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Corneal endothelial cell changes after phacoemulsification cataract surgery in eyes with different anterior chamber depth: A specular microscopy study

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Abstract
Background: Phacoemulsification surgery is performed in a limited space, therefore, anatomy and procedural parameters, such as sufficient anterior chamber depth (ACD), are essential for protecting endothelial cells during surgery from mechanical and heat damage. Specular microscope is a useful non-contact investigational technique that photographs the human corneal endothelium.
Methods: This a prospective comparative cohort non-randomized study included sixty eyes of phacoemulsification cataract surgery were collected from the outpatient clinics of Tanta University Hospitals and were admitted to Ophthalmology Department. Cases were divided into three groups according to ACD. All cases were subjected to: history taking, examination [visual acuity (VA), slit lamp examination, ACD measurement using IOL master, and Specular microscopy.
Results: The percentage of endothelial cell loss was much increased in the group A than in the group There was statistically significant increase in the mean CCT in the three groups post-operatively at 1week and 1month compared to pre-operative mean CCT. However, there was no notable differences in CCT among the three groups. There was no notable differences in Coefficient of variation (CV) among the three ACD groups over the entire study period.
Conclusions: taking in consideration the ACD as a very important prognostic factor to be considered before phacoemulsification cataract surgery. Eyes with shallow ACs can be vulnerable to more corneal endothelial cell loss during phacoemulsification surgery.

Keywords: Phacoemulsification, anterior chamber depth, specular microscopy

1. Introduction
The corneal endothelium is the innermost layer of the cornea, 4 to 6µm thick, which is important for maintenance of normal corneal hydration, thickness and transparency by the function of its metabolic pump [1].
At birth normal cell density ranges from 3500- 4000 cells/mm^2, adult cornea has densities of 1400- 2500 cells/mm^2**,** normally the central endothelial cell density decreases by 0.3% per year [2].
The anterior chamber is the area between the cornea anteriorly and the iris and lens posteriorly. The diameter of anterior chamber varies from 11.3 mm to 12.4 mm. [3].
Before performing an intervention on a cataract patient with a corneal illness characterised by a low endothelial cell count, one should consider the following factors. What is the likelihood of corneal affection as a result of the procedure? Is phacoemulsification the appropriate method? How may the corneal endothelium be compromised during the procedure? Should cataract removal and corneal therapy be combined? Even if maximum corneal endothelial protection is ensured during cataract surgery with high-viscosity ocular viscosurgical devices (OVD), corneal endothelial derrangement is possible [4].

Patients and Methods
This a prospective comparative cohort non-randomized study included sixty eyes of phacoemulsification cataract surgery were collected from the outpatient clinics of Tanta University Hospitals and were admitted to Ophthalmology Department. Cases were divided into three groups according to ACD. (Twenty cases were included in each group)

- **Group A** : cases with ACD ranging from 2.5 to 3 mm

- **Group B**: cases with ACD ranging from 3.01 to 3.5 mm
- **Group C**: cases with ACD more than 3.51 mm

Inclusion criteria
1. Cases aged from 60 y to 65 y
2. Cases with senile cataract prepared for cataract surgery. Only nuclear cataract will be included (Grade II, grade III) according to {The Lens Opacities Classification System III} (LOCS III) by slit lamp [5].
3. Cases with ECC more than 2000 cells/mm^2.
4. Cases with ACD ranging from 2.5 mm to 4.5mm.

Exclusion criteria
1. Cases with cataract other than nuclear cataract grade II and nuclear cataract grade III (congenital, traumatic, complicated, cortical, brown)
2. Previous ocular trauma.
3. Previous eye surgery.
4. Pre-existing ocular diseases such as uveitis, anterior segment pathology and coexisting glaucoma.

The method
Preoperative assessment
- History: cases' information (age, sex, occupation and residence), any chronic disease (e.g. diabetes).
- Complete ophthalmic examinations including the following :
- ✓ Visual acuity: The unaided and best corrected visual acuity.
- ✓ Slit lamp examination.
- ✓ IOP measurement with Goldmann applanation tonometer.
- ✓ Fundus examination using indirect ophthalmoscope and slit lamp biomicroscopy for exclusion of vitreous hemorrhage, retinal detachment, optic neuropathy or.
- Specular microscopy.

Central corneal endothelial photographs 0.25x0.55 mm. were taken preoperatively using a noncontact specular microscope Topcon SP-1P (Topcon Corporation, Japan)
- Optical biometry and ACD measurement.

Anterior chamber depth was measured using IOL master 500 (ZEISS Corporation, Germany)

All phacoemulsification cataract surgeries were carried out by the same surgon
Follow-up and Post-operative care
A - Postoperative treatment
1- Systemic
- Antibiotics- Analgesics if needed.

2- Topical
- Antibiotic eye drops: - moxifloxacin 0.5% 5times /day (Vigamox, Alcon, Fort Worth, Texas, USA)
- Steroids eye drops: - prednisolone acetate 1% 6times /day (Econopred plus, Alcon, USA) which were tapered gradually and discontinued after 2 weeks.

B - Post-operative follow-up:
Review the patient at 1st, 3rd day post-operative and one week post-operative then regular follow up was conducted at month 1, month 3 post-operative to each patient to ensure appropriate care.

1- 1st postoperative day special focusing on
- Any visual complaint.
- Unaided visual acuity.
- Slit lamp examination to observe:-
- Corneal incisions, any clinically apparent corneal edema, aqueous flare or cells, IOL position and stability.

2- Frequency of follow up
Cases were examined at 1 week, 1 month & 3 months after surgery.
In each visit the following parameters were evaluated and recorded:-
- Unaided visual acuity
- Refraction and assessment of Corrected Distance Visual Acuity (CDVA).
- Slit lamp examination.
- IOP.
- Specular Microscopy:

Using Topcon SP-1P non-contact specular microscope to measure
- Endothelial cell count (ECC).
- Central corneal thickness (CCT).
- Hexagonality (HEX).
- Coefficient of variation (CV).

Statistical Analysis
The results of the three groups were analyzed using ANOVA and Post Hoc Tests.
ANOVA; Analysis of variance is a set of statistical models and their related estimate processes (such as "variation" among and across groups) that is used to assess the differences between group means in a sample.
Ronald Fisher, a statistician and evolutionary scientist, invented ANOVA. Post-hoc (Latin, "after this") refers to the process of analysing experimental findings. They are frequently predicated on the chance of at least one Type I mistake in a collection (family) of comparison.

Results
This study included 60 eyes, 40 male and 20 female. Mean age ± SD was 62.36±1.82 years old. Cases were divided into three groups according to anterior chamber depth:
- ✓ **Group A:** cases with ACD ranging from 2.5 to 3 mm. The mean age of the cases in group A was 61.77 ±3.9, this group included 14 males and 6 females.
- ✓ **Group B:** cases with ACD ranging from 3.01 to 3.5 mm. The mean age of the cases in group B was 60.7±4.8, this group included 14 males and 6 females.
- ✓ **Group C:** cases with ACD ranging from 3.51 to 4.5 mm. The mean age of the cases in group C was 60.6±3. 6, this group included 12 males and 8 females. (Table1)

Preoperatively: The mean ECC of all cases was 2632.07±71.48 cell/mm2. The mean values were 2626.7±174.54 cell/mm2, 2630.8±168.77 cell/mm2 and 2635.7±130.84 cell/mm2 with no notable differences among the three groups (P = 0.985). The mean CCT in all cases was 530.40±65.13 µm preoperatively, the mean values were 529.25±41.63µm, 532.11±31.35µm and 531.4±43.25µm with no notable differences among the three groups (P = 0.675). The mean logMAR CDVA in all cases was 1.03±0.7 preoperatively, the mean values were 1.07±0.12, 1.05±0.1 and 0.97±0.14 with no notable differences among the three groups. (P = 0.152). The mean hexagonality in all cases was 35.61±7.7 preoperatively, the mean values were 34.45±5.6, 35.5±6.12 and 37.75±4.35 with no notable differences among the three groups. (P = 0.153). The mean CV in all cases was 35.07±3.2 preoperatively, the mean values were 34.5±4.12, 35.46±5.15 and 33.44±4.98 with no notable differences among the three groups. (P = 0.414)

Three months postoperatively: The mean ECC of all cases was 2348.27±138.02 cell/mm^2, the mean values were 2201.3±168.97 cell/mm^2, 2315.6±156.61 cell/mm^2 and 2528.9±135.42 cell/mm^2 with statistically significant decrease among the three groups. (P <0.001). The mean CCT of all cases was 536.60±34.58µm three months postoperatively, the mean values were 536.62±37.42µm, 538.6±33.7µm and 534.62±42.7µm with no notable differences among the three groups. (P =0.595). The mean logMAR CDVA of all cases was 0.04±0.05 three months postoperatively, the mean values were 0.033±0.052, 0.053±0.054 and 0.034±0.052 with no notable differences among the three groups. (P = 0.406). The mean hexagonality of all cases was 27.33±4.7 three months postoperatively, the mean values were 25.35±5.4, 26.07±4.26 and 31.07±6.87 with statistically significant decrease among the three groups. (P <0.001). The mean CV of all cases was 35.4±3.0, three months postoperatively, the mean values were 36.32±6.2, 36.3±4.14 and 34.5±5.6 with no notable differences among the three groups. (P = 0.475) (Table2)

Table 1: Preoperative data of the three groups (Horizontal statistical comparison)

Variable		Group A			Group B			Group C			Tests	
		Mean	SD	%	Mean	SD	%	Mean	SD	%	f/ X^2	P-value
Age		61.4	3.9		60.7	4.8		60.6	3.6		0.690	0.506
Sex	Male	14		70%		14	70%		12	60%	1.905	0.386
	Female	6		30%		6	30%		8	40%		

Table 2: Three months postoperative data of the three groups (Horizontal statistical comparison)

Variable	Group A		Group B		Group C		Tests	
	Mean	SD	Mean	SD	Mean	SD	f/ X2	P-value
Log MAR CDVA	0.03	0.05	0.05	0.05	0.03	0.05	0.915	0.406
CCT	536.62	37.42	538.6	33.7	534.16	42.7	0.524	0.595
ECC	2201.30	168.97	2315.156	56.61	2528.90	135.42	23.228	<0.001*
Hexagonality	25.35	5.4	26.07	4.26	31.7	6.87	39.687	<0.001*
Coefficient of variation CV	36.32	6.2	36.3	4.14	34.5	5.6	0.754	0.475

Post-hoc Tests using Multiple Comparisons "Scheffe" showed that the least mean endothelial cell loss among the 3 groups was that of the group C with ACD more than 3.51 mm. After 3 months postoperatively, the percentage of endothelial cell loss in group A was 16.26%, while in group B was 11.97%. The percentage of corneal endothelial cell loss in group C was the least of all, 4.12%.

The percentage of endothelial cell loss was much increased in the group A (mean ECC, 2626.7±174.54cells/mm2 preoperatively and 2201.3±168.97 cells/mm^2 3months postoperatively) than in the group C (mean ECC, 2635.7±130.84 cells/mm2 preoperatively and 2528.9±135.42 cells/mm^2 3 months postoperatively). (P < 0.05)

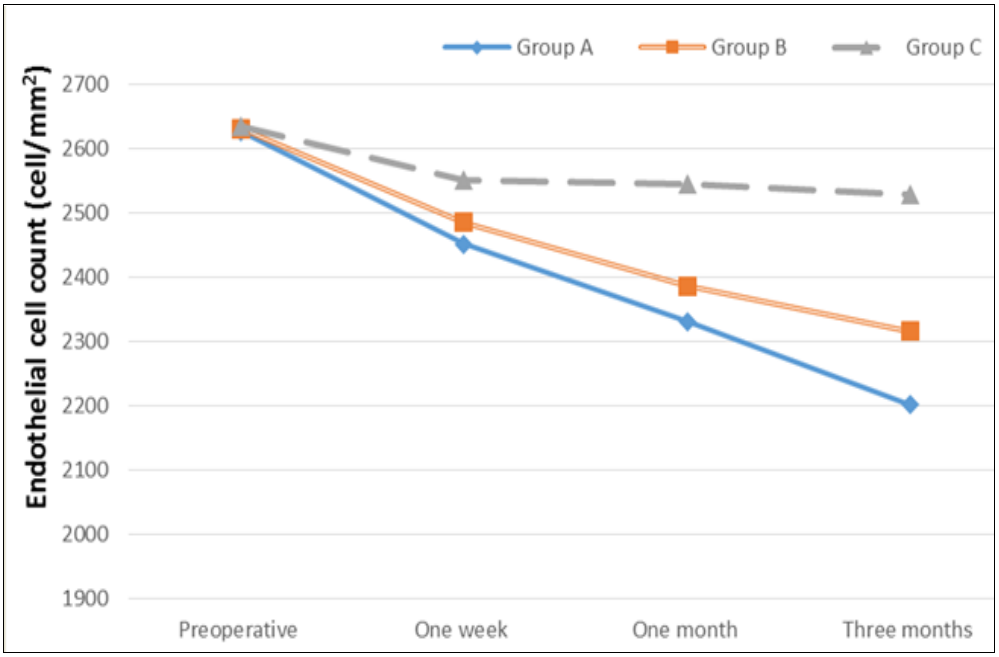

Fig 1: data analysis of Endothelial Cell loss in each group

The postoperative corneal edema was well correlated with corneal thickness measured by the specular microscope. thickness preoperatively was the same nearly like that after 3 months. There was statistically significant increase in the mean CCT in the three groups post-operatively at 1week There was marked increase in corneal thickness in all groups during the first week after surgery. The mean corneal and 1month compared to pre-operative mean CCT. However, there was no notable differences in CCT among the three groups (P > 0.05).

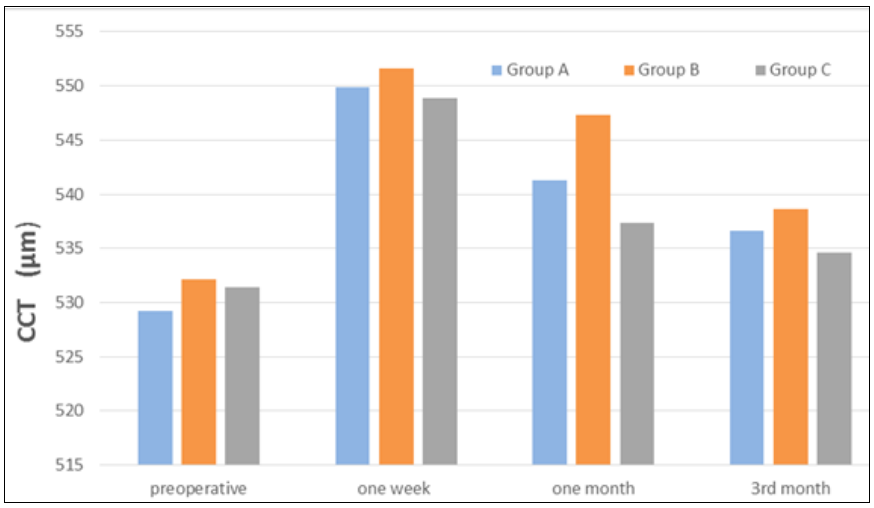

Fig 2: A chart showing the data analysis of Central Corneal Thickness in each group

In this study, There was a significant improvement in logMAR CDVA from the preoperative period to 3 months postoperatively in each group. However, there was no notable differences in CDVA among the three groups ($P > 0.05$)

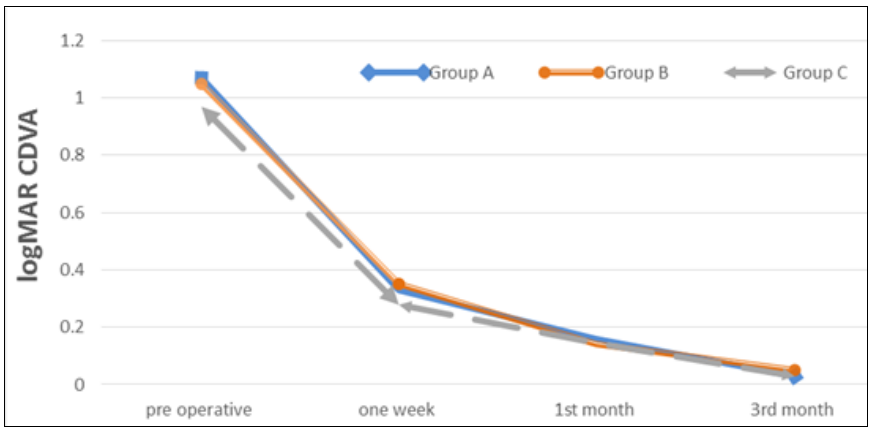

Fig 3: Comparison between the three ACD groups according to logMAR CDVA

In this study, the relation between preoperative, 1week, 1 months, 3 months post-operative hexagonality shows significant changes in each group. In group A, Pre-operative hexagonality with Mean (34.45±5.6) show significant decrease in 1st week ($P<0.05$), 1st month ($P<0.001$) and 3rd months post-operative ($P<0.001$) in relation to preoperative hexagonality. In group B, Pre-operative hexagonality with Mean (35.5±6.12) shows significant decrease in 1st week ($P<0.05$), 1st month ($P<0.05$) and 3rd months post-operative ($P<0.001$) in relation to preoperative hexagonality. In group C, Pre-operative hexagonality with Mean (37.75±4.35) shows significant decrease in 1st week ($P<0.05$), 1st month ($P<0.001$) and 3rd months post-operative ($P<0.001$) in relation to preoperative hexagonality**.**

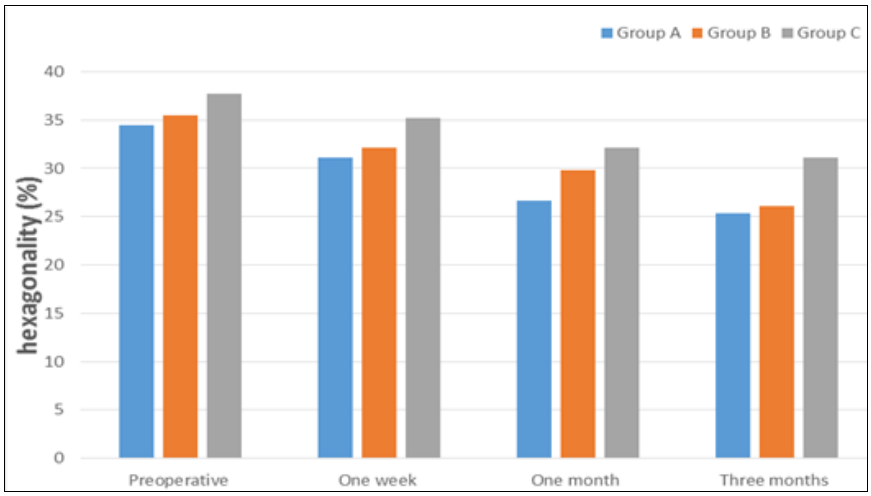

Fig 4: A chart showing the data analysis of hexagonality in each group

In this study, there was no notable differences in Coefficient of variation (CV) among the three groups over the entire study period. ($P > 0.05$)

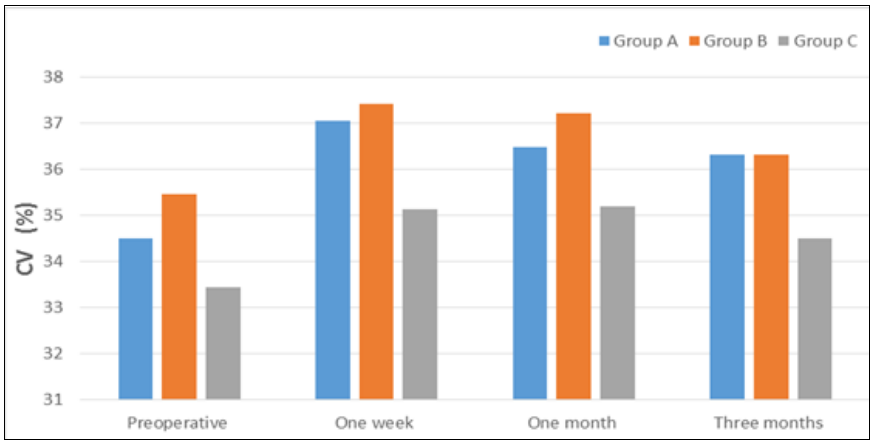

Fig 5: A chart showing the data analysis of Coefficient of variation (CV) in each group

Discussion

Although a controversy exists over the length of time required for the endothelial cell count to stabilize post-operatively, the majority of other studies have evaluated endothelial cell loss over a relatively short term period of 1month and long term period of 3 months [6].

We decided to follow up the endothelial loss at the first week, first month and the third month post-operative which is consistent with Khalid *et al*. 2019 study that followed up the endothelial loss at the same time interval post-operatively which revealed significant decrease in endothelial cells in both the short term and long term [7].

The majority of studies agree that phacoemulsification results in qualitative and quantitative alterations of the corneal endothelium [8].

Sugar *et al.*1978 found endothelial loss of 33.8% in 70 eyes compared with the fellow non operated eye. Therefore they came to a conclusion that phacoemulsification causes more damage to endothelium than intracapsular cataract extraction.

Tang *et al.*2017 agree with our present study. He found that cases have a significantly lower ECC at all post-operative time points in relation to preoperative data, eyes with moderately hard senile cataract are subjected to various changes due to cataract extraction procedure [9]. Corneal endothelium has shown morphological and morphometric alterations manifested by pleomorphism and polymegathism, as well as a lower percentage of hexagonal cells. In our study, it was found that ACD could be a risk factor for increasing endothelial cell loss during phacoemulsification. As such, the percentage of endothelial cell loss was much increased in the group A (mean ECC, 2626.7±174.54 cells/mm2 preoperatively and 2201.3±168.97 cells/mm^2 3months postoperatively) than in the group C (mean ECC, 2635.7±130.84 cells/mm2 preoperatively and 2528.9±135.42 cells/mm^2 3 months postoperatively). Khalid *et al*. 2019, found that ACD and AL affect the ECC during phacoemulsification and Intraocular Lens (IOL) implantation and can be considered as risk factors of intraoperative endothelial cell loss [7].

Nevertheless, O'Brien *et al*. (2004) revealed that there was no correlation with ACD or axial length and endothelial cell death during phacoemulsification, since appropriate surgical space could be created utilising irrigation flow [10].

Central Corneal thickness (CCT)

Siddique *et al*, 2016 In corneas with a sick endothelial cells or with borderline low endothelial cell numbers, corneal thickness measures have been suggested as a metric for measuring overall endothelial function. Endothelial count is more important for evaluating surgical trauma and endothelial health than endothelial count alone. This is due to the significant functional capacity of the endothelial cells and the fact that corneal cell depletion is not reflected in corneal thickness measures until there is a substantial loss of corneal endothelium [11].

In instances undergoing phacoemulsification, visual rehabilitation remains the primary priority notwithstanding any corneal alterations. Corrected distance visual acuity (CDVA) is one of the finest measures of a surgical technique's quality and efficacy [9].

Hwang HB *et al*. 2015 study carried on 135 eyeballs in 135 subjects planned to undergo phacoemulsification operation shown an equal and substantial improvement in logMAR CDVA from the preoperative period to 2 months postoperatively across the three ACD groups [12].

In our study, There was a significant improvement in logMAR CDVA from the preoperative period to 3 months postoperatively in each group. However, there was no notable differences in CDVA among the three ACD groups. These results were found to be compatible with Hwang HB *et al*. 2015 study [12].

Also, *Dervenis et al*. 2021, Bamdad *et al*. 2018, Mittra *et al.* 2000 and Memon *et al*. 2021 support our CDVA results.

Conclusion

Our study results suggest taking in consideration the ACD as a very important prognostic factor to be considered before phacoemulsification cataract surgery.

Eyes with shallow ACs can be vulnerable to more corneal endothelial cell loss during phacoemulsification surgery. Thus, more attention is needed to avoid corneal endothelial cell loss & corneal decompensation after phacoemulsification cataract surgery on these eyes.

Consent and ethical approval

The patient provided written informed consent. The research was done after approval from the Ethical Committee Tanta University Hospitals.

Conflict of Interest

Not available

Financial Support

Not available

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