HOSPITAL CHRONICLES 2019, 14(1): 7–12

ORIGINAL ARTICLE

A Clinical Prospective Study: Corneal Alterations After Cataract Surgery With the Technique of Phacoemulsification

†Angela I. Karekla, MD, Charalampia Linardi, MD,
Antonios Morphopoulos, MD, Ioannis K. Lamprinakis, MD

Ophthalmology Department, "Evangelismos" General Hospital of Athens, Greece

KEY WORDS: *Cataract, phacoemulsification, cornea, lens, endothelium, ultrasound, confocal microscopy*

Abbreviation List
CCT: central corneal thickness
CV: coefficient of variation
ECD: endothelial cell density
ECL%: endothelial cell loss%
SD: standard deviation.

Correspondence to:
Charalampia Linardi, MD, PhD, Msc
Director of Ophthalmology Department, "Evangelismos" General Hospital of Athens,
45-47, Ipsilandou street,
10676 Athens, Greece
Tel.: +30 6944 506360
E-mail: harilinardi@gmail.com

Manuscript received March 3, 2018; revised manuscript received June 12, 2019; Accepted June 12, 2019

ABSTRACT

The purpose of this study is to investigate the effect of ultrasound energy used during phacoemulsification on corneal structure, which is the most important refractive part of the eye. This will be achieved with the comparison of preoperative and postoperative parameters related to corneal thickness and endothelium and their correlation with clinical, intrasurgical and imaging diagnostic findings.

METHODS: This is a clinical prospective study conducted in Evangelismos G.H.A. The patients' enrollment was based on detailed medical history assessment, medication records as well as meticulous slit lamp examination, tonometry, best corrected visual acuity evaluation and thorough fundoscopy. Nuclear cataract sclerosis was evaluated with Lens Opacities Classification System III, and patients were scheduled for surgery. Preoperatively, with the use of specular microscopy (Tomey EM-3000; Tomey, Tennenlohe, Germany), CCT and several endothelial indices were recorded. The same measurements took place the 1st, 7th and 30th postoperative day. All the surgical operations were done without complications.

RESULTS: Statistical analysis from preoperative and postoperative data showed that central corneal thickness, although elevated during the 1st and 7th postoperative day, did not present statistical significant difference in the final evaluation, with a mean elevation of only 3,9μm. Endothelial cell density levels though were reduced in all postoperative measurements ($p<0{,}001$). The final ECL% was 18,58%, with the most profound loss being accounted in the first postoperative week. Corneal edema and endothelial cell loss were correlated with poor visual acuity, reduced corneal curvature, increased nuclear sclerosis and prolonged time of ultrasound metrics.

CONCLUSION: The use of confocal microscopy is a useful tool in pointing significant differences of corneal structure after uneventfull cataract phacoemulsification. The evaluation of a larger cohort of patients and a prolonged follow up procedure could give further information concerning corneal alterations after surgery.

The authors declare that there is no financial relationship or conflict of interest to disclose concerning this article

INTRODUCTION

Cataract is still one of the major causes of blindness worldwide and cataract surgery remains one of the most widespread operations in medicine.[1,2] Today, phacoemulsification has replaced older cataract surgery techniques in most cases. The advantages of phaco surgery compared with extracapsular extraction include faster healing with less corneal edema, lower complication rates and more predictable refractive results. Ongoing research and development of more efficient technical equipment, viscoelastics and intraocular lenses have created even more promising surgical achievements.

Pre-operative and post-operative diagnostic procedures have also been improved. The use of Scheimpflug corneal topography, ocular coherence tomography wavefront analysis and especially confocal microscopy led to better understanding the refractive capabilities before and after surgery both in uncomplicated and complicated cases, and to better demonstrate the changes that an operation may induce.[3]

The purpose of this study is to investigate the impact of phacoemulsification on corneal structure. In order to reveal corneal alteration due to surgery, a thorough comparison of preoperative and postoperative parameters will be attempted. This study will try to analyse corneal thickness and endothelial profile changes and to correlate them with clinical data like age, sex, preoperative refraction, corneal curvature, anterior chamber depth and ocular axial length. Furthermore, possible intraoperative parameter correlations were analysed, such as ultrasound placation time and total energy used.

MATERIALS AND METHODS

SETTING

This is a clinical-based prospective study. The protocol adhered to the tenets of the Helsinki Declaration and written informed consent was given by all participants. The study was conducted at the Ophthalmology Department of Evangelismos General Hospital of Athens, Greece, from January 2017 until November 2017.

PARTICIPANTS

Volunteers were recruited from the outpatient service of the Department of Ophthalmology of Evangelismos General Hospital, in a consecutive-if-eligible basis. The patients were selected after registering family and personal history, logMAR standard visual acuity, intraocular pressure with Goldmann applanation tonometer, and meticulous ocular examination of anterior and posterior segment. Maximum, minimum and mean corneal curvature was measured with Righton Speedy-i K-model kerato-refractometer. During slit lamp examination with mydriasis, the density of crystalline lens was calculated using the LOCSIII lens opacification grading system.[4] All patients were scheduled for cataract removal.

Before surgery, with the use of confocal microscopy (Tomey EM-3000; Tomey, Tennenlohe, Germany), the authors recorded several corneal structure indices like, central corneal thickness, amount and density of endothelial cells, the standard deviation (SD) of cell area and the coefficient of variation (CV) of cell area. The same measurements were repeated at day 1, day 7 and day 30 after the operation. Preoperative calculations also included axial length, anterior chamber depth and intraocular lens calculation with OcuScan RxP Ophthalmic Ultrasound System from Alcon Laboratories.

During surgery, local chemoprophylaxis included the topical use of 5% povidone iodine solution for 30 sec before the operation. All eyes were operated by the same surgeon with the same methods (divide and conquer) using the Alcon Infiniti System (Alcon, FortWorth, TX). The same viscoelastic was used in all cases (Viscoat – Provisc combination), phaco was applied with a straight phaco tip facing downwards and the same intraocular lens was inserted in the posterior chamber (IQ Alcon). All operations were uneventful and sutureless. After surgery topical ointment of tobramycin- dexamethazone was instilled.

EXCLUSION CRITERIA

1. Any kind of complication during surgery.
2. Endothelial cell number <1500/mm^2 before surgery.
3. History of ocular trauma, severe ocular inflammation and previous ocular surgery.
4. Any other pathological cataract beside age related one.
5. Pseudoexfoliation syndrome.
6. Any kind of keratopathy or corneal dystrophy.
7. Diabetes mellitus.

STATISTICAL ANALYSIS

Clinical and imaging parameters, like central corneal thickness, standard deviation of cell area, coefficient of variation of cell area, visual acuity, axial length, lens density and phaco duration were listed in excel tables. All measurements were repeated on day 1,7 and 30. The percentage of endothelial cell loss (ECL%) was calculated from endothelial cell density (ECD) according to the following equation: $ECL\% = \{(ECD\ preop - ECD\ postop) / ECD\ preop\} \times 100$.

Statistical analysis was performed with SPSS (statistical software version 15; SPSS, Inc, IBM, Chicago, IL 13). After sample distribution analysis, independent t-test was used to compare preoperative and postoperative values. Clinical and imaging data were correlated using the Pearson correlation test (SPSS, WESSA Software38). Statistical significance was set to $p<0,05$.

RESULTS

Eighty eyes from a total of 80 patients (36 male and 44 female) were included in the study. Mean age was 76,7 years old (mean deviation ±5,82, range 63-89). Mean visual acuity was 2,9/10 (±1,27), and nuclear sclerosis ranged from +2 to +5 LOCSIII. Mean axial length was 22,67mm ±0,62 and mean phaco duration 38,38±18,89 sec.

Central corneal thickness (CCT), ECD, SD of cell area, CV of cell area, mean values and ECL% values measured at the final examination are presented in Table 1.

During statistical analysis it is shown that CCT did not present statistical differences between preoperative and final examination, despite its significant increase on day 1and 7. ($p<0,001$) with a mean value of increase of 3,9μm±7,3. On the contrary, ECD was significantly decreased in all follow up examinations ($p<0,001$) (Figures 1, 2). The mean ECL% was 18,58%, while the biggest loss was noted in the first post-operative week.

Similar results were found for the rest of endothelial indices. SD and CV were increased in all postoperative days, especially on day one, when the worse corneal edema was noticed ($p<0,001$) (Table 2, Figure 3).

In this study it was also attempted to correlate endothelial cell loss and corneal edema (the difference of preoperative and postoperative corneal thickness) with several clinical and imaging parameters. Axial length, initial corneal thickness and endothelial cell number, CV and SD indices were not related to the final endothelial cell loss or final corneal edema. Instead, increased age correlated with more severe cell loss ($p<0,01$). Furthermore, nucleus sclerosis and deterioration of visual acuity showed a positive correlation with corneal edema and cell loss postoperatively ($p<0,001$).

Mean corneal curvature was negatively correlated with edema and cell loss ($p<0,03$, $p<0,04$ respectively) while higher astigmatism predisposed for more severe edema. Anterior chamber depth showed a borderline significant correlation with endothelial changes ($p<0,05$). Finally, increased phaco duration led to more severe edema and endothelial cell loss ($p<0,001$) (Tables 3, 4 and 5).

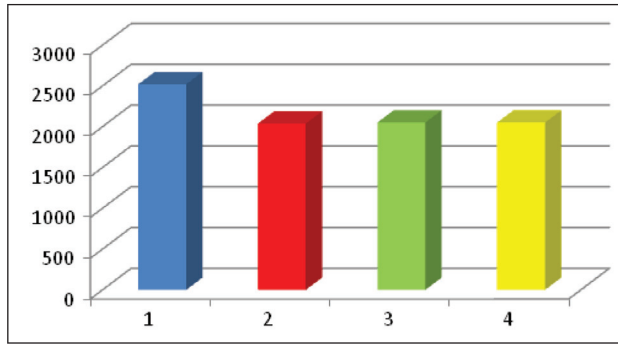

FIGURE 1. Preop and postop endothelial cell number: bar 1: preop cell number, bar 2: cell number day1, bar 3: cell number day 7, bar 4: cell number day 30.

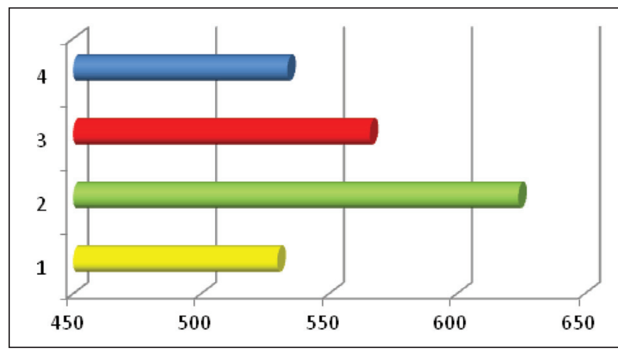

FIGURE 2. CCT preop and postop. Bar 1: preop CCT, Bar 2: CCT day 1, Bar 3: CCT day 7, Bar 4: CCT day 30.

TABLE 2. Statistic analysis.

Statistical differences	CCT	ECD	SD	CV
1d postop	P<0,001	P<0,001	P<0,001	P<0,001
7d postop	P<0,001	P<0,001	P<0,001	P<0,001
30d postop	P<0,1*	P<0,001	P<0,001	P<0,05

*not significant
1d postop, 7d postop, 30d postop

TABLE 1. Mean values and standard deviation of preop and postop. values. preop 1d postop: 1st postop day, 7th postop day, 30d postop: 30th day from surgery.

	CCT	ECD	SD	CV	ECL%
Preop	529,7±26,8	2520,9±252	167,3±48	41,5±7,4	(-)
1d postop	623,9±79,6	2037,2±307	313,8±164	62,8±22,7	(-)
7d postop	565,9±33,7	2051,4±297	237,6±76,9	48,3±8,8	(-)
30d postop	533,7±26,1	2049,1±288	224,8±81,1	46,3±9,1	18,56±9,2

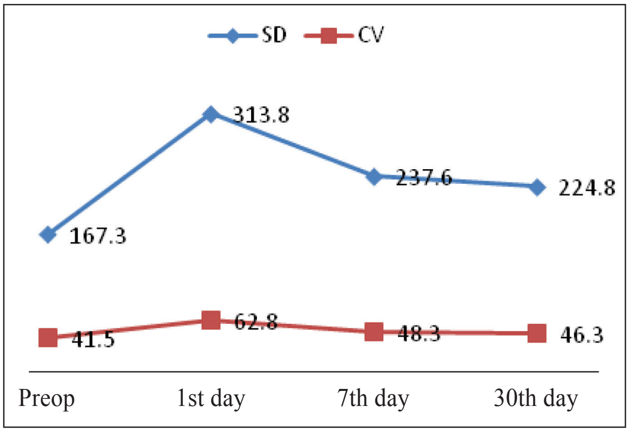

FIGURE 3. SD and CV changes preop and postop.

DISCUSSION

Phacoemulsification is the gold standard in treating lens opacification. The technique of surgery is constantly improving, including smaller incisions and better refractive results. The use of more effective and custom-fit viscoelastics, the new forms of phaco tips and the development of more efficient phaco software and hardware led to more stable anterior chamber during surgery and more predictable results. The protection of corneal structures has also been improved. A recent evolution in cataract surgery is the use of femptosecond laser. Femptosecond laser application results in more accurate corneal incisions, astigmatism treatment, predictable capsulorrhexis and nucleus fragmentation.[5,6] The goal is to decrease the amount of ultrasound used, to reduce the postoperative corneal edema and the corneal endothelial cell loss.[4,7,8]

Despite all this technological background, complications still occur. Severe intraoperative and postoperative complications, although rare, include endophthalmitis, posterior capsule rupture, nucleus drop, macular edema, retinal detachment and hemorrhage. Complications related to corneal dysfunction include corneal striae, persistent corneal edema, bullus keratopathy, and refractive changes and the impose a great problem to surgeons since they are directly correlated with vision deterioration.

Many studies have shown the effect of phacoemulsification on corneal physiology. The proper corneal function is based on the preservation of corneal endothelial integrity, shape and density of endothelial cells. These studies use similar endothelial analysis based on confocal microscopy.[9] Ozil technology (oscillating side-to-side motion by the phaco tip) was correlated with better endothelial density and lower paco energy released.[10] Similar results are presented with the use of Ellips™ FX transversal continuous ultrasound.[11]

Several phaco techniques were also related with corneal endothelial status. Both Phaco chop and divide and conquer

TABLE 3. Correlation of clinical-imaging indices with corneal edema and ECL%.

	AXL	CCT PREOP	ECD PREOP	Gender	Age	US time	BCVA	NS
CCT difference	r:+0,05 P<0,7*	r:-0,23 P<0,15*	r:-0,06 P<0,7*	r:-0,03 P<0,18*	r:+0,18 P<0,25*	r:+0,34 P<0,02	r:-0.32 P<0,04	r:+0,29 P<0,006
ECL%	r:+0,25 P<0,18*	r:+0,04 P<0,7*	r:+0,14 P<0,37*	r:-0,029 P<0,06*	r:+0,37 P<0,01	r:+0,61 P<0,001	r:-0,47 P<0,003	r:+0,5 P<0,001

AXL: axiallength, US TIME: phaco duration, BCVA: best corrected visual acuity, NS: nuclear sclerosis, r: Pearson correlation coefficient
*not significant.

TABLE 4. Correlation of best corrected visual acuity with corneal edema and ECL%, BCVA: best corrected visual acuity, r: Pearson correlation coefficient.

	BCVA
CCT difference	r:-0.32 P<0,04
ECL%	r:-0,47 P<0,003

TABLE 5. Correlation of anteriorchamber depth (ACD), mean cornealcurvature and astigmatism with corneal edema and ECL%, r: Pearson correlation coefficient.

	ACD	Mean corneal curvature	Astigmatism
CCT difference	r: 0,34 p<0,05	r: -0,35 p<0,03	r: 0,04 p<0,77*
ECL%	r:- 0,02 p<0,8*	r: -0,33 p<0,04	r: 0,38 p<0,009

* not significant.

nucleus fragmentation technique, caused statistically significant endothelial aggrevation.[12] Similar results were presented for stop-and-chop and nuclear preslice methods.[13] Their difference rests on lower phaco energy application of the chopping techniques. Microincision cataract surgery did not show significant differences in better preservation of corneal endothelium when compared with standard phacoemulcification.[14] Other parameters, like ocular axial length, phaco tip direction when entering the anterior chamber and type of viscoelastic were correlated with endothelial differences before and after surgery.[15,16]

Our study tried to take under consideration many clinical and imaging indices preoperatively and postoperatively and make a thorough comparison. Endothelial cell loss is confirmed in this study, with one important notice; most of the parameters of corneal endothelial function deteriorate at the middle rather than the final phase of the study suggesting that cornea is healing as expected. Although ECD and morphology alter after surgery, corneal edema is significantly improving, reaching preoperative values in the end phase of the study.

Several clinical parameters were correlated with worse corneal postoperative profile like lower preoperative visual acuity, dense lens opacities and time of phaco application. In contrast with previous reports, axial length didn't show a significant correlation with endothelial cell loss. Initial CCT and total cell account were also not correlated with endothelial dysfunction.

Another important result of this study is the correlation of low corneal curvature and higher astigmatism with worse corneal status after surgery. Low anterior chamber depth also seems to affect corneal edema and cell loss, a finding which differs from previous studies.[17,18] Finally age is an important factor of corneal behavior since older patients show a worse endothelial profile after surgery.

CONCLUSION – FUTURE ASPECTS

The use of confocal microscopy is able to reveal important differences in corneal tissue after an uneventful cataract operation. A closer look to the results of the study shows how crucial is the correct selection of patients, the proper time of surgery, the elaborate preoperative examination and the detailed surgery planning. Adopting better techniques and careful follow up is possible to eliminate severe postoperative complication and to improve visual rehabilitation. Moreover, it is very important to get familiar with new imaging procedures in order to better understand corneal pathology. Finally, ongoing research will be a scaffold to future technological evolution and treatment effectiveness. The main target remains; the improvement of patient's quality of life.

REFERENCES

1. Alkharashi M, Stark WJ, Daoud YJ. Advances in Cataract Surgery. *Expert Rev Ophthalmol* 2013; 8:447-456.
2. Congdon N, Vingerling JR, Klein BE et al. Prevalence of cataract and pseudophakia/aphakia among adults in the United States. *Arch Ophthalmol* 2004; 122:487–494.
3. Artal P, Berrio E, Guirao A, Piers P. Contribution of the cornea and internal surfaces to the change of ocular aberrations with age. *J Opt Soc Am A Opt Image Sci Vis* 2002; 19:137–143.
4. Nagy Z, Takacs A, Filkorn T et al. Initial clinical evaluation of an intraocular femtosecond laser in cataract surgery. *J. Refract. Surg* 2009; 25:1053–1060.
5. He L, Sheehy K, Culbertson W. Femtosecond laser-assisted cataract surgery. *Curr Opin Ophthalmol* 2011; 22:43–52.
6. Sutton G, Bali SJ, Hodge C. Femtosecond cataract surgery: transitioning to laser cataract. *Curr Opin Ophthalmol* 2012; 24:3–8.
7. Palanker DV, Blumenkranz MS, Andersen D et al. Femtosecond laser-assisted cataract surgery with integrated optical coherence tomography. *Sci Transl Med* 2010; 2:58ra85.
8. Takacs AI, Kovacs I, Mihaltz K et al. Central corneal volume and endothelial cell count following femtosecond laser-assisted refractive cataract surgery compared to conventional phacoemulsification. *J Refract Surg* 2012; 28:387–391.
9. Gharaee H, Kargozar A, Daneshvar-Kakhki R et al. Correlation between Corneal Endothelial Cell Loss and Location of Phacoemulsification Incision. *J Ophthalmic Vis Res* 2011; 6:13-17.
10. Fakhry MA, El Shazly MI. Torsional ultrasound mode versus combined torsional and conventional ultrasound mode phacoemulsification for eyes with hard cataract. *Clin Ophthalmol* 2011; 5:973-978. doi: 10.2147/OPTH.S22879. Epub 2011 Jul 15.
11. Assaf A, Roshdy MM. Comparative analysis of corneal morphological changes after transversal and torsional phacoemulsification through 2.2 mm corneal incision. *Clin Ophthalmol* 2013; 7:55-61. doi: 10.2147/OPTH.S39019. Epub 2013 Jan 8
12. Storr-Paulsen A, Norregaard JC, Ahmed S et al. Endothelial cell damage after cataract surgery: divide-and-conquer versus phaco-chop technique. *J Cataract Refract Surg* 2008; 34:996-1000. doi: 10.1016/j.jcrs.2008.02.013.
13. Pereira AC, Porfírio F Jr, Freitas LL et al. Ultrasound energy and endothelial cell loss with stop-and-chop and nuclear preslice phacoemulsification. *J Cataract Refract Surg* 2006; 32:1661-1666.
14. Wilczynski M, Drobniewski I, Synder A et al. Evaluation of early corneal endothelial cell loss in bimanual microincision cataract surgery (MICS) in comparison with standard phacoemulsification. *Eur J Ophthalmol* 2006; 16:798-803.
15. Faramarzi A, Javadi MA, Karimian F et al. Corneal endothelial cell loss during phacoemulsification: bevel-up versus bevel-down phaco tip. *J Cataract Refract Surg* 2011; 37:1971-1976. doi: 10.1016/j.jcrs.2011.05.034. Epub 2011 Sep 22.
16. Rosado-Adames N, Afshari NA. The changing fate of the corneal endothelium in cataract surgery. *Curr Opin Ophthalmol*

2012; 23:3-6. doi: 10.1097/ICU.0b013e32834e4b5f
17. Reuschel A, Bogatsch H, Oertel N et al. Influence of anterior chamber depth, anterior chamber volume, axial length, and lens density on postoperative endothelial cell loss. *Graefes Arch Clin Exp Ophthalmol* 2015; 253:745-752. doi: 10.1007/s00417-015-2934-1. Epub 2015 Mar 1.
18. Cho YK, Chang HS, La TY et al. Anterior segment parameters using Pentacam and prediction of corneal endothelial cell loss after cataract surgery. *Korean J Ophthalmol* 2010; 24:284-290. doi: 10.3341/kjo.2010.24.5.284. Epub 2010 Oct 5.