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ORIGINAL ARTICLE

Assessment of Changes in the Anterior Segment by Anterior Segment Optical Coherence Tomography and Intraocular Pressure After Phacoemulsification in Glaucomatous and Nonglaucomatous Patients

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Abstract

Background: **Phacoemulsification is widely recognized as the prevailing ocular surgical procedure conducted on a global scale. Multiple studies have provided evidence of a decrease in intraocular pressure (IOP) following phacoemulsification. The assessment of anatomical features in the anterior chamber has emerged as a key area of interest in determining the extent of IOP reduction following cataract surgery. Anterior segment optical coherence tomography (AS-OCT) has recently emerged as an objective and noninvasive method to assess the anterior chamber anatomy.**

Aim: **The work aims to study the effect of phacoemulsification on the anterior chamber and IOP in glaucomatous patients and nonglaucomatous patients using AS-OCT.**

Patients and methods: **The study was conducted on 25 eyes of known glaucomatous patients and 25 eyes of nonglaucomatous patients. All patients had IOP measurement and AS-OCT before and 3 months after phacoemulsification.**

Results: **Mean IOP was 17.34 mmHg preoperative, 15.82 mmHg postoperative with mean change −1.52 mmHg in the nonglaucomatous group, 17.53 mmHg preoperative, 16.12 mmHg postoperative with mean change −1.41 mmHg in glaucomatous wide-angle group and 18 mmHg preoperative, 15.88 mmHg postoperative with mean change −2.13 mmHg in glaucomatous narrow-angle group. Anterior chamber parameters measured by AS-OCT showed marked widening in all groups.**

Conclusion: **Phacoemulsification can decrease IOP and improve the morphology of the anterior chamber which may be of marked benefit for the glaucoma patients. AS-OCT offers a very useful tool for assessment of the anterior segment parameters. IOP changes after cataract surgery can be correlated with anterior segment parameters measured by AS-OCT.**

Keywords: Anterior segment optical coherence tomography, Glaucoma, Intraocular pressure, Phacoemulsification

1. Introduction

Phacoemulsification is a very common and highly refined surgery with a favorable risk/benefit profile including improved visual acuity and visual field. Numerous studies have provided evidence of IOP reduction during phacoemulsification. The extent of reported IOP drop following phacoemulsification surgery ranges from 1 to 6.5 mmHg.[1,2]

Various mechanisms for reducing IOP following cataract surgery have been suggested. However, it has been demonstrated that alterations in the anterior chamber angle (ACA) and anterior chamber depth (ACD) resulting from cataract removal constitute the primary mechanism for IOP modification.[3]

The application of anterior segment optical coherence tomography (AS-OCT) has lately been prominent as a noninvasive and noncontact imaging

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technique for the evaluation of the anterior segment. AS-OCT is a noninvasive imaging modality that provides high-resolution pictures and facilitates efficient and direct quantitative assessment of various anatomical structures. The patient in question exhibits desirable attributes, including high levels of repeatability and reproducibility, while simultaneously mitigating the potential for mechanical distortion of the angle.[4]

2. Patient and methods

The research was conducted on a sample of 25 eyes belonging to individuals diagnosed with glaucoma, as well as 25 eyes from individuals without a diagnosis of glaucoma. The group of individuals with glaucoma was further categorized into two distinct subgroups based on the angle of the anterior chamber of the eye: wide angle and narrow angle.

The study was approved by the ethics committee of the Department of Ophthalmology, Faculty of Medicine, Al-Azhar University. Written consent was taken from all participants before recruitment in the study after explanation of the purpose and procedures of the study.

All participants underwent a comprehensive process of gathering medical background information, including a thorough examination of the eyes which included measuring IOP, and utilizing AS-OCT.

The aim of this study was to evaluate the alterations in central corneal thickness (CCT), ACD, ACA, and angle opening distance 500 μm (AOD500) before and three months following phacoemulsification and intraocular lens implantation at Al-Hussein University Hospital, Sayed Galal University Hospital and Mataria Teaching Hospital.

2.1. Statistical analysis

The process involved the collection, revision, coding, and entry of data into the Statistical Package for Social Science (IBM-SPSS). The analysis of group comparisons using qualitative data was conducted utilizing the χ^2 *test*. The one-way analysis of variance test was employed to compare multiple groups given quantitative data and a parametric distribution. The Kruskall-Wallis test was employed to compare multiple groups with quantitative data and nonparametric distribution. The statistical analysis of comparing two pairs of groups with quantitative data and a parametric distribution was conducted using the Paired *t*-test. The Spearman correlated coefficients were employed to evaluate the correlation between two quantitative parameters within a single group.

The confidence interval was established at a 95% level, with a corresponding margin of error of 5%. The *P* value was deemed statistically significant based on the following analysis.

When the *P* value is greater than 0.05, the result is considered nonsignificant (NS). Conversely, when the *P* value is less than 0.05, the result is deemed significant (S). Furthermore, if the *P* value is less than 0.01, the result is classified as highly significant (HS).

3. Results

Demographic data of the studied patients showed that the range of the age was 50–73 y with the mean age 62.2 y and the sex distribution was 66% (33 cases) females and 34% (17 cases) males.

Table 1. Comparison between groups regarding intraocular pressure preoperative evaluation, post-operative evaluation and difference.

IOP (mmHg)	Nonglaucomatous groups	Glaucomatous groups (no = 25)		Test value	*P* value	Significance
		Glaucomatous wide-angle group	Glaucomatous narrow-angle group			
	No. = 25	No. = 17	No. = 8			
Before						
Mean ± SD	17.34 ± 2.79	17.53 ± 3.24	18.00 ± 2.07	0.162[a]	0.851	NS
Range	12–21	12–22	16–22			
After						
Mean ± SD	15.82 ± 2.95	16.12 ± 3.28	15.88 ± 2.03	0.053[a]	0.948	NS
Range	10–21	10–20	13–19			
Paired *t*-test	**−6.945**	**−4.556**	**−5.338**			
P value	**<0.001 (HS)**	**<0.001 (HS)**	**0.001 (HS)**			
Difference						
Mean ± SD	−1.52 ± 1.09	−1.41 ± 1.28	−2.13 ± 1.13	1.510[b]	0.470	NS
Range	−3–0	−3–2	−4–1			

[a] One Way analysis of variance test.
[b] Kruskal Wallis test.

Table 2. Comparison between groups regarding central corneal thickness preoperative evaluation, post-operative evaluation and difference.

CCT (μm)	Nonglaucomatous groups	Glaucomatous groups (no = 25)		Test value	*P* value	Significance
		Glaucomatous wide-angle group	Glaucomatous narrow-angle group			
	No. = 25	No. = 17	No. = 8			
Before						
Mean ± SD	543.20 ± 39.15	548.76 ± 24.33	545.13 ± 22.87	0.148[a]	0.863	NS
Range	438–645	502–580	514–571			
After						
Mean ± SD	544.72 ± 39.88	551.82 ± 24.70	546.13 ± 22.47	0.240[a]	0.788	NS
Range	436–646	510–586	518–572			
Difference						
Mean ± SD	1.52 ± 2.73	3.06 ± 4.32	1.00 ± 2.00	1.447[b]	0.485	NS
Range	−4–8	−3–14	−2–4			

[a] One Way analysis of variance test.
[b] Kruskal Wallis test.

IOP decrease postoperative was statistically highly significant in all groups and the degree of IOP reduction postoperative was more in the narrow-angle group, Table 1.

Comparison between groups regarding CCT preoperative, postoperative and difference was statistically nonsignificant and showed minimal increase in CCT postoperative in all groups, Table 2.

There was nonsignificant difference between all groups in postoperative ACD but significant difference between groups in the amount of change in ACD with more widening in glaucomatous narrow angle group. All groups had highly significant increase in ACD postoperative, Table 3.

Comparison between groups showed highly-significant difference between narrow-angle group and the other two groups. All groups had highly significant increase in ACA postoperative. The narrow angle group had more amount of change in ACA, Table 4.

Comparison between groups regarding AOD500 preoperatively was highly significant difference between narrow-angle group and the other two groups. The difference in the amount of increase in AOD500 was nonsignificant between all groups. All groups had highly significant increase in AOD500 postoperative, Table 5.

Correlation of age with change of IOP, CCT, ACD, ACA, and AOD500 was statistically nonsignificant except in CCT increase postoperative which correlates positively with age.

Correlation of IOP change with ACD preoperative showed significant correlation between preoperative ACD in glaucomatous narrow-angle group and the amount of reduction of IOP postoperative (Fig. 1).

Table 3. Comparison between groups regarding anterior chamber depth pre-operative evaluation, postoperative evaluation and difference.

ACD (mm)	Nonglaucomatous groups	Glaucomatous groups (no = 25)		Test value	*P* value	Significance
		Glaucomatous wide-angle group	Glaucomatous narrow-angle group			
	No. = 25	No. = 17	No. = 8			
Before						
Mean ± SD	2.73 ± 0.27	2.60 ± 0.24	2.29 ± 0.22	9.294[a]	0.000	HS
Range	2.1–3.21	2–2.9	2–2.5			
After						
Mean ± SD	3.40 ± 0.30	3.44 ± 0.29	3.35 ± 0.23	0.246[a]	0.783	NS
Range	2.88–4	3–3.9	2.9–3.71			
Paired *t*-test	**11.811**	**12.983**	**11.015**			
P value	**<0.001 (HS)**	**<0.001 (HS)**	**<0.001 (HS)**			
Difference						
Mean ± SD	0.67 ± 0.28	0.84 ± 0.27	1.06 ± 0.27	8.885[b]	0.012	S
Range	0.25–1.32	0.42–1.12	0.8–1.5			

[a] One Way analysis of variance test.
[b] Kruskal Wallis test.

Table 4. Comparison between groups regarding anterior chamber angle pre-operative evaluation, post-operative evaluation and difference.

ACA	Nonglaucomatous groups	Glaucomatous groups (no = 25)		Test value	*P* value	Significance
		Glaucomatous wide-angle group	Glaucomatous narrow-angle group			
	No. = 25	No. = 17	No. = 8			
Before						
Mean ± SD	32.95 ± 7.81	34.04 ± 5.14	18.67 ± 1.05	18.208[a]	0.000	HS
Range	16–43.8	23.3–42.3	16.4–19.7			
After						
Mean ± SD	41.62 ± 5.37	42.64 ± 5.15	36.53 ± 2.06	4.385[a]	0.018	S
Range	31–49.8	34.2–52.2	34.62–40.3			
Paired *t*-test	**7.171**	**7.592**	**18.729**			
P value	**<0.001 (HS)**	**<0.001 (HS)**	**<0.001 (HS)**			
Difference						
Mean ± SD	8.67 ± 6.04	8.60 ± 4.67	17.86 ± 2.70	15.170[b]	0.001	HS
Range	0–22.6	0.2–15.2	15.6–22.5			

[a] One Way analysis of variance test.
[b] Kruskal Wallis test.

Table 5. Comparison between groups regarding AOD500 pre-operative evaluation, postoperative evaluation and difference.

AOD500 (μm)	Nonglaucomatous groups	Glaucomatous groups (no = 25)		Test value	*P* value	Significance
		Glaucomatous wide-angle group	Glaucomatous narrow-angle group			
	No. = 25	No. = 17	No. = 8			
Before						
Mean ± SD	340.84 ± 81.36	355.06 ± 55.06	243.63 ± 16.12	8.235[a]	0.001	HS
Range	191–494	263–494	226–268			
After						
Mean ± SD	441.44 ± 63.76	462.41 ± 60.97	393.50 ± 29.19	3.727[a]	0.031	S
Range	311–578	374–610	334–426			
Paired *t*-test	**7.553**	**5.876**	**13.755**			
P value	**<0.001 (HS)**	**<0.001 (HS)**	**<0.001 (HS)**			
Difference						
Mean ± SD	100.60 ± 66.59	107.35 ± 75.33	149.88 ± 30.82	5.326[b]	0.070	NS
Range	0–278	0–270	86–184			

[a] One Way analysis of variance test.
[b] Kruskal Wallis test.

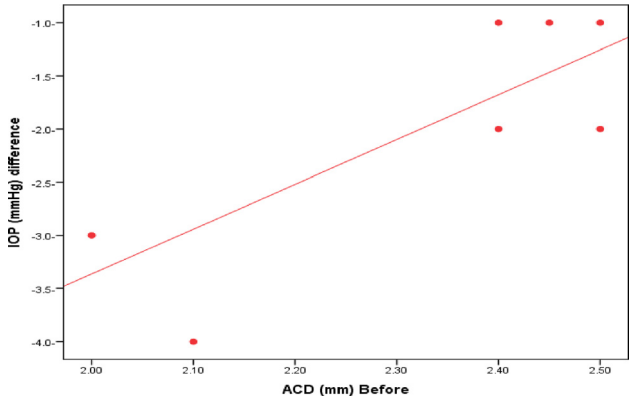

Fig. 1. Correlation of IOP change with anterior chamber depth preoperative in Glaucomatous narrow-angle group.

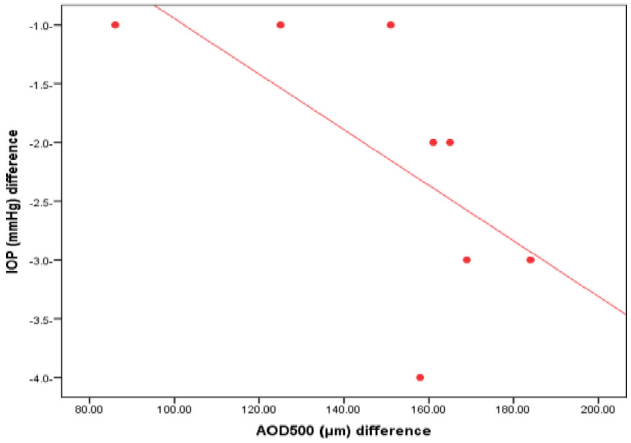

Fig. 2. Correlation of IOP change with change of AOD500 in Glaucomatous narrow-angle group.

Correlation of IOP change with change of AOD500 was significant in glaucomatous narrow-angle group (Fig. 2).

3.1. Case examples

Fig. 3.

- AS-OCT of case 4 measuring CCT preoperative and postoperative showing minimal increase in CCT (3 μm) (Fig. 4).
- AS-OCT of case 25 measuring ACD preoperative and postoperative showing significant increase in ACD by 0.63 mm (Figs. 5 and 6).
- AS-OCT of case 5 measuring ACA preoperative and postoperative showed a significant increase in the ACA by 12.72° (Figs. 7 and 8).
- AS-OCT of case 39 measuring AOD500 preoperative and postoperative showed significant increase by 140 μm (Figs. 9 and 10).

4. Discussion

Phacoemulsification, a widely practiced surgical treatment, has been extensively studied in relation to its impact on IOP decrease. Numerous papers have provided evidence of IOP reduction following phacoemulsification, both in individuals with normal eyes and those diagnosed with glaucoma.[2,5]

The utilization of AS-OCT has been increasingly prevalent as a reliable and non-invasive technique for evaluating the architecture of the anterior chamber. AS-OCT has the capability to quantitatively assess many parameters of the anterior segment, including ACA and ACD. The evaluation of these characteristics holds significant importance, especially in individuals presenting with narrow angle conditions. Research studies have demonstrated that phacoemulsification surgery leads to beneficial alterations in these parameters and a sustained reduction in IOP. The utilization of anterior segment imaging was employed in the creation of predictive models pertaining to the prospective reduction of IOP resulting from cataract extraction in a specific individual.[6,7]

Poley and colleagues conducted a study to investigate the enduring impacts of phacoemulsification, coupled with IOL implantation, on both non-glaucomatous and glaucomatous eyes. The reduction in IOP exhibited a proportionate relationship with the preoperative IOP levels. Specifically, the greatest decreases in IOP were observed in cases with higher preoperative IOP values, whereas those with lower preoperative IOP values had only a modest rise.[8]

Armstrong *et al*. conducted a comprehensive review of thirty-two studies, with a total of 1826 patients, in order to modify their records. Phacoemulsification resulted in reductions of IOP from baseline at the following time points: 6, 12, 24, and 36 months, with respective reductions of 12, 14, 15, and 9%.[9]

The study conducted by Altan and colleagues examined the impact of phacoemulsification on ACD, ACA, and IOP in eyes without glaucoma. Following the surgical procedure, there was a decrease in the mean IOP, whereas the ACD exhibited an increase. There was no observed correlation between the decrease in IOP and the changes in ACA or ACD. Additionally, it was found

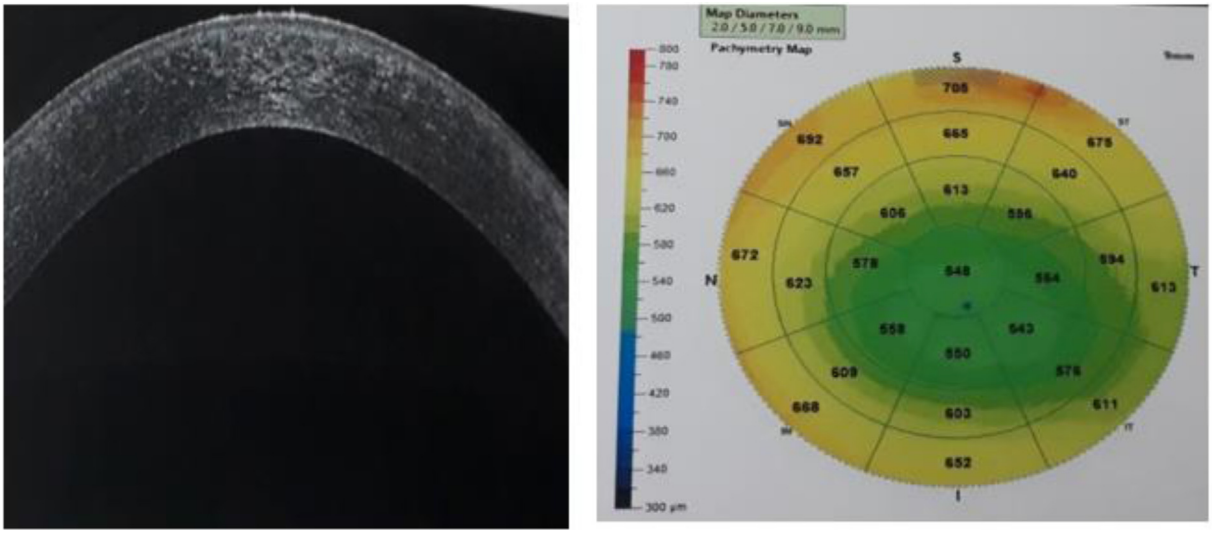

Fig. 3. Anterior segment optical coherence tomography showing the cornea of case 4 preoperative with CCT 548 μm.

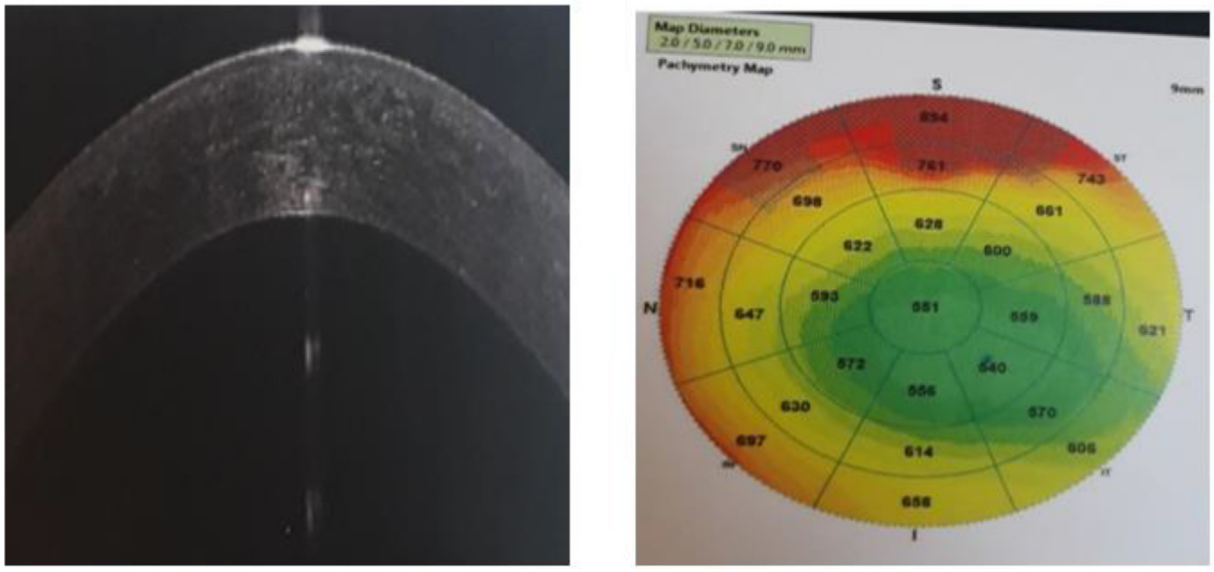

Fig. 4. Anterior segment optical coherence tomography showing the cornea of case 4 postoperative with CCT 551 μm.

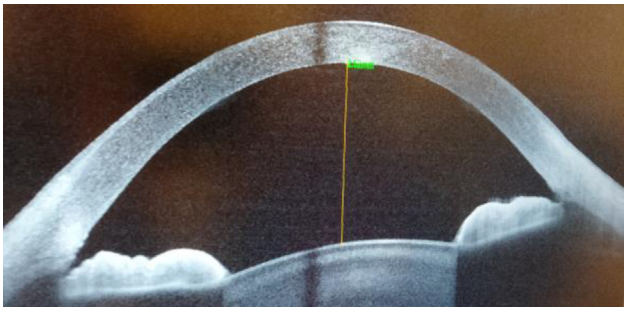

Fig. 5. Anterior segment optical coherence tomography of case 25 preoperative with anterior chamber depth 2.52 mm.

that the preoperative IOP was the sole predictor of the decline in postoperative IOP.[10]

The study conducted by Huang and colleagues examined the correlation between alterations in anterior chamber angle, average AOD500, and ACD with IOP reduction during phacoemulsification. The decrease in IOP following surgery was directly correlated with the rise in angle.[11]

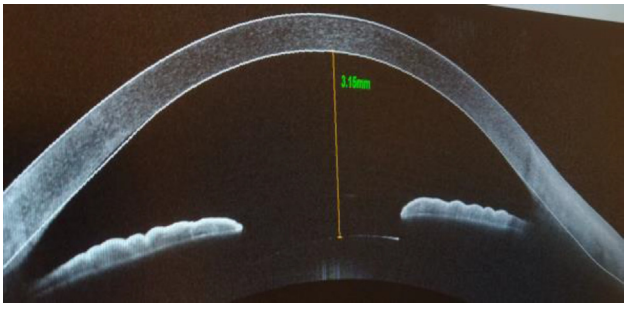

Fig. 6. Anterior segment optical coherence tomography of case 25 postoperative with anterior chamber depth 3.15 mm.

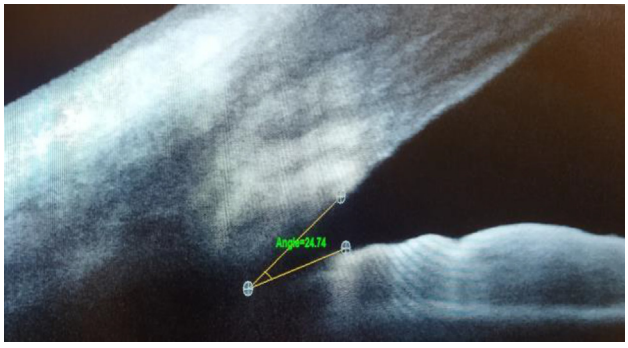

Fig. 7. Anterior segment optical coherence tomography showing anterior chamber angle of case 5 preoperative measuring 24.74°.

Lee and colleagues investigated the change of ACA and IOP reduction after cataract surgery in patients with normal-tension glaucoma using AS-OCT. IOP decreased while ACA and AOD increased after surgery. However, changes of angle

Fig. 8. Anterior segment optical coherence tomography showing anterior chamber angle of case 5 postoperative measuring 37.46°.

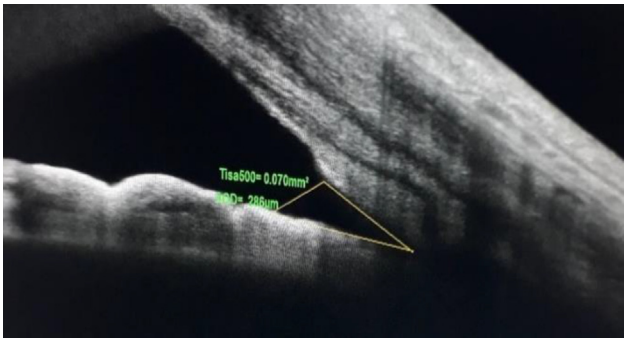

Fig. 9. Anterior segment optical coherence tomography showing AOD500 of case 39 preoperative measuring 286 µm.

parameters were more significant in glaucomatous group. The changes in angle were linearly correlated with postoperative IOP changes.[1]

In our study, we assessed IOP, CCT, ACD, ACA, and AOD500 in 50 cataractous patients, (25 glaucomatous and 25 nonglaucomatous) before and 3 months after phacoemulsification. The glaucomatous group was subdivided into two subgroups (wide-angle and narrow-angle).

Mean CCT was 544.72 µm postoperative in the nonglaucomatous group, 551.82 µm in the glaucomatous wide-angle group and 546.13 µm in the glaucomatous narrow-angle group. The results showed statistically nonsignificant difference between all groups in preoperative, postoperative or mean difference between them and showed minimal increase in CCT postoperative in all groups and we found significant correlation between that change and the age of the patients. Similar to our results,[12,13] showed that most of cases return to the preoperative CCT 3 months after surgery.

Mean ACD was 2.73 mm preoperative, 3.4 mm postoperative with mean difference 0.67 mm in nonglaucomatous group, 2.6 mm preoperative, 3.44 mm postoperative with mean difference 0.84 mm in glaucomatous wide-angle group and 2.29 mm preoperative, 3.35 mm postoperative with mean difference 1.06 mm in glaucomatous narrow-angle group. Measurements of ACD preoperative showed highly significant difference between narrow-angle group and the other two groups. There was nonsignificant difference between all groups in postoperative ACD but significant difference between groups in the amount of change in ACD with more widening in glaucomatous narrow-angle group. All groups had highly significant increase in ACD postoperative. Kim *et al.*[4] and Kashiwagi *et al.*[14] showed similar results about increased ACD postoperative and that cases with more shallow ACD preoperative had more increase in ACD postoperative.

ACA assessment showed highly significant increase in ACA measurement postoperatively in all groups. The mean ACA was 32.95° preoperative, 41.62° postoperative with mean difference 8.67° in the nonglaucomatous group, 34.04° preoperative, 42.64° postoperative with mean difference 8.6° in glaucomatous wide-angle group and 18.67° preoperative, 36.53° postoperative with mean difference 17.86° in glaucomatous narrow-angle group. There was highly significant difference between narrow-angle group and the other two groups. All groups had highly significant increase in ACA postoperative. The narrow-angle group had more amount of increase in ACA but still having lower mean postoperative ACA compared with the other two groups.

Mean AOD500 was 340.84 µm preoperative, 441.44 µm postoperative with mean difference 100.6 µm in the nonglaucomatous group, 355.06 µm preoperative, 462.41 µm postoperative with mean difference 107.35 µm in the glaucomatous wide-angle group and 243.63 µm preoperative, 393.5 µm postoperative with mean difference 149.88 µm in the glaucomatous narrow-angle group. There was highly significant difference between narrow-angle group and the other two groups. The difference in the amount of increase in AOD500 was nonsignificant between all groups. All groups had highly significant increase in AOD500 postoperative. Similar to our results[1,5] documented significant increase in ACA and AOD after surgery.

IOP assessment showed that mean IOP was 17.34 mmHg preoperative, 15.82 mmHg postoperative with mean change −1.52 mmHg in the nonglaucomatous group, 17.53 mmHg preoperative, 16.12 mmHg postoperative with mean change −1.41 mmHg in glaucomatous wide-angle group and 18 mmHg preoperative, 15.88 mmHg postoperative with mean change −2.13 mmHg in glaucomatous narrow-angle group. The drop in IOP

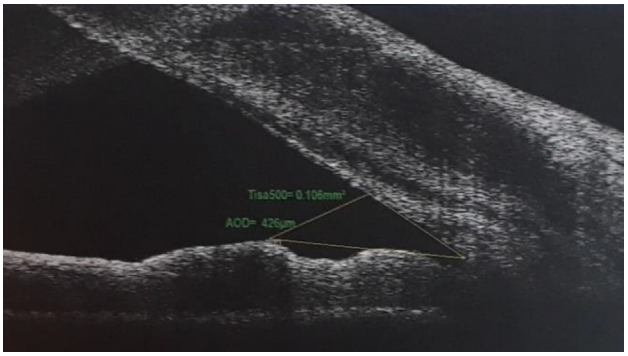

Fig. 10. Anterior segment optical coherence tomography showing AOD500 of case 39 postoperative measuring 426 µm.

after surgery was shown to be statistically significant in all groups. Furthermore, the narrow-angle group had a somewhat greater reduction in IOP postoperatively.

Our results agree with[8,9] that IOP significantly decrease after phacoemulsification in glaucomatous and non-glaucomatous patients. Lin *et al*.[15] and Hsia *et al.*[16] also reported more decrease in IOP in narrow-angle cases.

On studying the correlation between IOP reduction and preoperative parameters,[14] reported that the IOP reduction was significantly higher in eyes with a shallow preoperative ACD. Hsia *et al.*[16] showed that preoperative AOD 500 was a predictor for IOP reduction. Dooley *et al*.[17] A noteworthy association was observed between the reduction in IOP and the preoperative ACA and ACD.

In our study, the correlation of IOP change with preoperative IOP, ACD, ACA and AOD500 showed only significant correlation between preoperative ACD in glaucomatous narrow-angle group and the amount of reduction of IOP postoperative. Our results are different from[8,10] We have observed a statistically nonsignificant association between the preoperative IOP and the extent of postoperative IOP reduction.

On studying the correlation of IOP reduction with change of ACD, ACA and AOD500.[10,18] The study demonstrated that there was no significant correlation between the reduction in intraocular pressure and the alterations observed in ACD and ACA.

Huang *et al*.[11] A favorable link was discovered between the reduction in IOP and the augmentation of AOD500. In the present investigation, we observed that the association between the decrease of IOP and alterations in CCT, ACD, ACA, and angle AOD500 did not reach statistical significance for changes in CCT, ACA, and ACD. However, we did find a significant link between an increase in AOD500 within the glaucomatous narrow-angle group and the extent of IOP reduction.

The limitations of our study include the relatively small sample size and that the follow up was only 6 months.

4.1. Conclusion

Phacoemulsification with IOL implantation is a very common ophthalmic procedure that has been used widely to improve vision in cataractous patients. Besides this main benefit, this procedure can decrease IOP and improve the morphology of the anterior chamber which may be of marked benefit for the glaucoma patients. AS-OCT offers a very useful tool for assessment of the anterior segment parameters. IOP changes after cataract surgery can be correlated with anterior segment parameters measured by AS-OCT. Further studies are needed to prove or disprove the relation between various parameters and the degree of IOP changes after surgery.

Conflicts of interest

There are no conflicts of interest.

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