The Open Ophthalmology Journal
DOI: 10.2174/0118743641355493250410060817, 2025, 19, e18743641355493 **ISSN: 1874-3641**
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RESEARCH ARTICLE OPEN ACCESS

Changes in Corneal Characteristics, Anterior Chamber Depth, and Ocular Pressure after Phacoemulsification among Diabetic and Non-diabetic Adults

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Abstract:

Objective: The objective of this study was to assess the effects of phacoemulsification on Corneal Endothelial Cell (CEC) characteristics, Central Corneal Thickness (CCT), Anterior Chamber Depth (ACD), and Intraocular Pressure (IOP), and compare them between diabetic and non-diabetic adults.

Methods: An observational hospital-based study was conducted, including patients referred for phacoemulsification surgery between September 2019 and April 2021 at the Al-Neelain University Eye Hospital in Sudan who met the selection criteria. The selection criteria were normal CCT (500 to 600 µm), IOP ranging from 10 to 21 mmHg, ACD > 2 mm, Endothelial Cell Density (ECD) ≥ 1000, no active ocular pathology, and no refractive surgeries or contact lens use. Pre- and six-week post-operative measurements included endothelial cell parameters, CCT, ACD, and IOP.

Results: : A total of 180 patients (180 eyes) were divided into non-diabetic (n=97, 53.89%; mean age 61.7±7.52 years) and diabetic (n=83, 46.11%; mean age 61.4±6.78 years) groups. Significant changes were observed in both groups after surgery. The average changes for non-diabetic and diabetic patients, respectively, were as follows: decreased ECD (mm^3) from 2301.44±322.71 to 1907.25±1455.82, and from 2434.47±188.2 to 1432.2±350.5; increased average cell size from 438.63±77.07 to 630.27±206.02 and from 406.3±73.8 to 639.7±255.7; increased coefficient variation in cell size (%) from 39.87±6.63 to 28.48±24.70 and from 39.8±5.80 to 27.6±16.7; decreased cell number (mm^2) from 66.0±29.54 to 43.52±30.93 and 68.3±21.6 to 44.7±15.6 to 43.52±30.93; increased CCT (µm) from 483.2±38.7 to 512.4±53.5; and increased ACD (mm) from 2.71±0.24 to 3.16±0.23 and from 2.80±0.22 to 3.18±0.17.

Conclusion: Diabetic patients demonstrated variable changes compared to their non-diabetic counterparts post-phacoemulsification. Changes in both groups included endothelial cell loss, increased CCT and ACD, and decreased IOP, with more pronounced effects observed in diabetic patients. In the future, these findings will help cataract surgeons anticipate changes in these parameters after phacoemulsification.

Keywords: Cataract, Central corneal thickness, Corneal endothelium cells, Diabetes, Surgery, Sudan.

Received: September 08, 2024
Revised: February 12, 2025
Accepted: March 05, 2025
Published: May 08, 2025

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Cite as: Muhjoub N, Gammoh Y, Abdalla B. Changes in Corneal Characteristics, Anterior Chamber Depth, and Ocular Pressure after Phacoemulsification among Diabetic and Non-diabetic Adults. Open Ophthalmol J, 2025; 19: e18743641355493. http://dx.doi.org/10.2174/0118743641355493250410060817

1. INTRODUCTION

A cataract is a condition in which the crystalline lens loses transparency due to opacification, which develops slowly and worsens over time, interfering with vision. According to the World Health Organization, cataracts are the second leading cause of vision impairment and blindness, with 94 million people being affected, representing approximately half of global blindness [1]. Senile cataracts —those in persons over the age of 60 years—are the most common type of cataract and the leading cause of vision loss in older adults. Almost half of all adults suffering from blindness due to cataracts reside in low-income and developing countries [2], with approximately 7% of the global number of blind people living in Sudan. Cataracts are the leading cause of blindness, representing 60% of the blind Sudanese, one of the highest rates in Africa [2, 3].

Diabetes is one of the most common risk factors for cataracts. The incidence of cataracts is two to five times higher among diabetics than non-diabetics, with earlier onset. Approximately 20% of cataract surgeries are performed on patients with diabetes [4, 5].

Cataracts affect visual acuity and vision-related quality of life, social status, and household economic condition of patients [6]. Therefore, when clinically significant, they should be treated promptly [6].

Phacoemulsification with implantation of a posterior chamber Intraocular Lens (IOL) is one of the most secure and effective treatments for cataracts and is commonly performed worldwide [7]. Although phacoemulsification has a lower rate of complications compared to other types of cataract surgeries, it can nevertheless result in significant side effects. These include the loss of endothelial cells, corneal thickness, and corneal Endothelial Cell Density (ECD) during surgery, resulting in prolonged corneal edema. These complications may be more common and severe in diabetic patients [8].

The corneal endothelium is responsible for pumping fluid out of the corneal stroma, preventing the development of corneal edema. These cells cannot regenerate; thus, damage can result in the loss of transparency. Precautions should, therefore, be taken to protect the endothelial cells during cataract surgery, keeping the ECD in a normal range (2000–3000 cells/mm^2 in a normal adult eye) [9].

Limited data are available on the effect of phacoemulsification surgery on the anterior segment parameters of the eye in the diabetic and non-diabetic Sudanese population. Nonetheless, these data are valuable because of the high impact of cataracts on visual impairment in Sudan and the relationship between diabetes and cataract formation. Thus, this study aimed to investigate the effects of phacoemulsification surgery on corneal endothelial cell characteristics, comparing Sudanese adult diabetic and non-diabetic patients. Secondary measurements included changes in corneal thickness, anterior Chamber Depth (ACD), and Intraocular Pressure (IOP).

2. MATERIAL AND METHODS

The study was designed as an observational hospital-based study and conducted at the Al-Neelain University Eye Hospital, Faculty of Optometry and Visual Science, Khartoum, Sudan, from September 2019 to April 2021. Specular microscopy was conducted in patients pre- and post-cataract surgery. The University Eye Hospital provides healthcare for a wide spectrum of ophthalmological diseases at the highest level, performing more than 2000 cataract surgeries annually. It is the only regional center that conducts specular microscopy pre- and post-cataract surgery. The principles of the Declaration of Helsinki were followed when this study was conducted. Written permission was granted by the hospital's board of directors. Ethical approval was obtained from the Ethics Committee of the University Eye Hospital at Al Neelain University – Faculty of Optometry and Visual Science (IRB: UEH/ 4/4/2023 -2024). Participation was voluntary, and consent was obtained from every participant after being informed about the nature of the study and its objectives, with the freedom to leave at any time without any alteration in their treatment process.

Patients with senile cataracts who underwent phacoemulsification with IOL implantation during this period and met the inclusion criteria were recruited for the study. The selection criteria followed the hospital's standard protocol for phacoemulsification surgery (best-corrected visual acuity (BCVA) < 6/18–6/60, normal corneal thickness, endothelial cell count ≥ 1000 cells/mm^2, and blood sugar level between 80 and 140 mg/dL). Further criteria included the absence of any ocular or systemic diseases, previous refractive surgeries or contact lens use, normal IOP (10–21 mmHg), and ACD of more than 2 mm. Demographic data and patient histories were recorded.

Ophthalmologic examinations and measurements performed on all patients were as follows: Visual Acuity (VA) was measured using Snellen's Tumbling-*E* chart, and the refractive error of the eye was estimated objectively using a Heine retinoscope. A slit lamp was used to assess the outer and inner eyes and lens of the eye. The posterior eye, IOL calculation, and ACD measurements were performed using a NIDEK B-scan/biometer/pachymeter. Central Corneal Thickness (CCT) and corneal endothelial cell parameters were assessed with a non-contact Topcon computerized specular microscope (SP 3000), which included Endothelial Cell Density (ECD), Cell Number (CN), coefficient of Variation (CV) in cell size, and CCT. The IOP was measured using a Goldmann applanation tonometer attached to a slit lamp. These measurements were performed before phacoemulsification and at six weeks post-operation.

To minimize bias, all selected patients underwent an identical surgical procedure (venturi-based vacuum) performed by the same well-qualified ophthalmic surgeon. A clear corneal phacoemulsification surgery with posterior chamber IOL implantation was conducted through a temporal or superior small incision (2.4 mm to 2.8 mm in width). Ultrasound energy ranging from 30–60 hertz was used, according to the cataract density. In accordance with the Al-Neelain University Eye Hospital follow-up protocol, all patients were assessed on day one and one week, three weeks, one month, and six weeks after surgery.

2.1. Measurements

For the endothelial cell profile count, five fields (four quadrants and a central field) were counted, and the average of these counts was used to represent endothelial cell measurements.

The percentage of change was determined by dividing the difference between the pre- and post-operative measurements by the pre-operative measurements, and multiplying by 100 as follows:

Changes in measurements (%) = (pre-operative measurements – post-operative measurements / pre-operative measurements) ×100.

The ACD and IOL power were measured using the NIDEK Echo-Scan US 4000/500, which features B-scan, biometry, and pachymetry capabilities.

The device provides an average of ten biometric measures with a standard deviation. All biometric readings were obtained with a standard deviation of ≤ 0.05.

Data analysis was performed using SPSS version 27 (SPSS Inc., Chicago, IL, USA). Data are presented as mean ± standard deviation (SD). Pre- and post-operative variables were compared using an independent sample t-test, with the means compared between the two patient groups. Then, 95% confidence intervals were calculated for the mean values, and *p*-values <0.05 were considered statistically significant.

3. RESULTS

This study was conducted at the University Eye Hospital between September 2019 and April 2020. The 572 patients diagnosed with cataracts and referred for cataract surgery during the study period were screened for selection; 35.66% (n=204) met the admission criteria, and 8.82% (n=18) of eligible patients refused to participate. Although no notable post-operative complications were observed, 0.98% (n=2) of patients were omitted due to excessive tears, and 1.96% (n=4) of patients were lost to follow-up. Ultimately, 180 suitable patients (88.25%; n=180 eyes) were included in the study.

As many patients were observed to have diabetes, they were divided into two groups according to diabetic status. A total of 97 (53.89%) patients were non-diabetic; this group comprised 54.6% (n=53) males, with ages ranging from 45–74 years old (mean age 61.7±7.52 years). The second group comprised 83 (46.11%) diabetic individuals, of whom 39.8% (n=33) were males, with ages ranging from 43–70 years (mean age 61.4±6.78 years). All diabetic patients were using diabetes control medications. Their mean HbA1C level was 7.68±2.3%, corresponding to a mean blood sugar level of 131.3 ± 4.7 mg/dL. No significant differences were observed between the ages of the two groups (*p*=0.083) (Table **1**).

As shown in Table **2**, the mean BCVA improved significantly after surgery for normal patients from 0.21±0.03 to 0.74±0.3 and from 0.20±0.04 to 0.73±0.02 for diabetic patients.

Comparison of pre- and post-operative ECD revealed a significant decrease of 17.12% (*p*=0.009) in normal patients (from 2301.44±322.71 mm^3 to 1907.25±1455.82 mm^3). In diabetic patients, ECD decreased by 41.17%, from 2434.47±188.2 mm^3 to 1432.2±350.5 mm^3 (*p*=0.009).

The average cell size increased significantly, by 43.69% in non-diabetic patients (from 438.63±77.07 to 630.27±206.02) and by 57.45% in diabetic patients (from 406.3±73.8 to 639.7±255.7). An independent sample t-test indicated a significant decrease in CV of 28.57% (39.87±6.63 to 28.48±24.70) for non-diabetic and 30.06% (39.8±5.80 to 27.6±16.7) for diabetic patients pre- and post-surgery. The CN of the corneal endothelium significantly declined in both groups, by 34.06% (66.00±29.54 to 43.52±30.93 mm^2) in healthy patients, and by 43.56% (68.3±21.6 to 44.7±15.6 mm^2) in diabetic patients. A significant increase post-operation was also observed in the mean CCT, by 6.00% in healthy patients (483.2±38.7 to 512.4±53.5) and by 13.9% in diabetic patients (473.7±36.7 to 519.6±47.2). Detailed results are presented in Tables **3** and **4**.

Table 1. Age and gender distribution of the sample population (n=180).

-	Normal	Diabetic	
Gender (n, %)	Males 53, (54.6%)	Males 33, (39.8%)	
	Females 44, (45.5%)	Females 50, (60.2%)	
	Total 97 patients (53.89%)	Total 83 patients (46.11%)	
Age	Range: 45-74 years	Range: 43-70 years	*p* = 0.083
	Mean: 61.7±7.52	Mean: 61.4±6.78	

Table 2. Best corrected visual acuity (BCVA) for the sample population (n=180).

-	Before Surgery		After Surgery		-
-	Range	**Mean ± SD**	Range	**Mean ± SD**	*p*-value
Normal	0.1 to 0.33	0.21±0.03	0.50 to 1.00	0.74±0.3	<0.001*
Diabetic	0.1 to 0.33	0.20 ±0.04	0.50 to 1.00	0.73±0.02	<0.001*

Note: (*) Significant *p*-value.

Table 3. Comparison of parameters obtained pre-operatively for diabetic and non-diabetic patients.

Parameter	Non-Diabetics	Diabetics	*p*-value
	Mean & SD	Mean & SD	
CD (cells/mm2)	2301.44±322.71	2434.47±188.29	0.004*
AC (%)	438.63±77.07	406.39±73.85	0.054
CV (%)	39.87±6.63	39.87±5.80	0.969
CN	66.0±29.54	68.37±21.69	0.805
CCT (mm)	483.2±38.7	473.75±36.76	0.092
IOP mmHg	16.31±2.07	18.78±1.45	< 0.001*
ACD mm	2.71±0.24	2.80±0.22	0.331

Note: (*) Statistically significant *p*-value.

Abbreviations: CD = Endothelial cell density; AC, average size; CN, cell number; CV = Coefficient of variation of endothelial cell size; CCT = Central corneal thickness; IOP = Intraocular pressure; ACD = Anterior chamber depth.

Table 4. Comparison of parameters obtained post-operatively for diabetic and non-diabetic patients.

Parameter	Non-diabetics	Diabetics	*p*-value
	Mean & SD	Mean & SD	
CD (cells/mm2)	1907.25±1455.82	1432.2±350.5	0.006*
AC (%)	630.27±206.02	639.7±255.7	0.784
CV (%)	28.48±24.70	27.6±16.7	0.830
CN	43.52±30.93	44.7±15.6	0.916
CCT (µm)	512.4±53.5	519.6±47.2	0.472
IOP mmHg	14.3±1.91	16.1±1.72	<0.001*
ACD mm	3.16±0.23	3.18±0.17	0.473

Note: (*) Statistically significant *p*-value.

Abbreviations: CD = Endothelial cell density; AC, average size; CN, cell number; CV = Coefficient of variation of endothelial cell size; CCT = Central corneal thickness; IOP = Intraocular pressure; ACD = Anterior chamber depth.

Changes of 12.32% and 13.9% in IOP were observed in diabetic and non-diabetic patients, respectively. T-tests revealed a statistically significant decrease from pre- to post-operative IOP in non-diabetics (mean 16.31±2.07 to 14.3±1.91; p<0.001) and diabetics (mean 18.7±1.45 to 16.1±1.72; p< 0.001), as shown in Tables **3** and **4**.

The mean ACD significantly increased post-operatively in both groups. ACD increased by 16.61% (2.71±0.24 to 3.16±0.23) in healthy patients and by 13.57% (2.80±0.22 to 3.18±0.17) in diabetic patients, as detailed in Tables **3** and **4**.

4. DISCUSSION

While the effects of phacoemulsification on the ocular structure have been reported in various countries, there are limited data available from Sudan, with only one study evaluating its effects on the endothelial profile in a healthy population [8, 9]. The current study is considered the first to be conducted on both healthy and diabetic populations and was designed to assess the effect of phacoemulsification on endothelial cell characteristics, corneal thickness, IOP, and ACD.

Visual impairments resulting from age-related cataracts decrease vision-related quality of life, affecting activities of daily living and mobility, and can ultimately lead to physical injuries and mental health issues. However, cataract extraction and replacement with an IOL can restore a healthy lifestyle. Visual function can be improved in all patients, including healthy subjects, diabetic patients with and without retinopathy, glaucomatous patients, and those with other ocular diseases. Our study showed a significant improvement in BCVA in healthy and diabetic patients after cataract surgery, consistent with previous studies [10-14].

There are variations in reports of endothelial cell loss after cataract surgery, which may be due to differing surgical techniques, different patient populations, and the timing of evaluation after surgery [8]. Our study revealed statistically significant changes in ECD post-surgery in both healthy and diabetic patients, with a greater reduction in the diabetic group. The greater reduction observed in patients with diabetes may be due to the increased susceptibility of the endothelium to trauma in this group. This has also been reported in previous studies where significantly reduced ECD was found in non-diabetic and diabetic groups, with greater changes observed among diabetics [15]. It has been reported that diabetic patients exhibit lower ECD compared to non-diabetic individuals of the same age, and the endothelial cell count inversely correlates with the duration of diabetes [16]. The current study observed a higher reduction in ECD (17.12%) than that reported by an earlier study [8], whose finding (11.4%), in turn, was relatively high compared to most of the existing literature [8]. Our results are similar to those obtained by Khan and colleagues (2020) [17].

Our results showed significant changes in corneal endothelium morphology and thickness in normal patients, which aligns with data from healthy Sudanese populations who underwent age-related phacoemulsification surgery [18]. Compared to the findings of Mutwali *et al*. (2020), our results were similar to the average changes in CN (35.3%) and CV (2%), with a lower average change in CCT (2.3%) and a higher change in ECD (32.7%) [18]. It has been reported that there are significant increases in average CV in diabetic and non-diabetic patients, with greater changes in diabetic groups. This finding was also observed in the present study.

The current study showed a significant increase in mean CCT in both groups, with larger changes in the diabetic group. The post-operative increase in mean CCT could be due to changes in the size and morphology of the corneal endothelial cells and post-operative edema. Changes in corneal thickness affect hydration and nutritional metabolism, and subsequently impact transparency and refractive ability. Our findings are consistent with several studies that confirmed a significant increase in CCT after phacoemulsification [8, 17-19].

Several studies have reported significant changes in biometric parameters of the anterior segment after phacoemulsification. It has been found that phacoemulsification and IOL implantation can increase ACD [20-22]. Similarly, our study revealed a significant increase in mean ACD after phacoemulsification in both healthy and diabetic patients. The changes in the anterior chamber parameters could be due to the replacement of the thicker and relatively anterior cataractous lens with the thinner intraocular lens.

In addition to increasing ACD, it has been noted that phacoemulsification and IOL implantation can open the iridocorneal angle and decrease the IOP [20].

Therefore, cataract surgeries—even clear lens extraction—have become a first-line therapy for primary angle closure glaucoma. Despite the significant increase in CCT observed after post-phacoemulsification, the present study revealed a significant decrease in post-operative IOP in both groups, which is consistent with previous reports [20-24]. This observed drop in IOP can be attributed to the increases in ACD, the anterior angle of the eye, and remodeling of the trabecular meshwork [20, 25].

This study followed selection criteria similar to those of other interventions administered in the hospital, including studies on Ranibizumab injections and investigations of diabetic retinopathy patients from the same country and within a similar study period [26, 27].

A strength of the study is the lack of inter-user variability, as one qualified surgeon conducted the phacoemulsification surgery on all patients. Furthermore, one optometrist conducted the pre- and post-operative measurements. One limitation of this study is that it was derived from a single center, which may have limited patient variability. Furthermore, the use of a contact biometer with a high margin of variability may lead to over- or underestimation of ACD. Furthermore, the study was conducted during the COVID-19 pandemic, when ophthalmologists in Sudan reported considerable confusion regarding ophthalmic practice. The study results may, therefore, not be applicable to current post-COVID clinical practice [28].

CONCLUSION

Cataract extraction and replacement with an IOL can restore a healthy lifestyle, as visual function is improved in all patients, includinghealthy subjects, diabetic patients with and without retinopathy, glaucomatous patients, and those with other ocular diseases.

This study provides information on the changes that occur in the endothelial cornea, ACD, and IOP following phacoemulsification surgery in diabetic and non-diabetic Sudanese adults. There were marked changes in patients with diabetes, highlighting the overall effect of diabetes on the eye. Our study revealed statistically significant changes in ECD post-surgery in both normal and diabetic patients, with greater reductions observed in the diabetic group. This could be attributed to the increased susceptibility of the endothelium to trauma in these patients. One limitation of the study is that it was conducted during the COVID-19 pandemic, which affected the clinical practice of ophthalmologists and might affect the generalizability of the data obtained. Nonetheless, the results will allow healthcare practitioners to better understand the nature of the changes mentioned and provide better patient education on the importance of controlling diabetes, early detection, and management to avoid complications.

Furthermore, this study may be useful to ophthalmologists practicing in settings similar to Sudan, where access to eye care is limited and diabetes is prevalent, by providing insights into the interventions for surgical planning and follow-up.

AUTHORS' CONTRIBUTIONS

It is hereby acknowledged that all authors have accepted responsibility for the manuscript's content and consented to its submission. They have meticulously reviewed all results and unanimously approved the final version of the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Ethical approval was obtained from the Ethics Committee of the University Eye Hospital at Al Neelain University – Faculty of Optometry and Visual Science (IRB: UEH/ 4/4/2023 -2024).

HUMAN AND ANIMAL RIGHTS

All procedures performed in studies involving human participants were in accordance with the ethical standards of institutional and/or research committee and with the 1975 Declaration of Helsinki, as revised in 2013.

CONSENT FOR PUBLICATION

Consent was obtained from every participant who was voluntarily motivated to participate in this study after being informed about the nature of the study and its objectives, with the freedom to leave at any time without any alteration in their treatment process.

STANDARDS OF REPORTING

STROBE guidelines were followed.

AVAILABILITY OF DATA AND MATERIALS

The data and supportive information are available within the article.

FUNDING

None.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

ACKNOWLEDGEMENTS

Declared none.

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