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Ultrasound Biomicroscopy Versus Anterior Segment Optical Coherence Tomography to Assess Anterior Chamber Angle Before and After Cataract Surgery

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ABSTRACT

Background: Cataract extraction surgery might modify the anterior segment characteristics. Two non-invasive devices that can identify these alterations include; Anterior Segment Optical Coherence Tomography [AS-OCT], and Ultrasound Biomicroscopy [UBM].

Aim of the work: This study aims to investigate the change of anterior chamber angle morphology before and after cataract extraction surgery by ASOCT and UBM devices.

Patients and methods: Our study is a prospective randomized study. We included 100 Eyes with a significant cataract. Patients were randomized into four groups; Group A [25 eyes] with immature senile cataract, Group B [25 eyes] with intumescent cataract, Group C [25 eyes] with mature senile cataract, and Group D [25 eyes] with hyper mature senile cataract.

Results: Our study included 100 patients with a mean age of 66.7 ± 10.6 years. A considerable rise was revealed in the angle measurements postoperative as compared with the preoperative measurements. We compared ASOCT and UBM results in all study groups either preoperative or postoperative and we found no statistically significant difference between ASOCT and UBM in the assessment of anterior chamber angle before and after cataract surgery [p-value > 0.05]. The mean IOP decreased from 20.58 mmHg preoperative to 16.5 mmHg postoperative.

Conclusion: UBM and AS-OCT are helpful tools for imaging the anterior segment and performing the measurements required to determine the anterior chamber angle.

Keywords: Anterior segment; Optical coherence tomography; Phacoemulsification; Ultrasound biomicroscopy; cataract.

INTRODUCTION

Cataracts and glaucoma are the leading causes of blindness worldwide [1].

Glaucoma causes retinal nerve fiber layer damage and optic disc changes which are progressive in nature and irreversible, while cataract causes clouding of a clear crystalline lens that affects vision [2].

Lens extraction also decreases Intraocular pressure [IOP] and plays a role in the treatment of glaucoma by raising anterior chamber depth and widening the angle, so it alters the structural parameters of the anterior chamber, increasing aqueous flow and a varied reduction in IOP [3].

Early clear lens extraction is demonstrably better than topical and laser treatments as the first line of treatment for patients with angle closure glaucoma [4].

Anterior Segment OCT [AS-OCT] imaging is a non-contact and non-invasive technique for studying the structures of the anterior segment cross-sectionally such as the iris shape and angle of the anterior chamber [ACA] [5].

To accurately detect the angle structures, anterior segment imaging is crucial for both qualitative and quantitative measures [6].

The gold standard for visualizing the anterior region is ultrasound biomicroscopy [UBM] [7]. This test makes use of high-frequency ultrasound, which ranges in frequency [from 20-100 MHz] and has a resolution [20–50 μm] with a range of penetration [4–7 mm]. With its aid, imaging of the anterior portion of the eye in a noninvasive manner can be done, especially with regard to regions that are unreachable during a routine slit lamp examination. These include the haptic of an intraocular lens [IOL], the angle of the anterior chamber, the ciliary body, the crystalline lens periphery, or even the outermost portions of the retina [8].

These days' state-of-the-art AS-OCT systems use a laser beam with a wavelength of 1310 nm, allowing for axial resolutions as high as 5-7 m with spectral-domain OCT. AS-OCT has some limitations, including as a shallow depth of penetration [3-6 mm at a scan width of up to 16 mm], which limits its usefulness for imaging deeper structures like the iris [9].

PATIENTS AND METHODS

The ophthalmology department of Al-Azhar University in Damietta, Egypt, conducted this prospective interventional study between Jan. 2022 and July 2022. A sample size of 35 was calculated with a power of 95%. Our study followed the guidelines of the Helsinki Declaration, and ethical approval was obtained from the Institutional Review Board of Damietta Faculty of Medicine, Al-Azhar University. We included 100 eyes of 78 patients following the patient's informed consent obtaining. Patients were randomized into four groups; Group A [25 eyes] with immature senile cataract, Group B [25 eyes] with intumescent cataract, Group C [25 eyes] with mature senile cataract, and Group D [25 eyes] with hyper mature senile cataract. Our information was kept private. We selected the patient based on the following criteria:

The Inclusion Criteria include 1] Patient with circular, round and reactive pupils. 2] Patients with senile cataracts. 3] Normal anterior chamber depth [from 2.91 mm to 3.24]. 4] Normal corneal structure.

The exclusion criteria include 1] Unwilling to participate in the study. 2] Previous penetrating eye surgery. 3] Congenital or traumatic cataract patients. 4] Patient with intraoperative complications such as rupture posterior capsule, vitreous loss, dropped IOL and dropped nucleus. 5] Eye with peripheral anterior synechiae.

Data collection

Complete medical history and physical examination were done during recruitment. Comprehensive ophthalmic evaluations were done including; uncorrected visual acuity, best corrected visual acuity, Intra Ocular Pressure, Slit-lamp examination, and Bio microscopic fundus examination with 90D lens if possible, and with Ultrasound [B scan] in case of dense cataract patients. Anterior segment imaging was done by using the Topcon 3D OCT 2000 device and Accutome 4Sight UBM device standard resolution scans were performed with subjects facing forward to capture the temporal and nasal quadrants [nasal-temporal 0° -180°]. All the images were taken with the patients in a sitting position in the case of ASOCT and in a supine position in the case of UBM. UBM needs an eye cup filled with fluid as a coupling media between the transducer and eye after using a small amount of 2.5 % methylcellulose to seal the base and topical anesthesia. After several scans, we selected the best image.

Determination of the scleral spur [SS] is important for accurate measurement of the angle parameters. The less reflective ciliary muscle meets the more reflective sclera at the scleral spur insertion point. The temporal and nasal angles were measured. The Anterior Chamber Angle [ACA] and the Angle Opening Distance [AOD], in millimeters, are measures of the ocular angle. The AOD is measured from the scleral spur [SS] to the iris in a straight line and the ACA measures the angle formed by the iris and the trabecular meshwork.

The patients were followed up one day, one week, and three months postoperative.

Statistical Analysis

All data analysis was done using the SPSS version 25. Categorical data were presented as numbers and percentages and were compared using the Chi-Square Test. The normality of continuous data was initially checked by the Shapiro-Wilk test. All continuous data were not parametric, so we present it as Interquartile range and median [IQR]. Within-group comparison was done using the Kruskal-Wallis test, and every 2 groups were compared using the Mann-Whitney U-test. Wilcoxon signed-rank test was used to compare preoperative and postoperative outcomes in each study group.

RESULTS

One hundred patients with cataracts [n=100 patients] were included in our study, with 25 patients in each group. Baseline characteristics were described in Table 1. There was a significant difference between the study groups regarding ACA and AOD of nasal and temporal ASOCT and UBM [p-value <0.001].

As regards IOP, the median IOP was significantly higher in group B than in other groups [p-value <0.001]. In our study, we found that 15 patients had a narrow-angle measured below 20 degrees. As regards postoperative Nasal ACA and AOD of AS-OCT; we found a significant difference within all study groups [p-value <0.001]. However, by comparing every 2 groups we found that there was no significant difference between A and C, between A and D, and between C and D [p value< 0.9, 0.1, 0.4 respectively].

In relation to postoperative Nasal ACA, and AOD of UBM, we found a significant difference within all the study groups [p-value <0.001], and the median Nasal ACA and AOD of UBM was higher in group A than other three groups.

As regards postoperative Temporal ACA of AS-OCT; Group A had the highest median temporal ACA in comparison with the other three groups, with no significant difference among the four groups [p-value <0.06]. However, when we compared the two groups, we found a statistically significant difference between groups B, and group C [p-value< 0.021]. In relation to the Temporal AOD of AS-OCT, we found no statistically significant difference neither within the four groups nor in every two groups [p-value <0.08].

As regards postoperative Temporal ACA of UBM; we found a difference within the four groups, and this difference was significant statistically [p-value <0.01]. Unlike the Temporal AOD of UBM, the difference within the study groups was not significant statistically [p value< 0.1]. As regards postoperative IOP we found the highest significant median post-operative IOP was found to be in group C in comparison to the other three groups [p-value < 0.001].

We compared the preoperative and postoperative outcomes of each group, and the difference between pre and postoperative was significant statistically [p-value <0.001] [table 2].

Finally, we compared ASOCT and UBM results in all study groups either preoperative or postoperative and the difference between them was not significant statistically [p-value > 0.05] except for Postoperative temporal AOD in patients with Mature senile cataract and Postoperative nasal AOD in a patient with Hyper mature senile cataract in which the difference found was significant statistically [p-value < 0.001] [table 3, and 4].

Table 1: Demographic and baseline characteristics of the patients

Variables		Group A [n = 25]	Group B [n = 25]	Group C [n = 25]	Group D [n = 25]	P-value [a]
Age [years]		65 [56.5 – 66]	55 [50 – 62]	70 [64 – 73]	79 [75.2 –83.5]	**<0.001 [a] ***
Sex, n [%]	Males	5 [20%]	13 [52%]	9 [36%]	5 [20%]	0.12
	Females	20 [80%]	12 [48%]	16 [64%]	20 [80%]	
Nasal ACA of AS-OCT°		35.3 [29.5 – 39.6]	20.4 [14.9 – 22.2]	29.4 [25.6 – 36.1]	34.4 [29.6 –36.7]	**<0.001 [a] ***
Nasal AOD of AS-OCT [µm]		382 [299.5 – 460]	210 [135 – 250]	383 [320 – 393]	403 [344.7 – 438]	**<0.001 [a] ***
Nasal ACA of UBM° [µm]		34.4 [26.6 – 38.8]	19.3 [15 – 23]	28.02 [25 – 33.5]	34.5 [31.9 – 36.6]	**<0.001 [a] ***
Nasal AOD of UBM [µm]		380 [295– 450]	220 [135 – 250]	350 [310–405]	390 [370 – 430]	**<0.001 [a] ***
Temporal ACA of AS-OCT°		33.6 [28.2 – 40.3]	21.3 [14.03 - 28]	30.1 [25.3 – 32]	34.5 [31.9 – 36.6]	**<0.001 [a] ***
Temporal AOD of AS-OCT [µm]		389 [318 – 464]	230 [122.5 - 260]	360 [316 – 493]	395 [342.5 – 430]	**<0.001 [a] ***
Temporal ACA of UBM°		31.9 [27.9 – 38.8]	22.05 [12.9 – 24]	30 [23.5 – 32.1]	31.9 [28.5 – 36.9]	**<0.001 [a] ***
Temporal AOD of UBM [µm]		390 [335 – 390]	240 [130 – 320]	350 [290 – 430]	385 [330 – 410]	**<0.001 [a] ***
IOP [mm Hg]		17 [15 – 19]	23 [22 – 27]	20 [17 – 22]	19 [16 – 24.5]	**<0.001 [a] ***

[a]: Kruskal-Wallis Test. [b]: Chi-Square Test. *: significant. ACA; Anterior Chamber Angle. ASOCT; Anterior segment optical Coherence Tomography. AOD; Angle Opening Distance. UBM; Ultrasound Biomicroscopy. IOP; Intraocular Pressure

Table [2]: Comparison of the primary outcomes in each of the four studied groups throughout the Follow-Up Periods

Outcomes	Group	Preoperative	Postoperative	P value [a]
Nasal ACA of AS-OCT°	Group A	35.3 [29.5 – 39.6]	45.9 [40.3 – 51.7]	**<0.001 ***
	Group B	20.4 [14.9 – 22.2]	40.1 [37.04 – 42.5]	**<0.001 ***
	Group C	29.4 [25.6 – 36.1]	43.1 [39.5 – 52.3]	**<0.001 ***
	Group D	34.4 [29.6 –36.7]	42.4 [40.1 – 45.8]	**<0.001 ***
Nasal AOD of AS-OCT [µm]	Group A	382 [299.5 – 460]	503 [425 – 612.5]	**<0.001 ***
	Group B	210 [135 – 250]	400 [370 –518]	**<0.001 ***
	Group C	383 [320 – 393]	521 [410 – 562]	**<0.001 ***
	Group D	403 [344.7 – 438]	490 [420 – 515]	**<0.001 ***
Nasal ACA of UBM° [µm]	Group A	34.4 [26.6 – 38.8]	44.04 [39.6 – 50.07]	**<0.001 ***
	Group B	19.3 [15 – 23]	39.8 [37 – 43.01]	**<0.001 ***
	Group C	28.02 [25 – 33.5]	42.5 [39.06 – 50.9]	**<0.001 ***
	Group D	34.5 [31.9 – 36.6]	42.6 [39.6 – 44]	**<0.001 ***
Nasal AOD of UBM [µm]	Group A	380 [295– 450]	510 [425 –600]	**<0.001 ***
	Group B	220 [135 – 250]	390 [370 – 510]	**<0.001 ***
	Group C	350 [310–405]	510 [410 – 540]	**<0.001 ***
	Group D	390 [370 – 430]	495 [410 –517]	**<0.001 ***
Temporal ACA of AS-OCT°	Group A	33.6 [28.2 – 40.3]	46.5 [40.3 – 49.8]	**<0.001 ***
	Group B	21.3 [14.03 - 28]	41.5 [39.04 – 44.4]	**<0.001 ***
	Group C	30.1 [25.3 – 32]	45.6 [41.3 – 55.1]	**<0.001 ***
	Group D	34.5 [31.9 – 36.6]	43.2 [41.7 – 48.23]	**<0.001 ***
Temporal AOD of AS-OCT [µm]	Group A	389 [318 – 464]	520 [430 – 584.5]	**<0.001 ***
	Group B	230 [122.5 - 260]	410 [360 – 540]	**<0.001 ***
	Group C	360 [316 – 493]	516 [420 – 573]	**<0.001 ***
	Group D	395 [342.5 – 430]	501 [416 – 535]	**<0.001 ***
Temporal ACA of UBM°	Group A	31.9 [27.9 – 38.8]	43.5 [41.7 – 49.9]	**<0.001 ***
	Group B	22.05 [12.9 – 24]	42 [37.9 – 43.8]	**<0.001 ***
	Group C	30 [23.5 – 32.1]	45.09 [42.2 – 50.6]	**<0.001 ***
	Group D	31.9 [28.5 – 36.9]	45.01 [42 – 48.9]	**<0.001 ***
Temporal AOD of UBM [µm]	Group A	390 [335 – 390]	510 [430 – 570]	**<0.001 ***
	Group B	240 [130 – 320]	415 [365 – 530]	**<0.001 ***
	Group C	350 [290 – 430]	500 [415 – 560]	**<0.001 ***
	Group D	385 [330 – 410]	510 [411 –525]	**<0.001 ***
IOP [mm Hg]	Group A	17 [15 – 19]	15 [14 –16]	**<0.001 ***
	Group B	23 [22 – 27]	17 [16 – 19]	**<0.001 ***
	Group C	20 [17 – 22]	18 [17 –20]	**<0.001 ***
	Group D	19 [16 – 24.5]	16 [15 – 17]	**<0.001 ***

[a]: Wilcoxon Signed Ranks test.

Table [3]: Preoperative comparison between ASOCT and UBM results in the four studied groups

Outcomes	Group	ASCOT	UBM [μm]	P value [a]
Nasal ACA	Group A	35.3 [29.5 – 39.6]	34.4 [26.6 – 38.8]	= 0.4
	Group B	20.4 [14.9 – 22.2]	19.3 [15 – 23]	= 0.9
	Group C	29.4 [25.6 – 36.1]	28.02 [25 – 33.5]	= 0.4
	Group D	34.4 [29.6 –36.7]	34.5 [31.9 – 36.6]	= 0.6
Nasal AOD	Group A	382 [299.5 – 460]	380 [295– 450]	= 0.7
	Group B	210 [135 – 250]	220 [135 – 250]	= 0.7
	Group C	383 [320 – 393]	350 [310–405]	= 0.3
	Group D	403 [344.7 – 438]	390 [370 – 430]	= 0.9
Temporal ACA	Group A	33.6 [28.2 – 40.3]	31.9 [27.9 – 38.8]	= 0.3
	Group B	21.3 [14.03 - 28]	22.05 [12.9 – 24]	= 0.4
	Group C	30.1 [25.3 – 32]	30 [23.5 – 32.1]	= 0.4
	Group D	34.5 [31.9 – 36.6]	31.9 [28.5 – 36.9]	= 0.3
Temporal AOD	Group A	389 [318 – 464]	390 [335 – 390]	= 0.7
	Group B	230 [122.5 - 260]	240 [130 – 320]	= 0.9
	Group C	360 [316 – 493]	350 [290 – 430]	= 0.2
	Group D	395 [342.5 – 430]	385 [330 – 410]	= 0.2

[a]: Mann-Whitney U-test.

Table [4]: Postoperative comparison between ASOCT and UBM results in the four studied groups

Outcomes	Group	ASCOT	UBM [μm]	P value [a]
Nasal ACA	Group A	45.9 [40.3 – 51.7]	44.04 [39.6 – 50.07]	= 0.6
	Group B	40.1 [37.04 – 42.5]	39.8 [37 – 43.01]	= 0.5
	Group C	43.1 [39.5 – 52.3]	42.5 [39.06 – 50.9]	= 0.4
	Group D	42.4 [40.1 – 45.8]	42.6 [39.6 – 44]	= 0.3
Nasal AOD	Group A	503 [425 – 612.5]	510 [425 –600]	= 0.6
	Group B	400 [370 –518]	390 [370 – 510]	= 0.8
	Group C	521 [410 – 562]	510 [410 – 540]	= 0.3
	Group D	490 [420 – 515]	495 [410 –517]	**< 0.001***
Temporal ACA	Group A	46.5 [40.3 – 49.8]	43.5 [41.7 – 49.9]	= 0.5
	Group B	41.5 [39.04 – 44.4]	42 [37.9 – 43.8]	= 0.6
	Group C	45.6 [41.3 – 55.1]	45.09 [42.2 – 50.6]	= 0.8
	Group D	43.2 [41.7 – 48.23]	45.01 [42 – 48.9]	= 0.1
Temporal AOD	Group A	520 [430 – 584.5	510 [430 – 570]	= 0.6
	Group B	410 [360 – 540]	415 [365 – 530]	= 0.7
	Group C	516 [420 – 573]	500 [415 – 560]	**< 0.001***
	Group D	501 [416 – 535]	510 [411 –525]	= 0.7

*: significant; [a]: Mann-Whitney U-test.

DISCUSSION

Our study showed a significant difference between the study groups regarding the preoperative ACA and AOD of nasal and temporal ASOCT and UBM [p.<0.001]. Also, there was a significant difference between all groups regarding the preoperative IOP which was higher in the intumescent group than in other groups. Comparison between the preoperative and postoperative outcomes of each group showed a difference that was significant statistically [p.<0.001]. Also, a comparison between the ASOCT and UBM results in all study groups either preoperative or postoperative showed a difference that was not significant, except for Postoperative temporal AOD in patients with Mature senile cataract and Postoperative nasal AOD in a patient with Hyper mature senile cataract in which the difference found was significant [p. < 0.001].

In the outflow of aqueous humour, angles' structures and purposes are crucial. It is well knowing that a structure with an open-angle status drains aqueous humour better than one with a closed-angle status [10].

The dimensions and architecture of the anterior chamber are changed after cataract surgery with IOL implantation. According to previous literature, cataract removal extends and deepens the iridocorneal angle [11]. Generally, IOP is typically reduced as a result of after cataract surgery in patients with and without glaucoma [12, 13].

AS-OCT provides A long wavelength of light [1,310 nm] to produce high-resolution pictures, and it provides a quick and simple quantitative examination of diverse structures [14]. It is challenging to produce precise pictures of the structure located behind the pigmented iris due to ASOCT's incomplete penetration through the pigmented iris epithelium [15]. This ASOCT can only be carried out in a child who is seated and awake, in contrast to the ultrasound biomicroscopy [UBM] which can be done on a sleeping child and also, offers an assessment of the morphology of the anterior segment structure that is non-invasive, continuous, dynamic, and in-vivo. In contrast to AS-OCT, UBM also overcomes peripheral corneal opacities and other pathology like pterygium, gives good angle visualization, and can penetrate the iris through the iris-pigmented epithelium. Consequently, you can get it easily precise images of the structure located behind the pigmented iris as the ciliary body, lens periphery, and zonules [16, 17].

We compared our result with the study of **Said *et al*.** [12] who measured the changes in the anterior segment parameters and IOP following phacoemulsification cataract surgery, and reported significant changes in the ACA and AOD on the temporal and nasal side after cataract surgery P value <0.001, which agrees with our finding.

Another study done by **Nonaka *et al*.** [18] included a sample size of Thirty-one eyes of 31 patients diagnosed with primary angle closure who underwent cataract surgery. He discovered that AOD 500 dramatically increased significantly following cataract surgery, in comparison with measurements taken preoperatively. [P<0.001]. This finding is in line with our results.

Similar to our result, a study by A **Simsek *et al***. [19], found that the mean preoperative angle of anterior chamber measurement was 27°, and one month after surgery it had grown to 42°, at the 250 and 500 μm from the scleral spur, the mean angle-opening distances [AOD] increased from 208 ± 109 μm preoperative to 347 ±181 μm respectively one month after surgery. The average intraocular pressure preoperative was 14 mmHg, and one month after surgery, it was 11 mmHg, a 24% drop that was statistically significant [P 0.001]. The mean IOP in the Simsek study is less than our study and this can be explained by that our study contains variant types of cataract patients and lens morphology changes according to the type of cataract, which is a strength point in our study, but A **Simsek *et al*.** [19] sticky to single type of cataract patients so they missed major risk factor which is lens size in the form of cataract type. However, this study agrees with our study that there is a significant difference between the preoperative and postoperative IOP values.

Another study by **Qian *et al*.** [20] included 16 patients with secondary open-angle glaucoma. He measured the ACA and AOD by both UBM and AS-OCT, the measurement findings from the UBM and AS-OCT were statistically comparable., and the two imaging techniques have a high degree of agreement with one another. The above study agrees with us in that; there was no significant difference between the measurements using UBM and ASOCT.

Our study provides evidence that there is no difference between UBM and ASOCT in the assessment of the ACA and AOD. The two techniques [UBM, and ASOCT] are complementary to each other and no one can replace the other as every one of both had its benefits and limitation.

Strength points in our study include; our large sample size, we considered the lens morphology [cataract type] as a factor so we divided the participants into four groups according to cataract type, and we compared angle parameters in all four groups pre-operative and post-cataract surgery, also we compared each group with the other, and we compared ASOCT measurements by UBM and also compared IOP in all groups and how cataract extraction can affect IOP measurement. Our study had some limitations. First, the duration of this study was only three months; cataract patients are known to require longer follow-ups. Second, we did not consider the degree of illumination as a factor affecting angle measurement. Finally, angle measurement is subjectively done.

AS-OCT and UBM are recommended to be valuable techniques for a quantitative assessment of the elements of the anterior segment after cataract surgery. Both should be utilized side by side in the routine evaluation of patients with glaucoma or complex cataracts to establish the scheduling of surgery, therapeutic goals, and postoperative controls. Additional research with bigger sample size and more consistent patient features may be helpful. To verify these findings, additional research with a larger patient population and long-term follow-up is required.

Conclusions: Following cataract removal and IOL implantation, widening of the ACA and reduction of IOP occurs, also there is a high degree of agreement between the UBM and ASOCT in assessment angle measurements.

Conflict of interest and Financial Disclosure: None

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