Quantitative evaluation of corneal edema after phacoemulsification surgery using corneal densitometry

Rehab F. Abdelbary, Sherief E. El-Khouly, Hatem E. Elawady, Rania K. Farag.

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

Corresponding author: Rehab F. Abdelbary, Mansoura Ophthalmic Center, Faculty of Medicine, Mansoura University. Elgomhoria street, Mansoura, Egypt. Tel: 01063546622, E mail: Rehab fetoh@gmail.com.

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Short tile: Corneal edema after phacoemulsification surgery by corneal densitometry.

ABSTRACT

Purpose: To evaluate corneal edema after phacoemulsification surgery using corneal densitometry.

Methods: This study was conducted on 50 eyes of 50 patients who underwent cataract surgery using the phacoemulsification technique. They were imaged by Pentacam oculus Scheimpflug photography system before and after surgery from January 2020 to January 2021. Corneal thickness and densitometry parameter were imaged before surgery, first day post operative and one week postoperative. All individuals were subjected to full history and ocular examination.

Results: Densitometry scores increased from 21.58 before cataract surgery to 25.62 on day 1 ($P < 0.001$) then become 24.90 one week postoperative ($p<0.001$). Corneal thickness was 520.08 µm before surgery and increased to 597.43 µm ($P<0.0001$) on day 1 postoperative and start to decrease and become 576.97 µm ($p<0.001$) one week post operative. Densitometry reading correlated positively with corneal thickness.

Conclusion: Densitometry is useful to detect subclinical corneal edema that is not detectable by slit-lamp examination.

Keywords: phacoemulsification cataract surgery, Corneal edema, corneal Densitometry.

INTRODUCTION:

Cataract surgery is the most common ocular surgery in the world in adults over 50 years of age[1].

Cataract-related visual impairment has effects not only on daily life activities, but also on one's psychological wellbeing[2].

Some studies report that surgical damage or accidental contact with the endothelium results in corneal edema and swelling through the mechanism of local inflammation, loss of cytoskeletal structures, endothelial cell loss, and endothelial pump dysfunction[3,4,5]. With corneal edema, the corneal thickness and opacification increase[6].

Corneal opacification, caused by a thermal burn or iatrogenic trauma during cataract surgery, is related to edema or collagen condensation, which may compromise the visual outcome[7].

Corneal densitometry (also known as corneal backscatter) is an objective method for evaluating corneal clarity and transparency[8].

The advancement of Pentacam Scheimpflug imaging system has made corneal tissues evaluation effortless with valid and reproducible results. It provides precise data of anatomical features of anterior chamber such as corneal topography, corneal densitometry and lens densitometry meticulously, with minimal user dependent[9].

The Pentacam® (Oculus, Wetzlar, Germany), is a corneal tomography using a rotating Scheimpflug camera is a diagnostic tool for the anterior segment of the eye, allows quantitative evaluation of the optical media as "densitometry"[10]

Healthy cornea does not absorb visible light and the dispersal of light is minimal therefore densitometry can provide measurement of level of corneal transparency[11].

It is possible to compose amap of the amount of backscattered light in the different regions of the cornea, called a corneal densitometry map[12,13]. This is can be done in a single scan using the pentacam scheimpflug photography[14]. It can provide quantification assessment of light scattering and help to assess corneal edema.

PATIENTS AND METHODS:

Patient enrollment

This was a Prospective, interventional study that was conducted to evaluate corneal edema after phacoemulsification surgery using corneal densitometry. The study was conducted on 50 eyes of 50 patients who attended to Mansoura ophthalmic center in the period from January 2020 to January 2021.

After approval from Institutional review board (IRB), Faculty of Medicine,

All individuals were subjected to:

Full general and ophthalmic history which includes Age, Gender, Occupation and socioeconomic status were performed. Also, ocular history to exclude any previous refractive or ocular surgery and ocular injury was performed. Full ophthalmic examination including Visual acuity measurement using Landolt's broken ring chart then transformed to Log MAR was performed and Manifest refractions using the auto-refractometer were done. In addition, full slit lamp examination to assess the anterior segment was performed for cornea, sclera, anterior chamber, iris, pupil and lens. Fundus examination (ophthalmoscope) after installation of mydriatic eye drops and intraocular pressure (IOP) assessment was done.

As regards, the investigations, corneal densitometry and specular microscopy was done before and after surgery

The steps for corneal densito scanning were performed as following:

- After patients clinically examinated with slit lamp biomicroscopy, they were asked to place their chin on the chin-rest of pentacam (Fig**. 1**) and press their forehead against the forehead strap.
- The patients were asked to fix the eye on a certain point within the instrument and if failed external fixation was used for the other eye.
- At least 2 good quality pentacam images were obtained and compared for reproducibility then entered on corneal densito image on system.
- Only cases with acceptable image quality were included in the final analysis.
- A single trained operator performed all examinations.
- All parameters were automatically calculated by the Pentacam software (Version 1.20r36).

Fig.1: Oculus Pentacam HR **(Mansoura ophthalmology center)**.

Corneal Densitometry image analysis

Automatical analysis of an area of corneal surface with a diameter of 12mm. This area is further divided into 4 concentric radial zones. The first zone is 2mm in diameter and centered on the apex. The second zone is an annulus extending from a 2 to a 6 mm diameter circle. The third zone extends from 6 to 10 mm. The fourth zone extends from 10 to 12 mm diameter circle. The output can also be subdivided based on corneal depth into anterior, central and posterior layers. Anterior layer corresponds to the anterior 120μm and posterior layer to the most posterior 60 μm of the cornea. The central corneal layer is defined by subtraction of the anterior and the posterior layers from total thickness. (Figure.2)

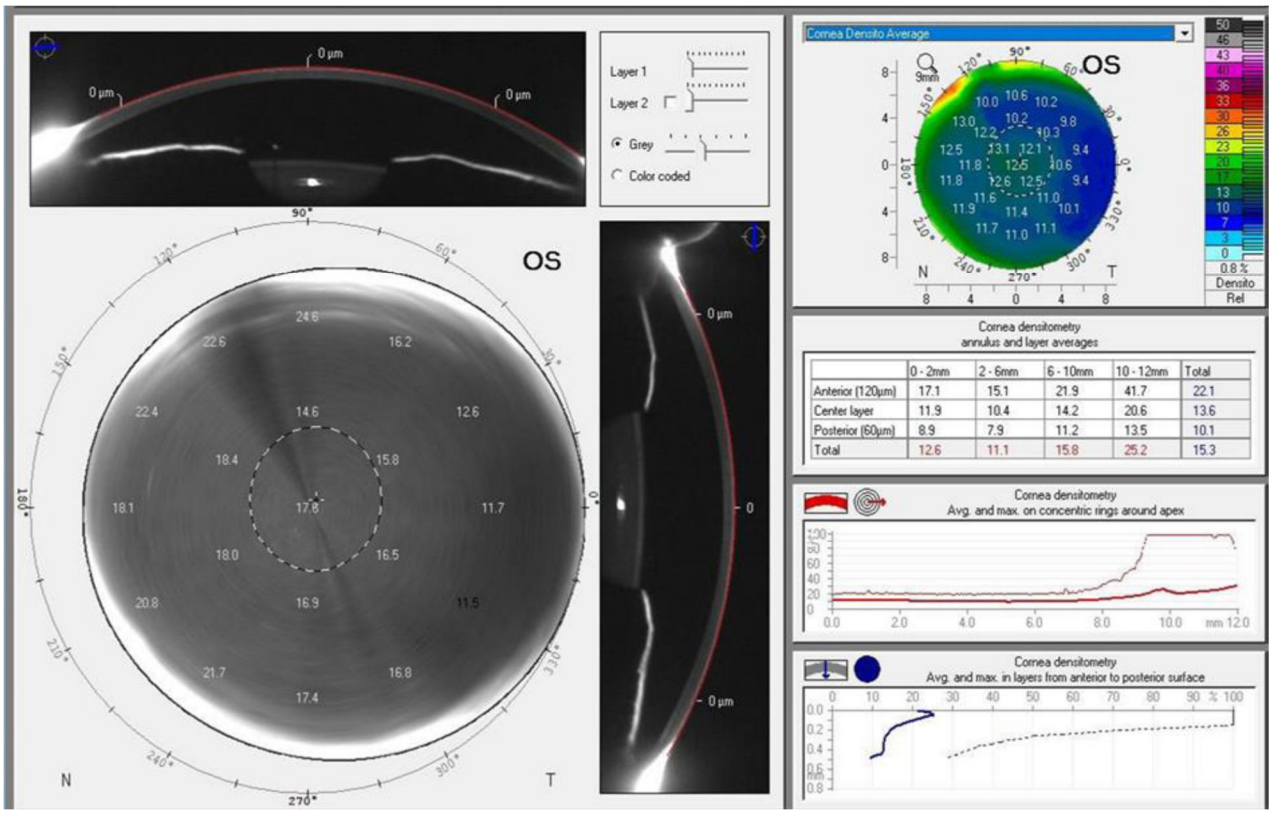


Fig.2: Normal Corneal densito image with no corneal backscatter on gray scale (**Mansoura ophthalmology center)**

Statistical Analysis of the Data:

Data were fed to the computer and analyzed using IBM SPSS Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp. Qualitative data were described using number and percent. Quantitative data were described using mean, standard deviation for parametric data after testing normality using Kolmogrov-Smirnov test. Significance of the obtained results was judged at the (0.05) level.

RESULTS:

This Prospective, interventional study included 50 eyes of 50 patients with senile immature cataract who underwent cataract surgery by phacoemulsification technique and corneal densitometry was assessed by Pentacam occulus Scheimpflug photography system before and after surgery from January 2020 to January 2021

1 - Demographic characteristics of the studied cases:

Studied patients included 28 males (56.0%) and 22 females (44.0%) with a mean age of 59.62± 3.85 years. (Table 1)**.**

Table (1): demographic characteristics of the studied cases.

	N=50	**%**
Age/years		
Mean±SD	59.62±3.85	
Sex		
Male	28	56.0
Female	22	44.0

Table (2): visual acuity, intraocular pressure and nuclear density in studied cases.

	N=50	**%**
Eye		
Left	24	48.0
Right	26	52.0
BCVA by (log MAR)		
mean±SD	0.095±0.075	
Median (Range)	0.083(0.02-0.33)	
Density		
N1	1	2.0
N2	31	62.0
N3	18	36.0
IOP(mm Hg)		
mean±SD	15.76±1.56	

This study included 50 eyes with average BCVA by log MAR 0.095±0.075. One case has nuclear cataract grade one, 31 cases (62%) have cataract grade 2 , the rest of cases have cataract grade 3 .Intraocular pressure in all cases was within normal range with average 15.76±1.56 mmHg.

Table (3): postoperative clinical examination of the cornea by slit lamp of the studied patients.

	N=50	%
Clear cornea	20	40.0
Epithelial oedema	17	34.0
Stromal oedema	13	26.0

Table (3) showed that 40% of patients showed postoperative clear cornea by clinical examination with slit lamp. Epithelial oedema was detected in34% of patients, while stromal oedema in 26% of patients.

Corneal densitometry parameters among studied patients:

Table (4): pre and post operative anterior corneal densitometry.

Anterior layer	Pre-operative	1st day Postoperative	1 week postoperative	test of significance	Delta change	% of change
(0-2)	25.47±5.99	37.92±14.65	35.30±14.51	p1<0.001*	12.45	48.9%
				p2=0.001*	9.83	38.6
				p3=0.005	2.62	6.9
(2-6)	23.45±4.87	32.89±9.99	29.96±8.85	p1<0.001*	9.44	40.03%
				p2<0.001*	6.51	27.8
				p3<0.001*	2.94	8.9
(6-10)	35.22±7.49	41.98±9.13	40.24±8.50	p1<0.001*	6.75	19.2%
				p2<0.001*	5.02	14.3
				p3=0.002*	1.73	4.1
(10-12)	43.94±12.86	48.73±12.47	47.88±12.27	p1=0.004*	. 4.87	10.9
				p2=0.018*	3.88	8.8
				p3=0.004*	0.90	1.8
Total	30.95±5.28	38.93±8.55	37.55±8.28	p1<0.001*	7.98	25.8%
				p2<0.001*	6.61	21.4
				p3=0.002*	1.37	3.52

t:Paired t test , parameters described as mean±SD

p1: comparision between preoperative and first day postoperative measurements.

P2: comparison between preoperative and one week postoperative measurements.

P3: comparison between and first day postoperative and one week postoperative measurements.

As shown in table (4) anterior layer densitometry measurements in 0-2 mm, 2-6 mm, 6-10 mm, 10-12 mm and total zones showed significant increase in first day post operative compared to pre operative measurements with slight decrease in one week post operative but still high than pre operative measurements (table 4)

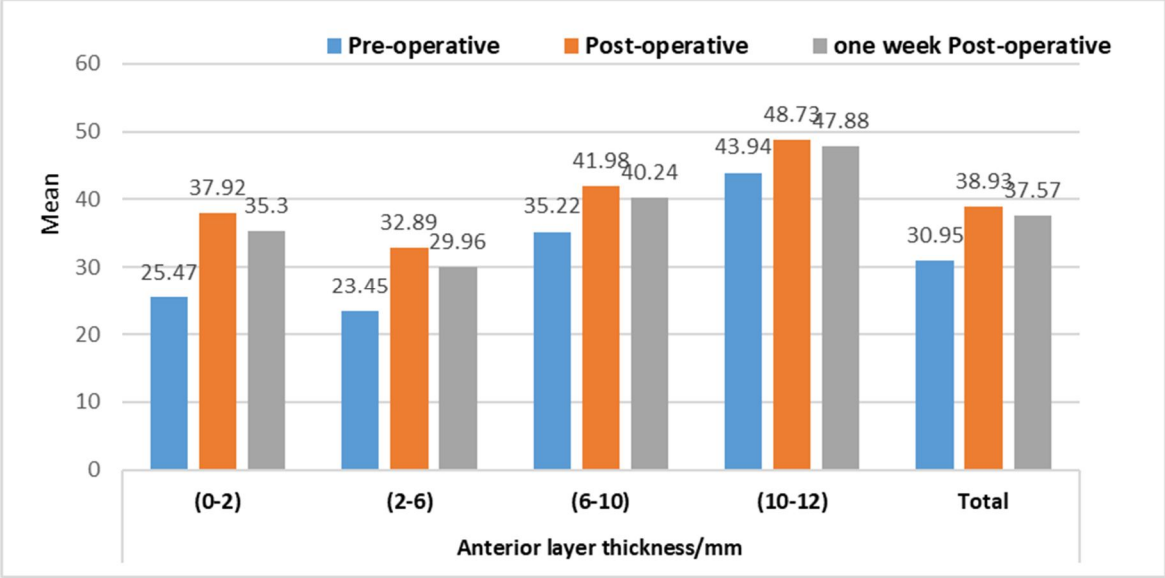


Figure (3): pre and post operative anterior corneal densitometry.

Table (5): pre and post operative central corneal densitometry parameter.

Central layer	Pre-operative	1st day Postoperative	1 week postoperative	test of significance	Delta change	% of change
(0-2)	15.38±3.42	20.67±7.21	18.78±5.29	p1<0.001*	5.28	34.3%
				p2=0.001	٣,٣٩	22.0
				p3=0.001	١,٨٩	9.1
(2-6)	14.53±3.25	18.38±5.13	17.07±4.24	p1<0.001*	3.85	26.4%
				p2=0.001	٢,٥٤	13.82
				p3=0.001	١,٣١	7.1
(6-10)	24.07±5.12	25.54±5.04	24.89±4.97	p1<0.001*	٣,٨٥	15.99%
				p2<0.001*	٢,٥٤	10.6
				p3<0.001*	١,٣١	5.13
(10-12)	25.80±6.38	27.59±6.33	26.61±5.83	p1=0.09	١,٧٨	6.9%
				p2=0.418	٠,٨٠	3.1
				p3=0.001*	٠,٩٨	3.6
Total	19.61±3.36	22.48±4.69	21.65±4.12	p1<0.001*	2.87	14.6%
				p2<0.001*	2.04	10.40
				p3<0.001*	0.833	3.7

t:Paired t test , parameters described as mean±SD

p1: comparision between preoperative and first day postoperative measurements.

P2: comparison between preoperative and one week postoperative measurements.

P3: comparison between and first day postoperative and one week postoperative measurements.

As regard central layer densitometry measurements in 0-2 mm, 2-6 mm, and 6-10 mm, 10-12 mm and total zones there was post operative increase in first day and one week postoperative compared to pre operative measurements? (Table 5& fig 23)

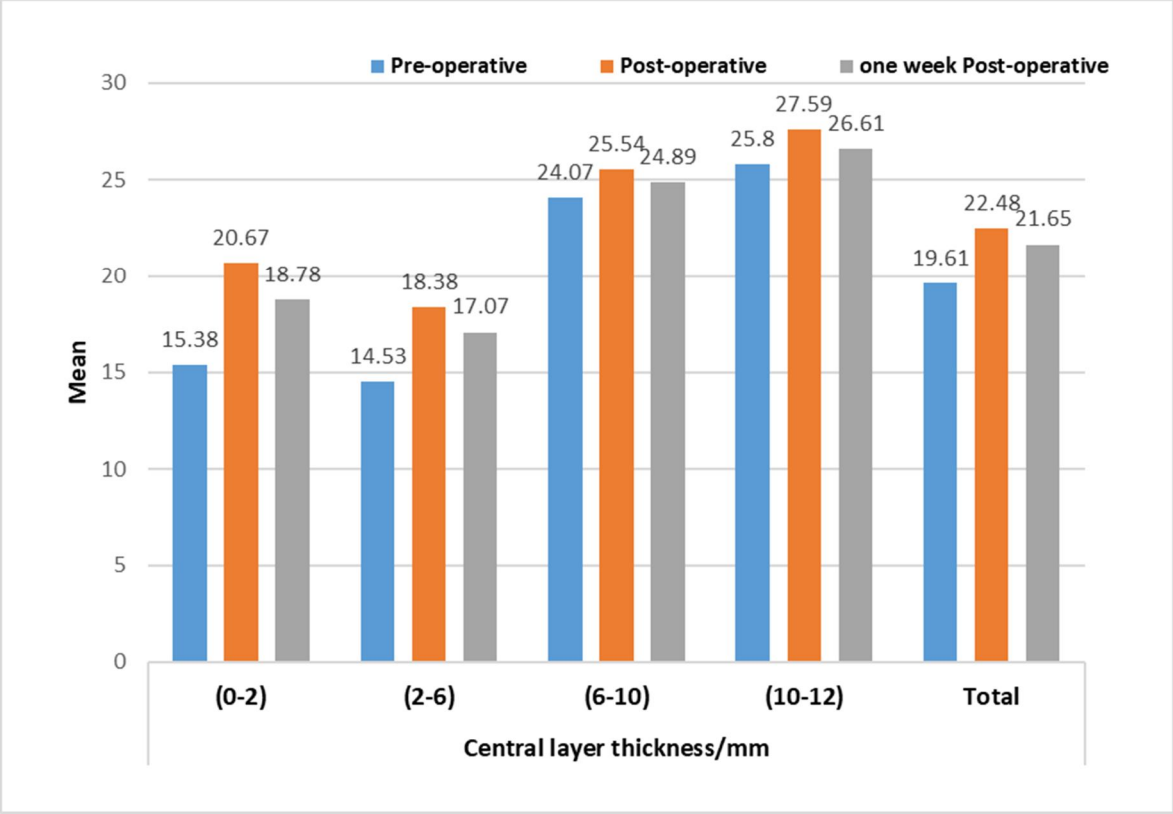


Figure (4): pre and postoperative central corneal densitometry.

Table (6): pre and post operative posterior corneal densitometry.

Posterior layer	Pre-operative	1 st day Postoperative	1 week postoperative	test of significance	Delta change	% of change
(0-2)	11.18±1.96	14.55±3.89	13.59±3.31	p1<0.001*	3.37	30.1
				p2=0.001*	2.42	21.6
				p3=0.001*	0.954	6.6
(2-6)	10.95±1.93	13.35±2.75	12.87±2.59	p1<0.001*	٢,٣٩	21.8
				p2=0.001*	١,٩٢	17.5
				p3=0.001*	٠,٤٧٩	3.58
(6-10)	17.70±3.43	17.40±3.17	16.73±2.96	p1=0.490	٠,٣٠٢	1.7
				p2=0.029*	٠,٩٧٦	5.5
				p3=0.001*	٠,٦٧٤	3.9
(10-12)	19.17±3.80	19.16±5.22	18.82±4.89	p1=0.99	0.01	0.052
				p2=0.627	0.349	1.82
				p3=0.07	0.339	1.8
Total	14.51±2.19	15.71±2.84	14.92±2.61	p1=0.001*	١,٢	8.3
				p2=0.202	٠,٤١٣	2.8
				p3=0.001*	٠,٧٩	5.0

t:Paired t test , parameters described as mean±SD

p1: comparision between preoperative and first day postoperative measurements.

P2: comparison between preoperative and one week postoperative measurements.

P3: comparison between and first day postoperative and one week postoperative measurements.

Regarding posterior layer densitometry measurements , there was post operative increase in densitometry reading in 0-2 mm , 2-6 mm zones compared to pre operative measurements with no significant change in 6-10 mm, 10-12 mm zones and total pre and post operative.(table 6 & fig 24)

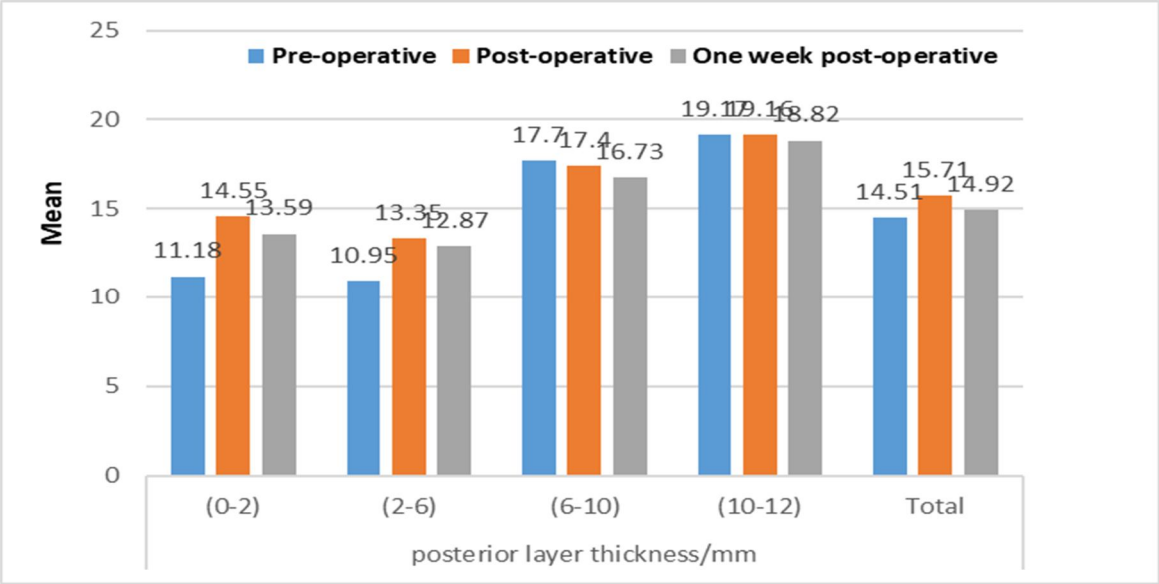


Figure (5): pre and post operative posterior corneal densitometry.

Table (7): pre and post operative total corneal densitometry.

Total	Pre-operative	1 st day Postoperative	1 week postoperative	test of significance	Delta change	% of change
(0-2)	17.28±3.46	24.31±8.22	23.01±7.13	p1<0.001*	٧,٠٣	40.7%
				p2<0.001*	٥,٧٣	23.6
				p3=0.001*	١,٣٠	5.3
(2-6)	16.25±3.18	21.44±5.62	20.65±5.21	p1<0.001*	٥,١٩	31.9%
				p2<0.001*	٤,٤٠	27.1
				p3=0.001*	٠,٧٩٠	3.7
(6-10)	25.57±5.24	28.28±5.25	27.43±5.36	p1<0.001*	٦,٧٦	10.6%
				p2<0.001*	٥,٠٢	19.6
				p3=0.002*	١,٧٣	6.12
(10-12)	29.61±5.25	31.69±7.07	30.88±6.76	p1=0.043*	2.08	7.0%
				p2=0.173	1.27	4.3
				p=0.02*	0.808	2.5
Total	21.58±3.49	25.62±5.04	24.90±4.66	p1<0.001*	4.04	18.7%
				p2<0.001*	3.32	15.4
				p3=0.001*	0.717	2.8

t:Paired t test , parameters described as mean±SD

p1: comparision between preoperative and first day postoperative measurements.

P2: comparison between preoperative and one week postoperative measurements.

P3: comparison between and first day postoperative and one week postoperative measurements.

As regard total layer densitometry measurements, there was post operative increase in densitometry reading in 0-2mm, 2-6 mm, 6-10mm, 10-12mm and total zones first day and one week postoperative compared to pre operative measurements (table 7 & fig 25)

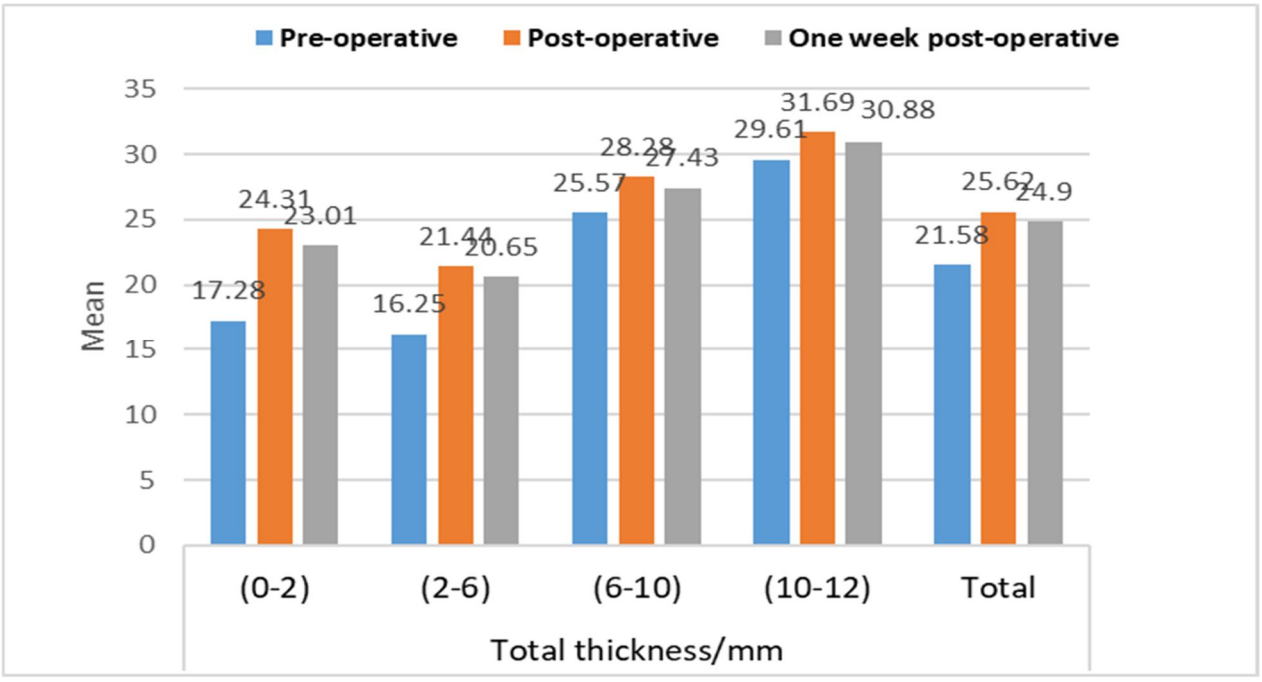


Figure (6): Pre and post operative total corneal densitometry.

Table (8): comparison of pre and post -operative corneal thickness.

	Pre-operative	First day Post-operative	One week post-operative	test of significance	Delta change	% of change
corneal thickness	520.08±30.11	597.43±76.52	576.97±68.50	p1<0.001*	77.36	14.9
				p2<0.001*	56.89	10.94
				p3<0.001*	20.47	3.4

t:Paired t test

Corneal thickness at corneal apex was 520.08±30.11 µm preoperatively and increased to 597.43±76.52 µm first day following surgery and start to decrease and become 576.97±68.50 µm one week post operative.

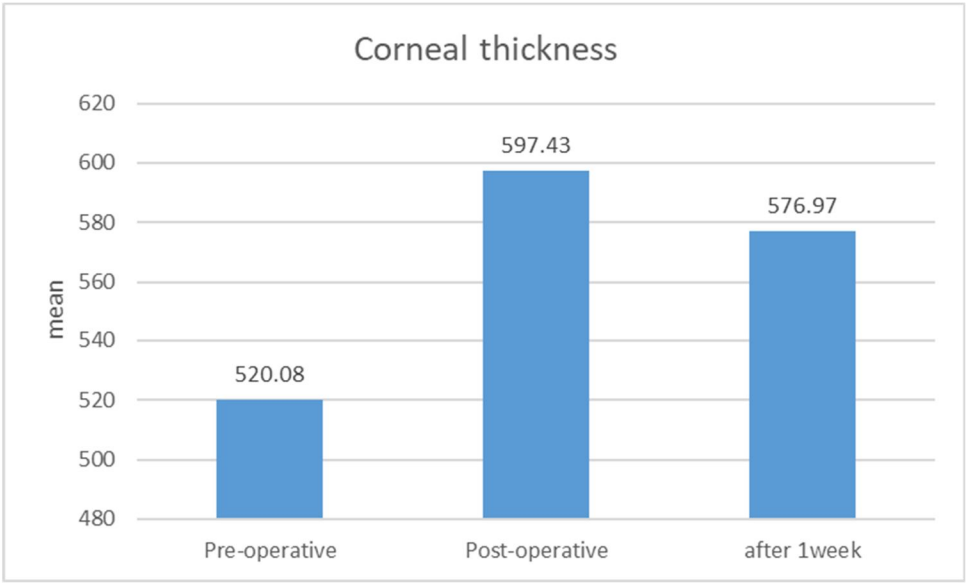


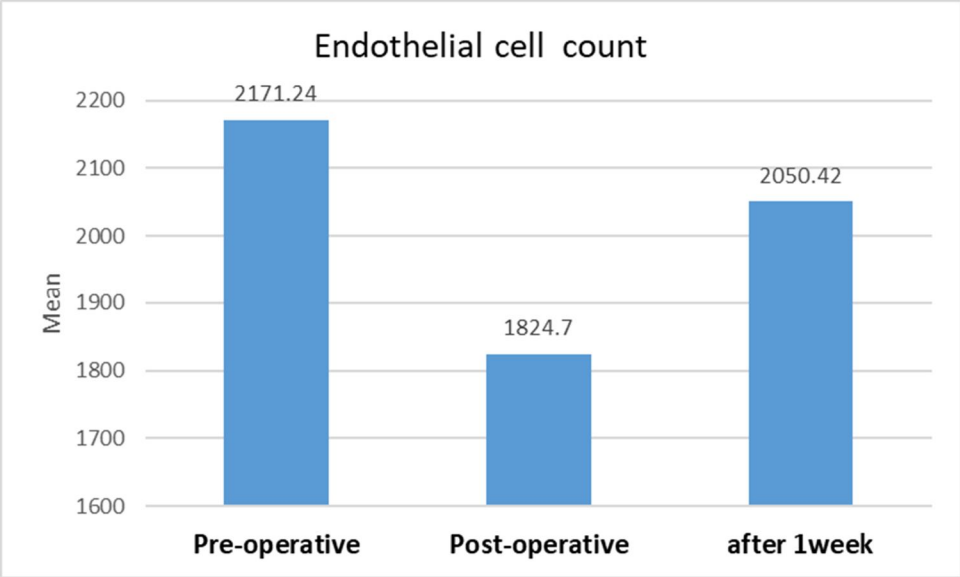
Fig (7): corneal thickness pre and post –operative

Table (9): comparison of pre and post operative endothelial cell count.

	Pre-operative	Post-operative	After 1week	test of significance	Delta change	% of change
Endothelial cell count	2171.24±443.26	1824.70±525.67	2050.42±453.38	p1<0.001*	346.54	15.9
				p2<0.001*	120.82	5.6
				p3=0.008*	225.72	12.4

t:Paired t test

Preoperative endothelial cell count be was 2171.24±443.26 and postoperatively it decrease to1824.70±525.67 then recovered to 2050.42±453.38 after one week post operative



.Fig (8): endothelial cell count pre and post -operative.

Table (10): correlation between postoperative densitometry and corneal thickness at first day.

post-operative densitometry first day		Corneal thickness first day post-operative
Anterior layer total	R	.361*
	P	.024
Central layer total	R	.095
	P	.565
Posterior layer total	R	-.064
	P	.698
Total	R	.237
	P	.147

r: Spearman correlation coefficient

In the current study correlation between densitometry reading and corneal thickness (corneal edema) in first day post operative showed significant positive correlation in anterior layer, insignificant positive correlation in central and total layers, insignificant negative correlation in posterior layer.

Table (11): correlation between densitometry and corneal thickness one week postoperatively.

One-week post-operative densitometry		Corneal thickness one-week post-operative
Anterior layer total	R	0.518
	P	0.001*
Central layer total	R	0.386
	P	0.015*
Posterior layer total	R	0.153
	P	0.353
Total	R	0.390
	P	0.014*

r:Spearman correlation coefficient

Correlation between densitometry reading and corneal thickness (corneal edema) one week postoperative showed significant positive correlation in anterior layer, central, total layers and insignificant correlation in posterior layer.

DISCUSSION:

Cataract surgery is the most common ocular surgery in the world in adults over 50 years of age[15].

The advancement of Pentacam Scheimpflug imaging system has made corneal tissues evaluation effortless with valid and reproducible results. It provides precise data of anatomical features of anterior chamber such as corneal topography, corneal densitometry and lens densitometry meticulously, with minimal user dependent[16].

This study was conducted to evaluate corneal edema following phacoemulsification surgery using corneal densitometry.

To the best of our knowledge, there is very limited number of studies that evaluated the role of corneal densitometry in the assessment of corneal edema and changes after cataract surgery.

In the current study, there was a statistically significant positive correlation between postoperative corneal thicknesses with the postoperative densitometry value of the total anterior layer. There was a positive correlation between postoperative corneal thickness with postoperative densitometry value of the total central layer and total area of the cornea while there was a negative correlation between postoperative corneal thickness with postoperative densitometry value of the total posterior layer.

This study included 50 eyes of 50 patients with senile immature cataract who underwent cataract surgery by phacoemulsification technique.

In the current study, there were 28 males (56.0%) and 22 females (44.0%) with an age of 59.62± 3.85 years with average visual acuity 0.095±0.075 by Log MAR and nuclear density grade 1 (2%), grade 2 (62%) and grade 3(36%).

In the current study, there was post operative increase in densitometry reading in 0-2 mm, 2-6 mm, 6-10 mm, 10-12 mm zones and the anterior corneal layer compared to pre operative measurements and was positively correlated with corneal edema.

This came in agreement with Ishikawa et al. (2018) who showed that densitometry readings in the central 2 mm zone within the anterior layer was 18.12 ± 1.76 before surgery, and increased significantly to 21.03 ± 3.84 on day 1 ($P < 0.001$) and 19.90 ± 2.46 on day 3 ($P = 0.017$) but recovered to 19.44 ± 1.58 on day 7 ($P = 0.131$) after surgery. The authors also reported that Densitometry readings in the 2–6 mm annulus within the anterior layer was 19.11 ± 4.66 before surgery and increased significantly to 22.18 ± 7.40[17].

Also, our present study matching with Hsieh et al. (2021) who reported that the total corneal densitometry were significantly increased in the anterior (p = 0.004) at the area (0 to 2.0 mm) and in the area (2.0 to 6.0 mm) (p = 0.001)[18].

In the current study, there was post operative increase in densitometry reading in 0-2 mm, 2-6 mm, 6-10 m zones and the central corneal layer compared to pre operative measurements and was positively correlated with corneal edema.

This agreed with Hsieh et al. (2021) who reported that the total corneal densitometry were significantly increased in the central region (p = 0.005) at the area (0 to 2.0 mm) and in the area (2.0 to 6.0 mm) (p = 0.021)[19].

In the current study, there was post operative increase in densitometry reading in 0-2 mm, 2-6 mm zones and the anterior corneal layer compared to pre operative measurements and was positively correlated with corneal edema.

This came in accordance with Hsieh et al. (2021) who reported that total corneal densitometry was significantly increased in the posterior region in the area (2.0 to 6.0 mm) (p = 0.025)[19].

In the current study, the highest degree of change in the corneal densitometry was reported in the anterior corneal layer.

In the current study, the mean preoperative corneal thickness was 520.08±30.11 µm and this was statistically significantly increased to 597.43±76.52 postoperative (p< 0.001).

This was in agreement with Ishikawa et al. (2018) who showed that total corneal thickness (mean ± standard deviation) at the corneal apex was 549.1 ± 32.7 µm before surgery and increased to 582.7 ± 46.3 µm on day 1 after surgery (P = 0.001), but recovered to 566.4 ± 29.7 µm on day 3 (P = 0.097) and 559.4 ± 32.4 µm on day 7 (P = 0.400) after surgery[20].

On the other hand, Ho et al. (2018) showed that mean preoperative corneal thickness was 497.56 ± 79.08 um and 509.22 ± 79.06 um postoperatively. There was no statistically

significant perioperative difference (P = 0.055), indicating that the endothelium was not compromised after surgery[21].

CONCLUSION:

Corneal densitometry which is a corneal profiling technique using the Scheimpflug device for measuring corneal scattering may be a useful tool to detect minimal sub clinical corneal edema usually undetectable by slit-lamp examination. Corneal densitometry also useful in evaluation of post operative corneal edema effects on corneal clarity.

Further studies are recommended for more evaluation of other beneficial uses of densitometry.

DATA AVAILABILITY

All data are included in this article.

ACKNOWLEDGEMENT

None

Conflict of Interest

Authors declare no conflicts of interest.

Corresponding author

Correspondence to: Rehab F. Abdelbary

Email: Rehabfetoh2@gmail.com

Affiliations

Rehab F. Abdelbary, Mansoura Ophthalmic Center, Faculty of Medicine, Mansoura University, Egypt.

Ethics declarations

Conflict of interest

Rehab F. Abdelbary, Sherief E. El-Khouly, Hatem E. Elawady, Rania K. Farag. all authors have no conflicts of interest that are directly relevant to the content of this review.

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