who had undergone surgery using 10 PPS pulse mode had better vision than those in the 60 PPS pulse mode group. 10 PPS pulse mode causes 0.112 reductions in log MAR compared to the 60 PPS pulse mode group (p-value: 0.001).

Corneal edema was assessed only on the first day and the first week after surgery. There was no fourth-grade corneal edema in the 10 PPS group. Corneal edema was in second and third grade in the 10 PPS group. Most of the patients in this group had first to second-grade corneal edema by the end of the first week after the operation. Patients in the 60 PPS group had higher grades of edema. Corneal edema was about third and fourth grade, lowered in one week, and resolved to second and third grade. The difference in corneal edema was significant between 10 and 60 PPS groups on the first and seventh post-operative day (p-value: < 0.0001). The mean cell density had no significant difference between the groups (p-value: 0.114).

Changes in cell density before and after the operation was not statistically significant between groups (p-value: 0.251). The 10 PPS group had more cell density than the 60 PPS group post-operation (2298.19 ± 85.36 versus 2281.25 ± 80.20).

Another parameter measured before and after surgery was central corneal thickness. Central corneal thickness had no statistically significant difference between both groups before operation. After one month, the central corneal thickness increased in both groups and more in the 60 PPS group (p-value < 0.0001).

Most of the cases had EPT of less than 20 seconds in both groups. Most cases were allocated to the 10PPS group (48 cases versus 36 cases) (p value = 0.018).

DISCUSSION

Phacoemulsification is the most common surgery among ophthalmic procedures. Technology advances and the development of various techniques in phaco procedure provide a safe way to operate different types of cataracts with different nuclear hardness.[10] The main goal of these developments is to reduce the ultrasound power delivered in the anterior chamber, which results in protection of endothelial cells and better visual acuity afterward. Phaco power is determined by a frequency which is the speed of needle movement (cycle per second) and stroke length.[11,12]

Phacoemulsification in moderate and severe cataract is more challenging and can have adverse effects on cornea. The authors designed the current study to evaluate the pulse mode with two different ultrasound frequencies (10 and 60 pulses per second).

Phacoemulsification produces heat in the anterior chamber, which correlates with the damage to the endothelial cells.[8,13] The extent of endothelial cell loss can be a predictor of temperature rise during operation. The healthy endothelial cell pump controls central corneal thickness.[14,15] Measuring corneal thickness is a way to evaluate the health and functioning of the remaining endothelial cells. Baraga-Mel et al. performed an in vitro study to detect the temperature rise in the anterior chamber during phacoemulsification with microbursts and hyper pulses modes.[8] This study had two subgroups in hyper pulsed mode: 8 PPS group and 75 PPS group with a 30% duty cycle. The temperature rises were 33.4˚C and 38˚C, respectively. In microburst mode with 4ms ON and 4 msOFFcycle, maximum temperature was 37.8 ˚C. At 6ms ON and 12ms OFF cycle, the maximum temperature was 38.7˚C.

In the study performed by Kim et al, endothelial cell loss was compared with different phacoemulsification mode.[16] Results revealed that burst and pulse mode had less adverse effect on cornea than continuous mode.

The current study had the same results as Baraga-Mele et al. study. Moderate and hard nucleus cataracts treated with 10 PPS pulse mode had lower corneal thickness might reflect the fact that heat production with this frequency of pulse mode was lesser than with 60 PPS mode. Measuring the cell density after one-month post operation showed the same results and it was not statistically significant.

The fine et al. study confirmed that using Burst mode in hard lenses leads to clear cornea in all patients at the first post-operative visit. All patients achieved visual acuity of more than 20/40.[4,6]

Yang et al. compared the conventional continuous mode of phaco with torsional and burst combination mode.[10] This study showed that Burst mode reduced the cumulative dissipation of energy during phacoemulsification of hard cataract. Besides, the torsional mode decreased the ultrasonic energy and

saved the phaco power. Torsional mode creates enough cutting energy with lower ultrasound power. Torsional and burst modes modify the damage to the endothelial cells and cause better vision postoperatively.[12.17]

The other parameter that affects the corneal endothelial cell during phacoemulsification is the EPT. Longer phaco time will produce higher temperature in the anterior chamber and consequently more damage to the endothelial cells.[18]

Another parameter that has impact on EPT and endothelial cell counts is ultrasound frequencies during phacoemulsification. Dewan and et al. compared different ultrasound frequencies in randomized clinical trial and proved that in hard cataract, higher frequencies had less EPT and less damage to the endothelium.[19] Bhavsar study revealed a positive correlation between central corneal thickness and EPT.[20]

There are several limitations regarding the present study including the small sample size, and the single-center and residual confounding by unmeasured or unknown covariates.

CONCLUSION

EPT varies among different settings of phaco machines. The current study proved that lower pulses in pulse mode, break the lens nucleus with lesser heat to save endothelial cells.

ACKNOWLEDGMENT

The authors would like to thank the participants of the study for their time and participation.

Conflicts of Interest

The authors declare no conflicts of interest.

REFERENCES

1. **Fishkind WJ.** The phaco machine: analysing new technology. Curr Opin Ophthalmol. 2013; **24 (1):** 41-46. Doi: 10.1097/ICU.0b013e32835b0770.
2. **Hüseyin Ünver H, Bakılan F, Berkan Taşçıoğlu F, Armağan O, Özgen M.** Comparing the efficacy of continuous and pulsed ultrasound therapies in patients with lateral epicondylitis: A double-blind, randomized, placebo-controlled study. Turk J Phys Med Rehabil. 2021; **67 (1):** 99-106. Doi: 10.5606/tftrd.2021.4789.
3. **Ozkurt YB, Evciman T, Sengor T, Haboglu M, Bas G, Kurna S, et al.** Comparison of burst, pulse, and linear modes used in phacoemulsification surgery. Eur J Ophthalmol. 2010; **20 (2):** 353-364. Doi: 10.1177/112067211002000215.
4. **Fine IH, Packer M, Hoffman RS.** Power modulations in new phacoemulsification technology: improved outcomes. J Cataract Refract Surg. 2004; **30 (5):** 1014-1019. Doi: 10.1016/j.jcrs.2003.09.062.
5. **Badoza D, Fernández Mendy J, Ganly M.** Phacoemulsification using the burst mode. J Cataract Refract Surg. 2003; **29 (6):** 1101-1105. Doi: 10.1016/s0886-3350(03)00074-9.
6. **Fine IH, Packer M, Hoffman RS.** Use of power modulations in phacoemulsification. Choo-choo chop and flip phacoemulsification. J Cataract Refract Surg. 2001; **27 (2):** 188-197. Doi: 10.1016/s0886-3350(00)00834-8.
7. **Tognetto D, D'Aloisio R, Cecchini P, Di Nicola M, Di Martino G.** Comparative clinical study of Whitestar Signature phacoemulsification system with standard and Ellips FX handpieces. Int Ophthalmol. 2018; **38 (4):** 1697-1702. Doi: 10.1007/s10792-017-0649-5. Epub 2017 Jul 13.
8. **Braga-Mele R.** Thermal effect of microburst and hyperpulse settings during sleeveless bimanual phacoemulsification with advanced power modulations. J Cataract Refract Surg. 2006; **32 (4):** 639-642. Doi: 10.1016/j.jcrs.2006.01.037.
9. **Bencić G, Zorić-Geber M, Sarić D, Corak M, Mandić Z.** Clinical importance of the lens opacities classification system III (LOCS III) in phacoemulsification. Coll Antropol. 2005; **29 Suppl. 1:** 91-94.
10. **Yang WJ, Wang XH, Zhao F, Mei ZM, Li S, Xiang Y.** Torsional and burst mode phacoemulsification for patients with hard nuclear cataract: A randomized control study. Medicine (Baltimore), 2019; **98 (22):** e15870. Doi: 10.1097/MD.0000000000015870.
11. **Tognetto D, Cecchini P, Leon P, Di Nicola M, Ravalico G.** Stroke dynamics and frequency of 3 phacoemulsification machines. J Cataract Refract Surg. 2012; **38 (2):** 333-342. Doi: 10.1016/j.jcrs.2011.07.041.
12. **Kongsap P.** Central corneal thickness changes following manual small incision cataract surgery versus phacoemulsification for white cataract. Rom J Ophthalmol. 2019; **63 (1):** 61-67.
13. **Ataş M, Demircan S, Karatepe Haşhaş AS, Gülhan A, Zararsız G.** Comparison of corneal endothelial changes following phacoemulsification with transversal and torsional phacoemulsification machines. Int J Ophthalmol. 2014; **7 (5):** 822-827. Doi: 10.3980/j.issn.2222-3959.2014.05.15.

14. **Patil S, Melmane S.** Effect of power used in phacoemulsification surgery on corneal endothelium in various types of cataract. Intern J Healthcare Biomed Res. 2014; **2 (4):** 164-167.
15. **Namrata S, Deepali S, Sreelakshmi P, Pranita S, Sreeshankar SS, Kumar MP.** Corneal edema after phacoemulsification. Indian J Ophthalmol. 2017; **65 (12):** 1381-1389. Doi: 10.4103/ijo.IJO_871_17
16. **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. Doi: 10.1016/j.jcrs.2011.04.024. Epub 2011 Aug 11.
17. **Demircan S, Atas M, Yurtsever Y.** Effect of torsional mode phacoemulsification on cornea in eyes with/ without pseudoexfoliation. Int J Ophthalmol. 2015; **8 (2):** 281-287. Doi: 10.3980/j.issn.2222-3959.2015.02.12.
18. **Tsorbatzoglou A, Kertész K, Módis L, Németh G, Máth J, Berta A.** Corneal endothelial function after phacoemulsification using the fluid-based system compared to conventional ultrasound technique. Eye (Lond). 2007; **21 (6):** 727-732. Doi: 10.1038/sj.eye.6702314. Epub 2006 Mar 3.
19. **Dewan T, Malik PK, Tomar P.** Comparison of effective phacoemulsification time and corneal endothelial cell loss using three different ultrasound frequencies: A randomized controlled trial. Indian J Ophthalmol. 2022; **70 (4):** 1180-1185. Doi: 10.4103/ijo.IJO_2163_21.
20. **Bhavsar SG, Kshatriya Etjjohs, Education P.** Central corneal thickness Correlation with effective phaco time in Phacoemulsification surgery at a tertiary care hospital of Gujarat, India. J Heal Sci Prof Educ. 2021; **1 (2):** 41–44.

Authors' Designation and Contribution

Shahram Bamdad; *Concepts, Design.*

Ali Reza Eslampoor; *Literature Search, Manuscript Review.*

Hamed Tabesh; *Data Acquisition.*

Soheyla Jafarpour; *Data Analysis, Statistical Analysis.*

Mehrnoosh Maalhagh; *Data Acquisition, Manuscript preparation, Manuscript editing.*

Akbar Derakhshan; *Concepts, Design.*