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Comparison of axial length, intraocular lens power and refractive results using optical and ultrasound biometry

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ABSTRACT

Aims: The aim of the study was to determine whether a new non-contact partial coherence interferometry method utilized by the Nidek-AL Scan agrees sufficiently with applanation ultrasound A-scan technique in intraocular lens power calculation to replace it.

Methods: This was a prospective study of 150 eyes of 125 patients who underwent cataract surgery with the Nidek AL-scan and ultrasound biometry. The intraocular lens power AL and ACD were compared between two methods with Pearson correlation and Bland-Altman analysis. The mean difference between final spherical equivalent refraction and the prediction with each technology was compared.

Results: On average, the axial lengths measured by the Nidek AL-scan were longer by 0.11±0.13 mm compared to the ultrasound biometry ($p<0.001$). Pearson correlation analysis showed a very high correlation between the 2 devices for AL and IOL power ($r>0.90$, $p<0.05$) and a high correlation for ACD (r: 0.886 $p<0.001$). On Bland-Altman analysis, 95% limits of agreement for all parameters were within clinically acceptable limits, and there was good agreement between 2 devices. The mean absolute error when the SRK-T formula for AL-scan was 0.20±0.17 D, whereas for US, 0.29±0.25 D ($p<0.001$).

Conclusion: The intraocular lens power and AL derived from both groups were similar. The agreements between them were high. Two techniques may be used interchangeably.

Keywords: Biometry, axial length, IOL power

INTRODUCTION

Nowadays modern cataract surgery offers refractive surgery as well as visual rehabilitation. It also targets emmetropia. In other words, patients should not wear glasses after surgery. Rapid advances in cataract and refractive surgery, in parallel with these developments, patients vision expectations after surgery have increased. these advantages are cataract surgeries performed through sutureless incisions.[1] widespread use of optical biometrics that take measurements independently of the observer[2] and especially development of aspheric, multifocal and toric intraocular lenses that began to be used.[3] Therefore, it required accurate calculation of intraocular lens power. Refractive errors that occur after cataract surgery cause extreme patient dissatisfaction. Therefore, to calculate consistent and accurate intraocular lens power, the margin of error must be minimal.

Various biometry devices are available today. It works on the principle of 'partial coherence interferometer' IOLMaster (Zeiss) and working with the principle of 'optical low coherence reflectometry' Lenstar (Haag-Streit). AL-scan (Nidek) working with the new 'partial coherence interferometer' method device and is available in our clinic. The most important disadvantage of optical biometrics is that they cannot measure dense cataracts.

It is not able to take measurements or even if it takes measurements, it is taken with low reliability. Zeiss company has developed immersion ultrasound called 'sonolink connection' for IOLMaster. A method that takes measurements using the method and can directly transfer information to optical biometry. NIDEK company also provides A-mode applanation ultrasound measurement for AL-scan. Presented an A-mode ultrasound probe that receives and transmits the same information to AL-scan. Both options presented to solve inability to take measurements in patients with dense cataracts.

The aim of this study is to compare AL-scan optical biometry and which is compactly located in the same device. A-mode ultrasound probe's measurements according to axial length, intraocular lens power and refractive results in terms of consistency and reliability.

METHODS

This prospective sequential cross-sectional non-randomized study was conducted in Turgut Özal University Faculty of Medicine Hospital between August 2013 and March 2014. 150 eyes of 125 patients who underwent phacoemulsification surgery due to cataract were included in the study.

Ethical approval for the study was received from the Turgut Özal University Clinical Researches Ethics Committee (Date: 22.08.2013, Decision No: 825). All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki.

Patients who had uncomplicated phacoemulsification surgery and with capsule one-piece hydrophobic acrylic IOL (Tecnis ZCB00, AMO) implantation were included.

Exclusion Criteria

- Optical biometry cannot take axial length measurement
- Previous eye surgery (vitrectomy, excimer laser)
- Patients with visual acuity lower than 20/40 after surgery due to reasons other than cataract (macular degeneration, diabetic macular edema, amblyopia, advanced corneal pathology (dystrophy, existing irregular astigmatism or pterygium)
- Development of complications during surgery (posterior capsule rupture, development of zonule dialysis, placement of a capsule tension ring)
- Corneal astigmatism greater than 2.5 D
- Cataract surgery combined with a secondary procedure (trabeculectomy, limbal relaxing incision)

After a full ophthalmological examination of the cases, all patients are first examined with Nidek AL-scan by an experienced technician. Keratometry, AL, ACD and limbus-limbus distance were measured in automatic dual mode. Then, IOL power was calculated using SRK-T, Hoffer Q, Holladay-1 and Haigis formulas targeting emmetropia postoperatively. Following application of topical anesthetic proparacaine 0.5% (Alcaine 0.5%) drops A-Scan ultrasound mode was switched on and measurements were made with the ultrasound probe as recommended by the company guide. Ten times touched during measurement. Axial lengths taken with ultrasound were transferred to the main screen and IOL power was calculated with SRK-T, Hoffer Q, Holladay-1 and Haigis formula. The power of the IOL to be implanted is SRK-T recommended by optical biometry.

During the surgical procedure, a 2.8 mm wide corneal incision was made, as approximately 5.5 mm diameter capsulorhexis was made, phacoemulsification was performed with WHITESTAR Signature® AMO, and the IOL was placed in the capsular bag. All patients were observed on the 1st day, 1st week and 1st month after surgery. Final refractive results were obtained at 1 month with an autorefractometer (KR 8800, Topcon, Japan) and confirmed by subjective refraction.

Biometry parameters (AL, K, and ACD) and IOL power were compared. To compare the predictability and consistency of biometrics, the target refractive value was compared with the refractive value obtained after surgery. Consistency and predictability were evaluated by numerical error (NE) and absolute error (AE). The difference between the refractive error obtained after the surgery and the target refractive error was determined as 'numerical error' (NE), and the absolute value of the difference between them was determined as 'absolute error' (AE) and evaluated.

Statistical Analysis

The data obtained were recorded on the computer in SPSS 16.0 (statistical Package for the Social Sciences, IBM). Paired samples t test was used to compare the data obtained from the devices. Correlation between measurements was evaluated by Pearson correlation analysis. It is a number between (-1,00 -0,90) and (+1,00 +0,90) values evaluated very good, between (-0,89 -0,70) and (+0,89 +0,70) values evaluted good, between (-0,69 -0,50) and (+0,69 +0,50) values evaluated moderate and between (+0,49 -0,49) values evaluated bad. Evaluations were made within a 95% confidence interval, and a p value of less than 0.05 was considered a statistically significant difference. Bland-Altman plots were drawn to evaluate inter-device agreement. In these graphs, the 95% concordance limit was taken as±1.96 standard deviation.[4]

RESULTS

Patients included in the study 60 were women and 65 were men. The average age of the patients was 63±6.2 years. There was a very good correlation between AL measurements taken with AL-scan and Ultrasound. (r=0.995 p<0.001). There was a good correlation in ACD measurements. (r=0.886 p<0.001). The IOL power obtained with both devices correlates very well according to 4 separate formulas. (r=0.993 for SRK-T, r=0.992 for Hoffer Q, r=0.993 for Holladay, r=0.991 for Haigis).

Mean AL measurements were 23.54±1.33 mm for AL-scan and 23.43±1.35 mm for ultrasound biometry (p<0.001). Higher AL measurements were obtained with AL-scan compared to ultrasound. ACD measurements were 3.17±0.44 mm for AL-scan and 3.16±0.39 mm for ultrasound biometry respectively. (p=0.486). There is a statistically significant difference between the IOL powers obtained by AL-scan and Ultrasound according to 4 formulas (p<0.001). IOL power values obtained with AL-scan are higher than ultrasound biometry (Table 1).

Table 1. Comparison of AL, ACD and IOL power measured by AL-scan and ultrasound biometry

Parameters	AL-scan	A-mode US	p value
AL (mm)	23.54±0.11 (1.33)	23.43±0.11 (1.35)	<0.001
ACD (mm)	3.17±0.035 (0.44)	3.16±0.031 (0.39)	0.486
IOL Power SRK-T (D)	21.06±0.30 (3.76)	20.89±0.30 (3.70)	<0.001
IOL Power Hoffer Q (D)	21.04±0.33 (4.06)	20.77±0.32 (3.97)	<0.001
IOL Power Holladay (D)	21.04±0.32 (3.94)	20.84±0.32 (3.87)	<0.001
IOL Power Haigis (D)	21.09±0.31 (3.82)	20.91±0.32 (3.93)	<0.001

ACD: Anterior chamber depth, IOL: Intraocular optic lens

The mean difference between AL-scan and US was 0.11±0.13 mm for AL and 0.012±0.20 mm for ACD. In terms of IOL power, it was 0.167±0.43 D for SRK-T formula, 0.27±0.50 D for Hoffer Q, 0.20±0.48 D for Holladay, and 0.18±0.53 D for Haigis (Table 2).

Table 2. Difference and compliance range between the parameters measured by AL-scan and ultrasound biometry

		%95 agreement range	
Parameters	**Difference±SD**	**Lower limit**	**Upper limit**
AL (mm)	0.110±0.13	-0.145	0.365
ACD (mm)	0.012±0.20	-0.38	0.40
IOL Power SRK-T (D)	0.167±0.43	-0.69	1.02
IOL Power Hoffer Q (D)	0.27±0.50	-0.72	1.25
IOL Power Holladay (D)	0.20±0.48	-0.75	1.14
IOL Power Haigis (D)	0.18±0.53	-0.86	1.22

SD: Standart deviation, IOL: Intraocular optic lens

When the compatibility of the measurements and IOL power values of both methods was examined with Bland-Altman graphs, the 95% agreement range of all data obtained was narrow and there was good agreement. All data were within clinically acceptable limits (Figure 1).

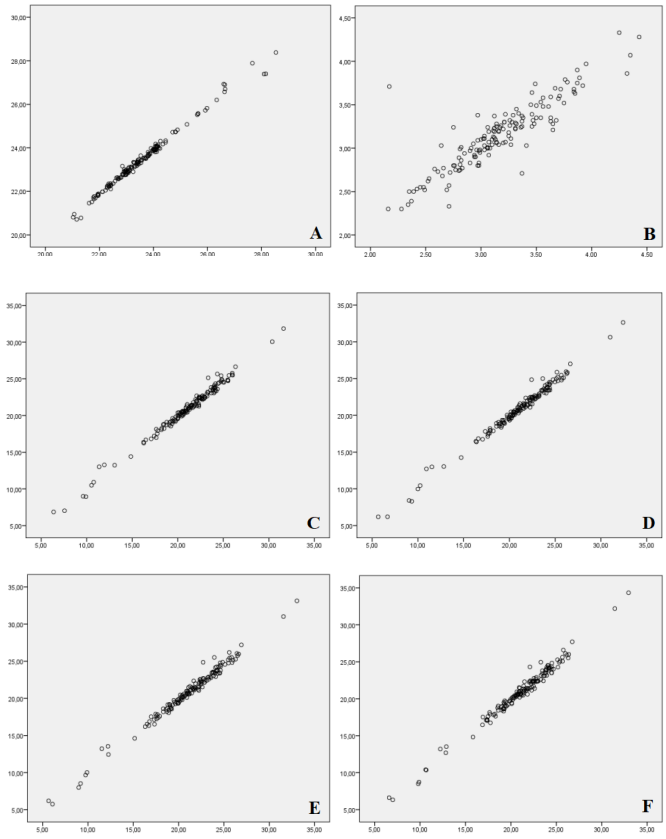

Figure 1. Bland- Altman analysis between AL-scan optical biometry and ultrasound biometry for AL, ACD, A) Axial length, B) Anterior chamber depth, C) IOL power SRK-T, D) IOL power holladay, E) IOL power hoffer Q, F) IOL power haigis
IOL: Intraocular optic lens

While there is no statistically significant difference between the keratometric values obtained from 2.4 mm and 3.3 mm with AL-scan in flat keratometry (K1), there is a significant difference between step keratometry (K2) and average keratometric values (K mean) (p<0.001) (Table 3).

Table 3. Keratometric values

Parameters	**2.4 mm**	**3.3 mm**	**p value**
Flat K, K1 (D)	43.64±1.65	43.62±1.67	0.267
Steep K, K2 (D)	44.47 ±1.71	44.39 ±1.68	<0.001
K Mean (D)	44.05 ±1.65	44.00 ±1.65	<0.001

Considering the refractive results, the average numerical error for AL-scan is -0.02±0.26 D for the SRK-T formula, is -0.01±0.33 D for Hoffer Q, is -0.01±0.28 D for Holladay, is -0.04±0.34 for Haigis respectively. As a for numerical error distrubition 107 eyes (71%) are within±0.25 D, 140 eyes (93%) are within±0.50 D for SRK-T, 84 eyes (56%) are within±0.25 D, 131 eyes (87%) are within±0.50 D for Hoffer Q, 100 eyes (67%) are within±0.25 D, 136 eyes (91%) are within±0.50 D for Holladay, 74 eyes (50%) are within±0.25 D, 128 eyes (85%) are within±0.50 D for Haigis respectively. All eyes are within±1.00 D for all 4 formulas (Table 4, Figure 2).

Table 4. Numerical error and absolute error

	Numerical error			**Absolute error**		
	AL-scan	**Ultrasound**	**p value**	**AL-scan**	**Ultrasound**	**p value**
SRK-T	-0.023±0.26	0.09±0.37	<0.001	0.20±0.17	0.29±0.25	<0.001
Hoffer Q	-0.011±0.33	0.17±0.42	<0.001	0.26±0.21	0.36±0.28	<0.001
Holladay	-0.012±0.28	0.13±0.35	<0.001	0.21±0.19	0.30±0.24	<0.001
Haigis	-0.042±0.34	0.083±0.45	<0.001	0.28±0.20	0.35±0.29	<0.002

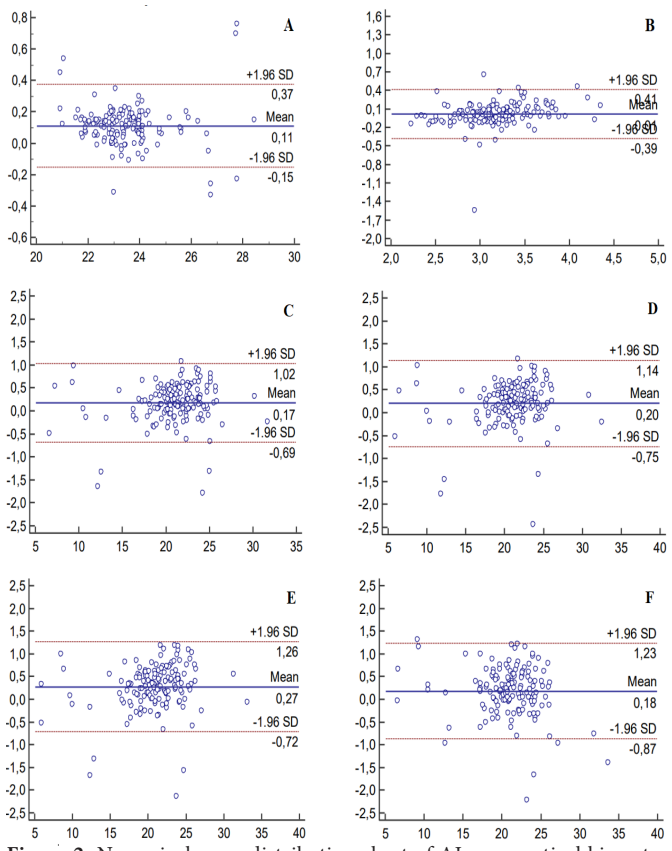

Figure 2. Numerical error distribution chart of AL-scan optical biometry and ultrasound biometry, A) Aksial length, B) Anterior chamber depth, C) IOL power SRK-T, D) IOL power holladay, E) IOL power hoffer Q, F) IOL power haigis
IOL: Intraocular optic lens

The average numerical error for ultrasound biometry is 0.09±0.37 D for the SRK-T formula, is 0.17±0.42 D for Hoffer Q, is 0.13±0.35 D for Holladay, is 0.08±0.45 D for Haigis

respectively. As a for numerical error distrubition 83 eyes (55%) are within ±0.25 D, 124 eyes (83%) are within ±0.50 D for SRK-T, 69 eyes (46%) are within ±0.25 D, 111 eyes (74%) are within ±0.50 D for Hoffer Q, 76 eyes (50%) are within ±0.25 D, 121 eyes (81%) are within ±0.50 D for Holladay, 63 eyes (42%) are within ±0.25 D, 113 eyes (75%) are within ±0.50 D for Haigis respectively. All eyes are within ±1.50 D in the 4 formulas (Table 4, Figure 3).

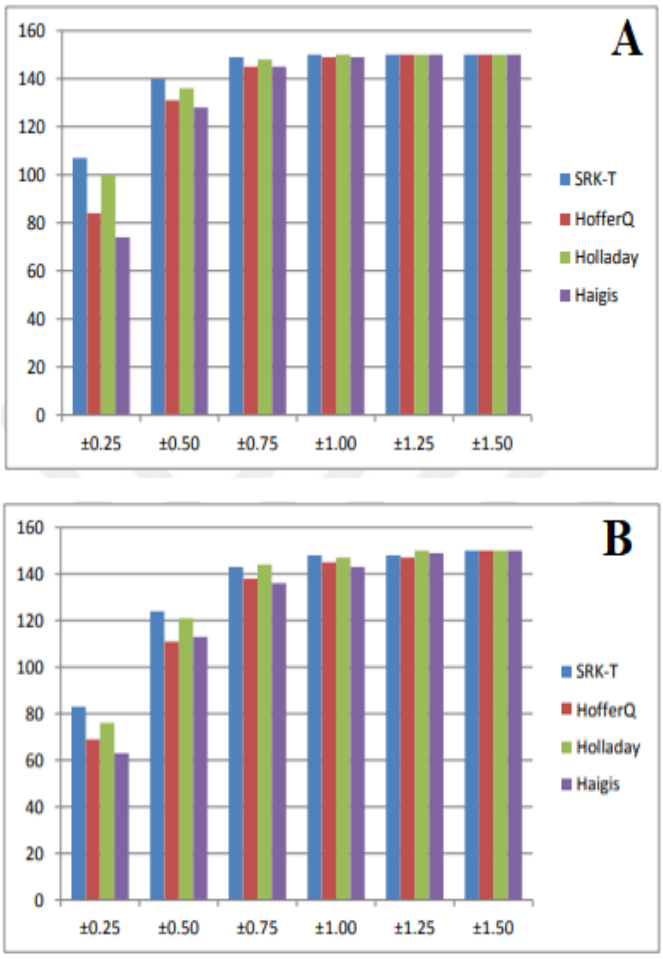

Figure 3. A) Numerical error distrubition chart of AL-scan optical biometer, B) Numerical error distrubition chart of ultrasound biometer

DISCUSSION

When AL cannot be obtained with optical biometrics, many doctors perform IOL power calculating with ultrasound or immersion biometry in addition to auto-keratometry. Keratometry and AL measurements cannot be used interchangeably, even when the efficiency obtained with different biometry methods is used in the same formula. In addition, it is not a practical method to enter an AL measurement that we obtained externally with a different device into the optical biometry device. Due to this structural difficulty, Nidek; In addition to optical biometry, the AL-scan device, which measures axial length with A-mode ultrasound and transfers information to the same device, has been introduced into clinical practice.

In this study, we compared the measurements of AL-scan, a new optical biometry device, with the measurements made by the contact A-mode ultrasound probe in terms of consistency and reliability in terms of axial length, intraocular lens power and refractive results.

Accurate AL measurement is critical in calculating IOL power. Many modifications have been developed for accurate AL measurement with the US method.[5,6] Since the introduction of optical biometrics, accurate measurement of AL has been improved significantly.[7,8] An error of 0.10 mm in AL measurement causes an average refraction deviation of 0.27 D.[8] Additionally, a 1.0 D increase or decrease in IOL power causes a refractive deviation of approximately 0.67 D.[9]

In a study conducted by Eleftheriadis on 100 patients, the average axial length taken with IOLMaster was found to be 0.47 mm longer than the average axial length taken with ultrasonic biometry.[8] In their study comparing Lenstar and US biometry, Buckhurst et al.[10] found the measurements taken from US to be 0.14 mm shorter. In another study by Roncevic et al.,[11] the axial length taken with Lenstar was found to be 0.24±0.25 mm longer than US. Additionally, they found the 95% concordance limit to be between -0.51 and 0.02. Roncevic et al. attributed the applanation US method's ability to obtain shorter AL measurements compared to optical biometry to the pressure on the cornea and the fact that the two methods take measurements from different points. While optical biometrics take measurements from the front surface of the cornea to the retina pigment epithelium, US biometrics take measurements up to the inner limiting membrane. In addition, while optical biometrics take measurements from the visual axis because they are fixation-based, US biometrics take measurements from the optical axis.

In our study, AL-scan optical biometry gave longer results than AL measurements taken with US (0.11±0.29 mm). The 95% concordance limit is between -0.145 and 0.365 and is clinically acceptable.

Apart from Axial Length, one of the other important factors for accurate IOL calculation are keratometric measurements and anterior chamber depth. A 0.1 D error in the keratometry value causes approximately 0.1 D refractive error. When calculating IOL power, optical biometry AL-scan uses K values obtained from 2.4 mm, while US uses K values obtained from 3.3 mm. In the study conducted by Huang et al.[12] with AL Scan, they found that the K values taken from 2.4 mm were 0.03 D steeper for flat K, 0.43 D steeper for steep K, and 0.03 D steeper for average K than the K value taken from 3.3 mm.

In our study, 2.4 mm was 0.02 D for flat K, 0.08 D for vertical K, and 0.08 D for vertical K compared to 3.3 mm. The average K was found to be 0.05 D steeper. While there is no statistically significant difference for flat K ($p=0.267$), there is statistically significant difference for steep K and average K. However, this difference is not clinically significant.

Anterior chamber depth is required when using the biometry formulas Haigis, Holladay 2 and Olsen formulas. Using the Haigis formula, a 0.12 mm difference in anterior chamber depth in an eye with an axial length of 23.5 mm and an average keratometry of 44 D causes a deviation of 0.06 D in the target refractive result.[13] When Savini et al.[14] compared the Sirius device, which measures with the Scheimpflug principle, and A-mode US according to the anterior chamber depth, they found the ACD obtained by the Scheimpflug device to be 0.04 mm deeper than that of A-mode US. In our study, ACD showed a good correlation between AL-scan and US, which work on the Scheimpflug principle (r: 0.886 $p<0.001$). ACD measurements were 3.17±0.44 mm for AL-scan

and 3.16±0.39 mm for ultrasound, respectively, and there was no statistically significant difference (p=0.486). The 95% agreement range was -0.27 to 0.51, indicating good clinical agreement.

In the study conducted by Turhan et al.[15] there was high correlation between biometric measurements and IOL power calculations, however the mean differences between the two biometry devices were significant. Another clinical trial Can et al.[16] considering that Lenstar optical biometry is an acceptable biometric device today and that ultrasound biometry gives different measurements in our results, it is concluded that ultrasound biometry cannot be used instead of new generation optical biometrics, even though there is a very good correlation between the two devices.

In our study, although there is a statistical difference between the two devices in terms of parameters, the confidence interval in the Bland Altman model is within the 95 percent confidence interval. Since our study also includes postoperative refractive results in addition to these studies, it does not seem possible to reach a definitive conclusion without evaluating refractive deviations.

When the IOL power values obtained from AL-scan and US biometry are compared according to the 4 formulas, the IOL power values obtained with AL-scan are higher than those obtained from ultrasound biometry and there is a statistically significant difference. However, when examined by Bland-Altman analysis, there was good agreement between the 2 methods according to all 4 formulas and it was at a clinically acceptable level.

When we examine the numerical and absolute refractive errors obtained by the 2 methods, the average numerical error for AL-scan is -0.02±0.26 D for the SRK-T formula, -0.01±0.33 D for Hoffer Q, -0.01±0.28 for Holladay, respectively. For D and Haigis it is -0.04±0.34 D. The numerical error for ultrasound biometry is 0.09±0.37 D for the SRK-T formula, 0.17±0.42 D for Hoffer Q, 0.13±0.35 D for Holladay, and 0.08±0.45 D for Haigis, respectively. Refractive results obtained with US are more hyperopic than those obtained with AL-scan optical biometry. Although there is a statistically significant difference between the mean numerical errors, it is at a clinically acceptable level.

The absolute error for AL-scan is 0.20±0.17 D, 0.26±0.21 D, 0.21±0.19 D and 0.28±0.20 D for SRK-T, Hoffer Q, Holladay and Haigis formulas, respectively. For US, they are 0.29±0.25 D, 0.36±0.28 D, 0.30±0.24 D and 0.35±0.29 D, respectively.

Refractive results obtained with US biometry showed more deviation from the target refraction than AL-scan. Although there is a statistically significant difference between the absolute errors obtained by the 2 methods, this difference is at a clinically acceptable level.

In their study with IOLMaster and US, Roy et al.[17] obtained absolute refractive error as 0.30±0.25 D and 0.94±1.10 D, respectively. US biometry showed greater deviation from target refraction than IOLMaster.

European Cataract and Refractive Surgery Society reported in 2012, biometric measurements in cataract surgery in order to be considered of good quality, at least 87% of the patient group must have a score of ±1.00 D must be within the refractive error margin.[18]

Rajan et al.[19] also compared IOLMaster with US biometry. While the numerical absolute error was 0.52±0.32 D in the IOLMaster group, it was 0.62±0.40 D in the US group, and US biometry deviated more from the target refraction than IOLMaster.

The disadvantages of our study are that we make a separate classification for short normal and long aksial length and whether the 2 biometric measurements differ in these different groups.

CONCLUSION

As a result, AL, ACD and IOL power values obtained by AL-scan (Nidek) optical biometry and ultrasound biometry offered in the same device complex are in good agreement with each other, and measurement differences and refractive errors between methods are clinically negligible. Therefore, AL-scan optical biometry and ultrasound biometry can be used interchangeably in biometric measurements before cataract surgery.

ETHICAL DECLARATIONS

Ethics Committee Approval

The study was carried out with the permission of Ethical Committee of Turgut Özal University (Date: 22.08.2013, Decision No: 825).

Informed Consent

All patients signed and free and informed consent form.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

The authors declared that this study has received no financial support.

Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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