ORİJİNAL ARAŞTIRMA ORIGINAL RESEARCH

The Deterministic Values of Angle Parameters Measured by Ultrasound Biomicroscopy in Patients with Open Angle After Cataract Surgery

Katarakt Cerrahisi Sonrası Açık Açılı Hastalarda Ultrason Biyomikroskopisi ile Ölçülen Açı Parametrelerinin Belirleyicilik Değerleri

Ümit AYKAN,[a]
İlhami SALCAN[b]

[a]Department of Ophthalmology, Near East University School of Medicine, Lefkoşa
[b]Department of Ophthalmology, Ardahan Military Hospital, Ardahan

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Yazışma Adresi/*Correspondence:*
Ümit AYKAN
Near East University Faculty of Medicine, Department of Ophthalmology, Lefkoşa, KKTC/TRNC
umitaykan@yahoo.com

ABSTRACT Objective: To investigate the deterministic values of angle recess area (ARA), angle opening distances at the locations 250 µm (AOD_{250}) and 500 µm (AOD_{500}) anterior to the scleral spur and trabecular-iris angle (TIA) in patients with open angle undergoing cataract surgery. **Material and Methods:** Thirty-three eyes of 33 patients with open angle undergoing cataract surgery were enrolled in this study. Ultrasound biomicroscopy (UBM) examination was performed preoperatively and 1 month postoperatively under a standard protocol. At each examination, radial sections of the angle at four quadrants were obtained. The images were analyzed using UBM Pro 2000 software for AOD and ARA semiautomatically, and for TIA manually. **Results:** The postoperative increases in the ARA, TIA, AOD_{250} and AOD_{500} were statistically significant at four quadrants ($p<0.0001$). The average increase in the ARA was 0.064±0.037 mm² (44%), in the AOD_{250} was 0.056±0.02 mm (70%), in the AOD_{500} was 0.074±0.03 mm (56%) and in the TIA was 12.3±4.8º (52%). We determined statistically significant correlations between changes in the ARA with AOD_{250} (r=0.54, p=0.001) and AOD_{500} (r=0.74, p=0.0001). The lowest extraction value was AOD_{250} and the highest extraction value was AOD_{500} in three quadrants. Differently, the highest extraction value was determined as ARA at the nasal quadrant. **Conclusion:** Our study showed that AOD_{500} is as valuable as ARA in patients with open angle in the quantitative evaluation of the angle. This may not be the case in closed or occludable angles. AOD can be used reliably for the evaluation of the angle by the observers having UBM models without image analysis software.

Key Words: Ultrasonography; anterior eye segment

ÖZET Amaç: Katarakt cerrahisi uygulanacak açık açılı hastalarda, açı açıklık alanı (AAA), skleral mahmuzun 250 µm (AAM_{250}) ve 500 µm (AAM_{500}) önündeki lokalizasyonlarda açı açılım mesafesi (AAM), ve trabekülum- iris açısının (TİA) belirleyicilik değerlerini araştırmak. **Gereç ve Yöntemler:** Bu çalışmada katarakt ameliyatı olacak açık açılı 33 hastanın 33 gözü çalışmaya dahil edilmiştir. Ameliyat öncesinde ve ameliyattan 1 ay sonra standart bir protokol halinde ultrason biyomikroskopisi (UBM) yapılmıştır. Her muayenede, 4 kadranda açının radial kesitleri elde edilmiştir. Görüntülerde AAM ve AAA, UBM Pro2000 yazılımı ile yarı-otomatik olarak, TİA ise manüel olarak analiz edilmişlerdir. **Bulgular:** AAA, TİA, AAM_{250} ve AAM_{500} değerlerindeki ameliyat sonrası artışlar 4 kadranda istatistiksel olarak anlamlıdır. ($p<0,0001$). AAA'da ortalama artış miktarı 0,064±0,037 mm² (%44), AAM_{250}'de 0,056±0,02 mm (%70), AAM_{500}'de 0,074±0,03 mm (%56) ve TİA'da 12,3±4,8º (%52)'dir. AAA ile AAM_{250} (r=0,54, p=0,001) ve AAM_{500}'deki değişiklikler (r=0,74, p=0,0001) arasında istatistiksel olarak önemli korelasyonlar saptadık. Üç kadranda en düşük çıkarım değeri AAM_{250}, en yüksek çıkarım değeri ise AAM_{500} idi. Farklı olarak, nazal kadranda en yüksek çıkarım değeri AAA olarak saptandı. **Sonuç:** Çalışmamız, açık açılı hastalarda açının kantitatif değerlendirilmesinde, AAM_{500}'ün AAA kadar değerli olduğunu göstermiştir. Bu bulgu kapalı ya da kapanabilir açısı olan hastalarda geçerli olmayabilir. AAM, görüntü analiz yazılımlarına sahip olmayan UBM modellerini kullananlar tarafından açının değerlendirilmesi için güvenilir şekilde kullanılabilir.

Anahtar Kelimeler: Ultrasonografi; anterior göz segmenti

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Previously, quantitative assessment of anterior eye structures was not possible for angle structures. Angle structures could only be assessed semi-quantitatively by estimating the peripheral anterior chamber depth and the angular width of the angle recess.[1,2] Anterior segment imaging has been a rapidly developing field of ophthalmology to aid in the quantitative assessment of the anterior chamber angle (ACA) since 1990.[3] Ultrasound biomicroscopy (UBM), anterior segment-optical coherence tomography (AS-OCT), Scheimpflug photography and scanning peripheral anterior chamber depth analyzer (SPAC) are the current techniques to obtain objective, high-resolution images of the anterior segment and iridocorneal angle structures.

UBM and AS-OCT are the most preferred modalities.[4-8] Initially, Pavlin et al. proposed various manual quantitative measurement parameters that do not require any software use for assessment of the ACA such as angle opening distances at the locations 250μm (AOD_{250}) and 500 μm (AOD_{500}) anterior to the scleral spur and trabecular-iris angle (TIA).[5] Then, Ishikawa et al. developed a semi-automated program (UBM Pro2000) that calculated several important parameters once the scleral spur is identified.[9] Using this software, one can obtain the AOD_{250}, AOD_{500}, and angle recess area (ARA) with the placement of a single mark identifying the scleral spur. In addition, the software provides a linear regression of the AOD out to 750 μm of the scleral spur, producing two figures: the acceleration and the *y*-intercept.

It is well known clinically that cataract surgery changes the angle configuration and the anterior chamber depth.[10-12] All these studies confirm using quantitative methods that what has been known clinically as ACA widens after lens removal. An enlarged lens causes narrowing of the ACA. In addition to the removal of the lens, the iris shifts backward consequently after cataract surgery, since the cataractous lens is no longer present.

The superiority of the ARA to AOD has been proposed particularly in patients who have irregularities of iris contour and curvature (occludable or closed angle). In this study, we aimed to reveal the value of the AOD_{250} and AOD_{500} in defining the changes in the angle and to investigate if they can be used reliably in the quantitative evaluation of the angle in UBM devices without semi-quantitative measurement.

MATERIAL AND METHODS

We prospectively studied 33 eyes of 33 patients who consecutively underwent cataract surgery for senile or presenile cataracts. At least 30 patients, which are necessary for using parametric tests according to the central limit theorem, are used for determining the sample size of this study. Surgeries were performed at GATA Haydarpasa Training Hospital, in Istanbul, Turkey, under topical anesthesia by the same surgeon (UA). Surgical technique consisted of phacoemulsification and aspiration through a 3.2 mm clear temporal corneal incision followed by foldable intraocular lens (IOL) implantation in the capsular bag. All eyes received AcrySof MA60BM (Alcon Laboratories, TX, USA) acrylic IOLs that have a 6-mm optic diameter and were 13 mm in overall length. The study was approved by the institutional Ethics Committee, and informed consents were obtained from the patients.

All patients underwent complete ophthalmic examination including best corrected visual acuity, slit lamp biomicroscopy, gonioscopy, applanation tonometry, and indirect ophthalmoscopy. IOL powers were determined by using optic coherence interferometer (IOL Master, Zeiss, CA, USA).

Patients with the history of preoperative trauma, uveitis, glaucoma, ocular surgery, intraoperative complications such as incomplete capsulorhexis, posterior capsule rupture, vitreous loss, patients who needed corneal suture or with occludable or closed angle (as to Schaffer grading system; grade 2 and under) and patients with >5 D spherical and/or >3 D cylinder refractive errors were excluded from the study.

The UBM was performed before and 1 month after surgery (VuMax II, Sonomed, USA), which incorporated a 50-MHz transducer. The quantitative assessments of the angle width (AOD_{250}, AOD_{500}, ARA and the linear regression analyses) were obtained from the images acquired using UBM Pro2000 software. The image analysis program requires only manual identification of the scleral spur. In addition, by using the angle caliper included in the equipment software, we measured TIA on the temporal quadrant.

In our study, we used the established standards for the quantitative measurement of anterior chamber parameters, developed by Pavlin et al.[5] In their study, AOD_{250} and AOD_{500} were defined as the length of the line drawn from the point on the endothelial surface 250-500 μm anterior to the scleral spur to the iris surface, perpendicular to the corneal endothelial surface (Figure 1). Trabecular-iris angle (TIA) was defined as an angle formed with the apex at the iris recess and the arms passing through the point on the meshwork 500 μm from the scleral spur and the point on the iris perpendicularly opposite (Figure 1). TIA defines the angle in degrees. The position of the scleral spur is used as a reference point for most of their parameters, because it can be consistently distinguished in the ACA region. Ishikawa et al. introduced a software for the quantitative evaluation of ACA and described new parameters such as ARA, the acceleration and the y-intercept.[9] Thus; ARA was defined as triangular area bordered by the anterior iris surface, corneal endothelium, and a line perpendicular to the corneal endothelium drawn to the iris surface from a point 750 μm anterior to the scleral spur (Figure 2). Acceleration was defined as how rapidly the angle widens from the root and it is an estimated value used to describe the angle opening. The *y*-intercept refers to the estimated distance between the scleral spur and the iris surface along a line perpendicular to the trabecular meshwork plane. (Figure 3). We also used the same parameters and measurement techniques which were standardized by Pavlin et al. and Ishikawa et al. which are described above in detail.[5,9] While AOD_{250}, AOD_{500} and ARA were measured at 4 quadrants, TIA was measured at only the temporal quadrant.

All UBM examinations were made under a standard protocol (dim room illumination, when

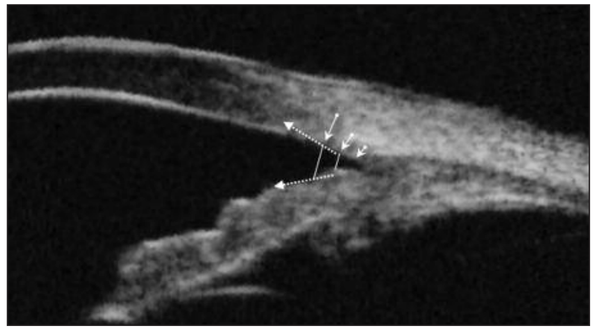

FIGURE 1: Schematic image of AOD250, AOD500 and TIA.
AOD_{250}: Angle opening distance at 250 μm from the scleral spur; AOD_{500}: Angle opening distance at 500 μm from the scleral spur, TIA: Trabecular-iris angle. Long arrow: AOD_{500}, Middle arrow: AOD_{250}, Short arrow: Scleral spur, dotted arrows: TIA.

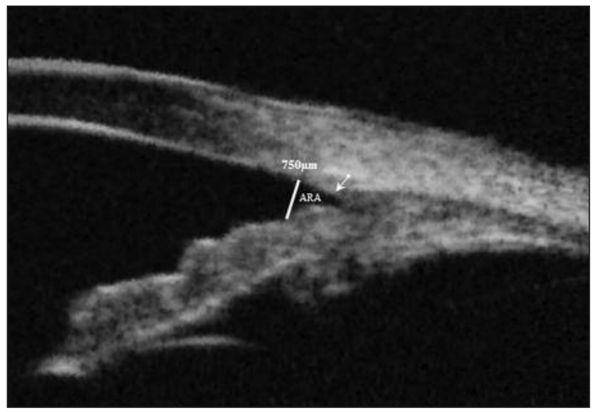

FIGURE 2: Schematic image of ARA.
ARA: Angle recess area; Arrow: Scleral spur.

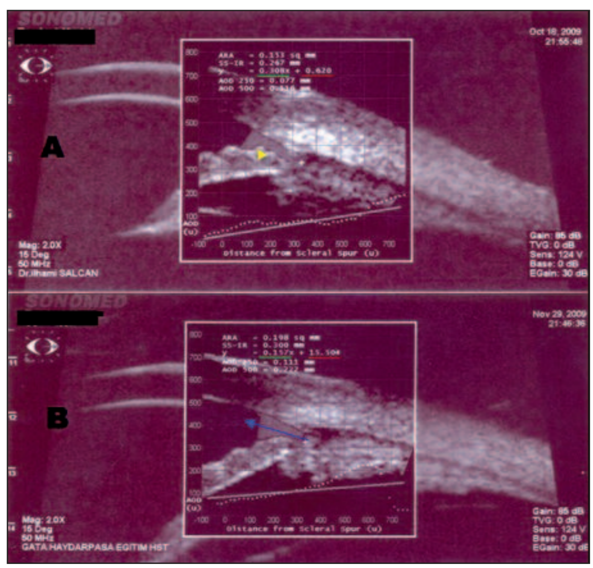

FIGURE 3: Preoperative (Top) and postoperative (Bottom) UBM Pro2000 results of the same patient. We see a sudden increase in the angle width (yellow arrow head) in the preoperative period while linear widening of the angle is seen in the postoperative period (blue arrow). While acceleration decreases in the postoperative period (green), increase of the y-intercept (red) is seen. (See for colored form http://tipbilimleri.turkiyeklinikleri.com/)

the patient was in the supine position and she/he was asked to fixate on a small red target at the ceiling for accommodation control). We used 0.9% saline solution for immersion. We paid attention to gently hold the eyecup just to prevent leak during the examination, due to a possibility of causing artefactional angle widening. We obtained radial section images of the angle on the superior, temporal, inferior and nasal quadrants. When we were obtaining angle images, we paid attention to select best reflective images with an obvious interface reflective line between the sclera and the ciliary body for accurate and easy localization of the scleral spur. Image acquisition and measurements were obtained by the same examiner (IS).

We used SPSS for Windows 17.0 for statistical analyses. Comparisons of UBM parameters measured before and after cataract surgery were performed using paired samples t tests. The correlation analyses were assessed by using Pearson correlation coefficients. The parameters used for evaluation of ACA were different in units, mean and standard deviation values. For this reason, Principal Component Analysis (PCA) was used to extract deterministic values of the differences obtained post surgically in each quadrant. Before applying PCA, Kaiser-Meger-Olkin (KMO) coefficient was calculated as 0.892. It means that the date is suitable for using PCA and Bartlett Chi Square $p<0.001$. P value <0.05 was considered statistically significant.

RESULTS

A total of 33 eyes of 33 patients with open angle who underwent cataract surgery were included in this study. There were 21 men (63.7%) and 12 women (36.3%) and the mean age was 69.0 ± 8.3 (range 42-82) years.

The results of the UBM measurements are shown in Tables 1 and 2. The postoperative increase in the ARA, TIA, AOD_{250} and AOD_{500} were statistically significant at four quadrants ($p<0.0001$). The average increase in the ARA was 0.064 ± 0.037 mm² (44%), in the AOD_{250} it was 0.056 ± 0.02 mm (70%), in the AOD_{500} it was 0.074 ± 0.03 mm (56%) and in the TIA it was 12.3 ± 4.8º (52%). Among these increments, the most prominent was the increment in the AOD_{250}.

Statistically significant correlations were found between all ACA parameters obtained pre-

TABLE 1: Descriptive statistics of UBM measurements.

Quadrant	ARA (mm²)	AOD_{250} (mm)	AOD_{500} (mm)	Acceleration	y-intercept
Superior					
Preoperative	0.142±0.034	0.078±0.028	0.127±0.037	0.329±0.132	-0.46±8.17
Postoperative	0.205±0.026	0.133±0.024	0.206±0.024	0.054±0.160	21.37±9.88
p value	0.001	0.001	0.001	0.001	0.001
Temporal					
Preoperative	0.147±0.036	0.080±0.031	0.141±0.035	0.330±0.132	1.41±9.37
Postoperative	0.213±0.029	0.137±0.026	0.211±0.020	0.025±0.186	23.86±9.94
p value	0.001	0.001	0.001	0.001	0.001
Inferior					
Preoperative	0.143±0.032	0.078±0.025	0.132±0.034	0.318±0.152	0.068±9.93
Postoperative	0.207±0.027	0.136±0.024	0.205±0.018	0.057±0.150	22.71±8.89
p value	0.001	0.001	0.001	0.001	0.001
Nasal					
Preoperative	0.142±0.034	0.078±0.026	0.130±0.037	0.308±0.148	0.204±9.08
Postoperative	0.207±0.029	0.135±0.021	0.206±0.003	0.039±0.167	22.64±9.13
p value	0.001	0.001	0.001	0.001	0.001

UBM: Ultrasound biomicroscopy; ARA: Angle recess area; AOD: Angle opening distance.

TABLE 2: The comparisons of the mean preoperative and postoperative UBM measurements.

	Preoperative	Postoperative	Difference	p value
ARA (mm^2)	0.144±0.03	0.208±0.02	0.064±0.37	0.0001
AOD250 (mm)	0.079±0.02	0.135±0.02	0.056±0.02	0.0001
AOD500 (mm)	0.133±0.03	0.207±0.02	0.074±0.03	0.0001
TIA (°)	22.7±5.0	35.1±2.9	12.3±4.8	0.0001

ARA: Angle recess area; AOD: Angle opening distance; TIA: Trabecular-iris angle.

operatively (Table 3). Only ARA and AOD_{250} (r=0.42, p=0.013), AOD_{250} and AOD_{500} (r=0.34, p=0.046) were correlated significantly when the same analysis was performed for the postoperative ACA parameters (Table 4).

There were statistically significant correlations between changes in the ARA and AOD_{250} (r=0.54, p=0.001) and AOD_{500} (r=0.74, p=0.0001). We did not find statistically significant correlation between changes in the TIA with other parameters except for AOD_{500} (r=0.46, p=0.007) (Table 5).

According to the PCA results of the temporal quadrant, the extraction values of the differences of the parameters before and after surgery were 33.3% for the TIA, 52.0% for AOD_{250}, 72.1% for ARA and 74.4% for AOD_{500}.

It was 57.0% for AOD_{250}, 72.5% for ARA and 74.0% for AOD_{500} at inferior quadrant, and 51.0%, 74.6% and 79.0% respectively, at the superior quadrant.

At nasal quadrant, the extraction value was calculated as 48.6% for AOD_{250}, 73.9% for AOD_{500} and 87.7% for ARA.

We determined the decrease of acceleration and increase of *y*-intercept at four quadrants and the results were statistically significant (Table 1).

TABLE 3: Preoperative correlation coefficients.

Parameter	ARA(mm^2)	AOD_{250} (mm)	AOD_{500} (mm)	TIA(°)
ARA(mm^2)		r=0.86, p˂0.001	r=0.83, p˂0.001	r=0.56, p=0.001
AOD_{250} (mm)			r=0.73, p˂0.001	r=0.50, p=0.002
AOD_{500} (mm)				r=0.73, p˂0.001
TIA (°)				

ARA: Angle recess area; AOD: Angle opening distance; TIA: Trabecular-iris angle.

TABLE 4: Postoperative correlation coefficients.

Parameter	ARA (mm^2)	AOD_{250} (mm)	AOD_{500} (mm)	TIA(°)
ARA(mm^2)		r=0.42, p=0.013	p=0.161	p=0.911
AOD_{250} (mm)			r=0.34, p=0.046	p=0.417
AOD_{500} (mm)				p=0.163
TIA(°)				

ARA: Angle recess area; AOD: Angle opening distance; TIA: Trabecular-iris angle.

TABLE 5: Correlation coefficients of the differences between preoperative and postoperative UBM measurements.

Parameter	ARA (mm^2)	AOD_{250} (mm)	AOD_{500} (mm)	TIA(°)
ARA(mm^2)		r=0.54, p=0.001	r=0.74, p=0.0001	p=0.072
AOD_{250} (mm)			r=0.47, p=0.005	p=0.487
AOD_{500} (mm)				r=0.46, p=0.007
TIA(°)				

ARA: Angle recess area; AOD: Angle opening distance; TIA: Trabecular-iris angle.

DISCUSSION

In this study, we investigated the deterministic values of ARA, AOD and TIA in patients with open angle undergoing cataract surgery, and tried to figure out whether they were interchangeable parameters or not.

In the present study, we found that ACA significantly increased after cataract extraction, by approximately 50% of the initial value, by the four parameters used: AOD_{250}, AOD_{500}, TIA and ARA. These findings suggest that an enlarged lens narrows the ACA. In addition to the volume of the lens, the iris shifts backwards after cataract surgery, since the cataractous lens is no longer present.

The first case series was reported by Pavlin et al.[5] The authors first suggested the use of AOD_{250}. The trabecular meshwork (TM) was thought to be located in this region. In the case of apposition in that location, it was assumed that there would be no flow of fluid through the TM. However, AOD may be influenced by the variabilities in the anterior iris surface. Therefore, the AOD_{250} is rarely used at present due to the high variability in iris configuration at this location. Currently, in general, the authors tend to rely on the AOD at 500 μm as the best estimate of angle opening. However, it should be remembered that AOD_{500} also may be influenced by the variabilities in the anterior iris surface since it also refers to only a single point on the iris surface.

When evaluated by paired sample t test, AOD_{250} was initially found as the most prominent parameter which increased 70% in our study. To eliminate the potential bias which could be created by the presence of different units, means and standard deviations, the PCA analysis was performed and revealed that the lowest extraction value was AOD_{250} and the highest extraction value was AOD_{500} in all quadrants. Differently, at nasal quadrant, the highest extraction value was determined as ARA. There were also a statistically significant positive correlations in the postoperative, preoperative values and the differences obtained after surgery between the ARA, AOD_{250} and AOD_{500} parameters.

Pavlin et al. also attempted to define the angle in degrees and introduced the term TIA.[4] Our results showed that the TIA also increased significantly after cataract extraction similar to the other parameters. However the change in TIA was only correlated well with the AOD_{500}. This finding supports the value of AOD_{500} among the ACA parameters. On the other hand, it should be remembered that the angle definition in degrees is also somewhat subjective due to variation in the iris configuration. The image analysis was difficult, because the observers were required to manually place calipers in order to derive values from each image. We think that manually placing calipers on the areas of interest in order to derive values from each image is an important limitation of the UBM technology. The semi-automated program that calculates ACA parameters once the scleral spur is identified is capable to overcome the issue of reproducibility.

Ishikawa et al. reported that AOD assumes the iris surface as a straight line and it does not take irregularities of iris curvature into consideration.[9] In order to overcome this issue, they defined ARA and developed a quantitative image analysis program (UBM Pro2000). The two important data, acceleration and *y*-intercept, were provided by the linear regression analysis performed on the AOD measurements by UBM Pro2000. They suggested that by using three numerical values (ARA, acceleration, and *y*-intercept), many types of angle configurations can be described quantitatively in a more accurate fashion. It is obvious that using ARA and linear regression analysis of the ACA gives us more reliable information about angle, especially in the patients with narrow, occludable or closed angle, since these parameters take the irregular curvature of the iris surface into account. Furthermore, we suppose that using these parameters in the evaluation of the ACA before or after any ocular intervention will be more appropriate for the accuracy of the measurements.

In our study, the *y*-intercept, which measures the distance between the scleral spur and the iris surface along the line perpendicular to the plane of the TM, was significantly increased at all quadrants after the cataract extraction, while the acceleration decreased (Figure 3). The changes of these two parameters along with the change in ARA are strong indicators of the accuracy of UBM measurements for the influence of the surgery on ACA parameters.

Although the idea of superiority of the ARA to AOD is obvious, our study showed that AOD_{500} is as valuable as ARA in the quantitative evaluation of the patients with open angle. We suggest that AOD_{500} can be used for the evaluation of the angle before and after any ocular intervention in patients with open angle by the observers who do not have UBM Pro2000 software in their UBM model. The UBM models with image analysis software can provide more accurate quantitative information by measuring ARA, acceleration and *y*-intercept. However it should be remembered that the accuracy of such measurements are difficult to assess since no exact method exists to determine the dimensions of ocular structures. To eliminate sources of possible errors, attempts must continue to improve the precision of measurements and the accuracy and reliability of each ACA parameter.

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