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Refractive Outcome after Phacoemulsification Using Optical Biometry versus Immersion Ultrasound Biometry

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ABSTRACT
Purpose: To compare refractive outcome after phacoemulsification using optical biometry versus immersion ultrasound biometry (US) .**Patients and methods:** A prospective, comparative, non-randomized interventional study included 100 eyes divided into 2 groups: **Group (A):** (Immersion US biometry) included 50 eyes. Axial Eye Length (AEL) was measured by immersion B scan (immersion A-scan with B- mode guided image). It was further subdivided into **Group A1** (AEL ≥ 25 mm) and **Group A2** (AEL < 25 mm). **Group B** (Optical biometry) included 50 eyes. AEL was measured using optical biometry. It was also subdivided into **Group B1** (AEL ≥ 25) mm and **Group B2** AEL < 25. Intra ocular lens (IOL) power was calculated using Haigis formula targeting post-operative refraction –0.5 to -1 D. Phacoemulsification with posterior chamber IOL was performed. The 2 groups were compared preoperatively for AEL, Keratometic measurements, uncorrected visual acuity (UCVA), best corrected visual acuity (BCVA) and density of cataract. They were compared postoperatively for UCVA, BCVA, spherical equivalent (SE) and mean absolute error (MAE). **Results:** The study included (100 eyes). Group A1 included 9 eyes (18%) and Group A2 included 41 eyes (82%). Group B1 included 18 eyes (36%) and Group B2 Included 32 eyes (64%). Preoperative comparisons revealed insignificant statistical differences between the 2 groups in the mean AEL, IOL power, preoperative UCVA and BCVA, degree and density of cataract, and K readings. Post operatively there was insignificant statistical differences between the 2 groups in the mean of UCVA and BCVA. There was insignificant statistical differences between subgroups A1and B1 and subgroups A2 and B2 in the median of SE and MAE. **Conclusion:** The immersion B scan biometry and optical biometry gave comparative results with precise final post-operative refractive outcome.
Keywords: Optical biometry, Immersion ultrasound biometry, phacoemulsification.

INTRODUCTION
Biometry is the process of measuring the axial eye length (AEL), the keratometric (K) readings and assessing these data and use special formulas to determine the ideal intraocular lens (IOL) power [(1)]**.** Accurate IOL power calculation is crucial to ensure satisfactory post-operative refractive outcome after cataract surgery [(2)]. Precise measurements of AEL data and keratometric values are critical[(3)]. Applantion ultrasound biometry has been the gold standard for IOL calculation, however the introduction of optical biometry using partial coherence interferometry (PCI) has steadily established itself as the new standard [(4)]. Ultrasound biometry (US) utilizes the ultrasound waves, emitted by a piezoelectric crystal and delivered with a probe with average frequency of 10 MHz. Determination of eye morphometry via ultrasound is based upon the differential return of the ultrasonic waves by varying tissue types. The AEL can be measured using either contact or immersion techniques. In the contact method, the probe touches the cornea and may result in corneal compression and a shorter axial length. Immersion A-scan eliminates corneal compression by removing probe contact, as it remains between 5 to 10 mm away from the cornea, allowing more precise measurements and has been shown to be superior to contact biometry [(5)(6)] . The immersion B- scan (known as immersion A-scan with B-mode guided image) is an immersion A-scan with B-mode guided image, which integrates the advantages of immersion A scan and the B-scan and overcome the weakness of the two methods [(7)] .The optical method is a non –contact technique that is highly reproducible, observer-independent and therefore potentially more accurate [(8)] . While the partial coherence interferometry (PCI) based models use diode laser infrared light to measure AEL, the low-coherence optical reflectometry (LCOR) based models use a super luminescent diode laser [(9)] .

The differences between ultrasound biometry and optical biometry have clinical implications. The first difference is that the resolution improves as wavelength decreases. As light has a short wavelength compared to sound, laser has better resolution. Therefore, the accuracy of AL with ultrasound is approximately 0.10-0.12mm compared to 0.012 mm for optical AL. The second difference is that the U/S biometry measures AEL along the anatomic axis or optical axis, from the corneal vertex to the internal limiting membrane (ILM**)** of the fovea, whereas the optical biometry measures AEL from the second principle plane of the cornea (0.05 mm deeper than the corneal apex) to the photoreceptor layer (0.25mm deeper than ILM of the fovea [(10)] .

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PATIENTS AND METHODS

A prospective, comparative non-randomized interventional study was carried out at Al-zahraa university hospital between May 2016 and April 2018. **The study protocol adhered to the tenets of the declaration of Helsinki and was approved by the ethics board of Al Azhar University. An informed written consent was signed by each patient .**

We included 100 eyes with different grades of cataract scheduled for phacoemulsification with foldable IOL implantation. We enrolled patients with clear cornea and uneventful phacoemulsification surgery.

We excluded patients with:

- Previous ocular surgery
- History of ocular trauma
- Uncooperative patients
- Ophthalmic diseases (other than cataract) that could affect vision, ability to fixate or axial length measurements e.g.: retinal detachment, retinitis pigmentosa, macular disease or glaucoma
- Corneal opacities or irregularities
- Eventful phacoemulsification surgery e.g.: Posterior capsule rupture, vitreous prolapse, zonular dialysis, IOL decentration, wound suturing, and conversion to ECCE.

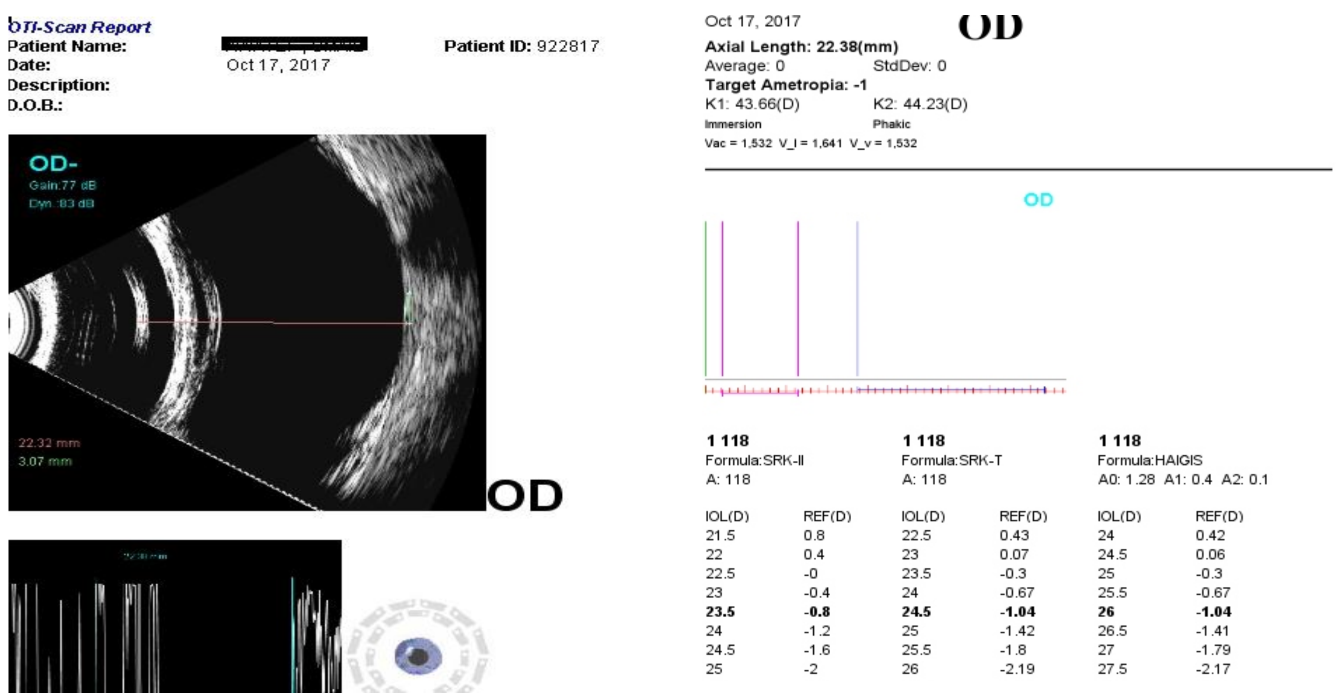
Preoperative ophthalmic examination were done for all patients included:

- Visual acuity assessment: unaided and best correct visual acuity using Landolt C chart and was converted to Decimal notation
- Slit lamp examination for the anterior segment, Cataract were graded according to Lens Opacities Classification System III (LOCS III)
- Intra-ocular pressure measurement using the Goldmann applanation tonometer
- Fundus examination for the posterior segment using 90 D non-contact lens.
- Automated keratometry using NIDEK: KM -500 AUTO KERATOMETER® (NIDEK, Gamagori, Japan) which gives K readings in two perpendicular meridians.

Patients were divided into 2 groups:

Group (A): Included 50 eyes. AEL was measured by immersion ultrasound biometry B-scan (immersion A with B-mode guided image) using OTI Scan 2000, (Optos ,Florida, USA).

The probe was inserted into the immersion shell 5-10 mm from the cornea. Patient directed to watch the center of the probe. AEL was determined by estimating an optical line through the eye (perpendicular to the cornea and lens) thus ensuring precise centration of the corneal peak. The point where the vector A-super sample line crossed the retina was approximately 3mm from the optic disc edge (Fig. 1) or approximately 4.5 mm from the disc center (Fig.2). Final AL was obtained by the average value of 3 consecutive measurements of the distance from corneal vortex to the macula or from crest of anterior corneal surface to the crest of the macular retinal surface with an electronic measuring scale [7].



A B

Fig.(1): A. AEL measured by an immersion A scan mode with B –mode guided image, the vector A-super sample line crossed the retina was approximately 3mm from the optic disc edge. ***B.*** The calculated IOL data

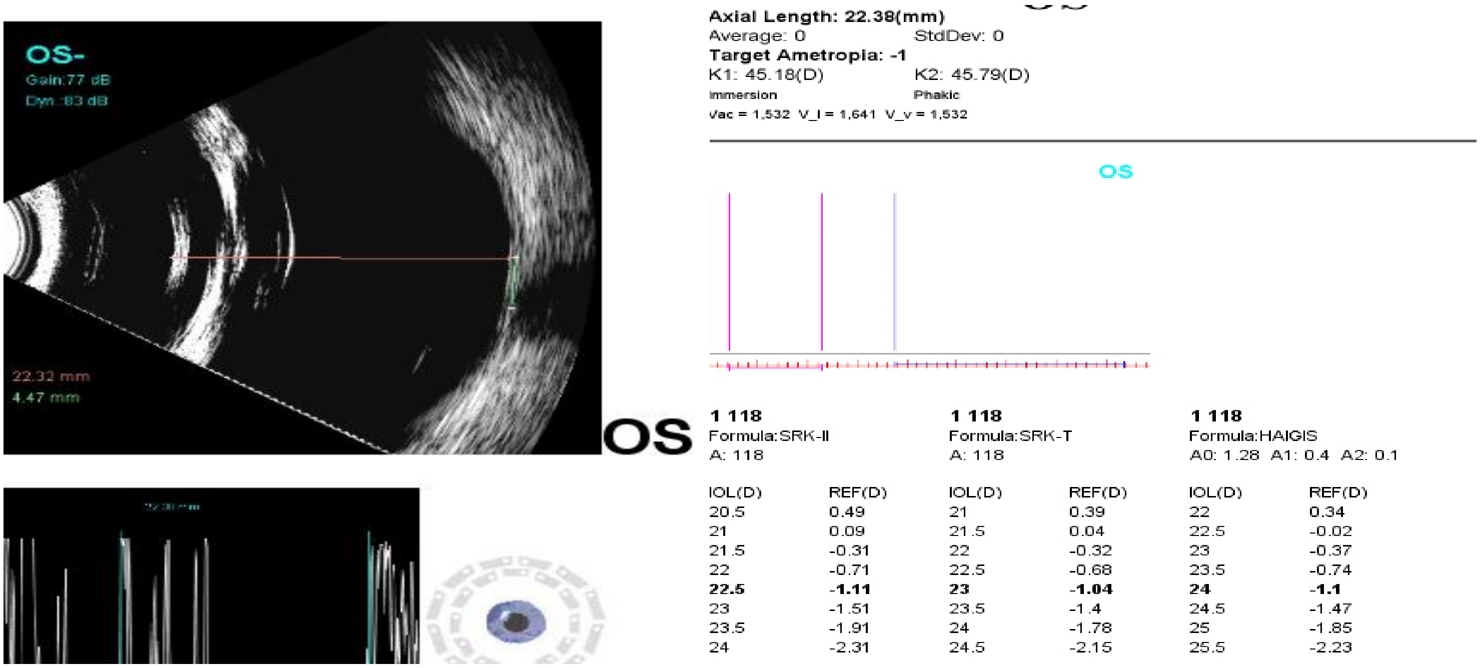
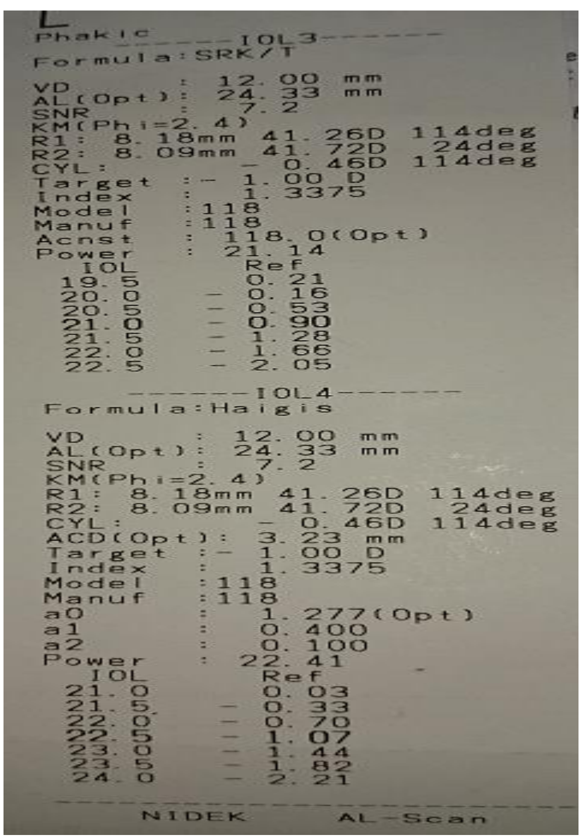


Fig. (2): A. AEL measured by an immersion A scan mode with B –mode guided image, the vector A-super sample line crossed the retina was approximately 4.5 mm from the optic disc center.

B. The calculated IOL data

Group (B): Included 50 eyes. Axial length of the globe was measured using optical biometry NIDEK AL Scan® (Nidek, Gamagori, Japan) Fig.3

IOL power calculation was determined using Haigis formula aiming for post-operative refraction – 0.50 to -1 D


L
Phakic ------IOL3------
Formula:SRK/T
VD : 12.00 mm
AL(Opt): 24.33 mm
SNR : 7.2
KM(Phi=2.4)
R1: 8.18mm 41.26D 114deg
R2: 8.09mm 41.72D 24deg
CYL: - 0.46D 114deg
Target :- 1.00 D
Index : 1.3375
Model :118
Manuf :118
Acnst : 118.0(Opt)
Power : 21.14

IOL	Ref
19.5	0.21
20.0	- 0.16
20.5	- 0.53
21.0	- 0.90
21.5	- 1.28
22.0	- 1.66
22.5	- 2.05

------IOL4------
Formula:Haigis
VD : 12.00 mm
AL(Opt): 24.33 mm
SNR : 7.2
KM(Phi=2.4)
R1: 8.18mm 41.26D 114deg
R2: 8.09mm 41.72D 24deg
CYL: - 0.46D 114deg
ACD(Opt): 3.23 mm
Target :- 1.00 D
Index : 1.3375
Model :118
Manuf :118
a0 : 1.277(Opt)
a1 : 0.400
a2 : 0.100
Power : 22.41

IOL	Ref
21.0	0.03
21.5	- 0.33
22.0	- 0.70
22.5	- 1.07
23.0	- 1.44
23.5	- 1.82
24.0	- 2.21

NIDEK AL-Scan

Fig. 3. Print out of the optical biometry.

Surgical Technique: Standard Phacoemulsification cataract surgery using the phacoemulsification machine white star Signature® (AMO, California, USA), Hydrophilic Foldable IOL implantation in the bag with the A Constant 118, Eyecryl®(BIOTECH VISIONCARE ,India).

Post-operative: Follow up visits were done after one day, one week, two weeks and one month post-operatively. UCVA, BCVA, refraction, slit examination for the anterior segment, applanation tonometry, fundus examination using 90 D non-contact lens were done.

All data were analyzed using SAS_ (release 6.12 for Windows). The collected data were revised, coded, tabulated using statistical package for social science (SPSS 15.01 for windows; SPSS Inc, Chicago, IL, 2001). P value is considered statistically significant if $P < 0.05$ and statistically highly significant if $P < 0.001$.

RESULTS

The study included 100 eyes. They were divided into 2 groups: ***Group A*** (Immersion US biometry): included 50 eyes. They were subdivided into ***Group A1*** (AEL ≥25 mm): included 9 eyes (18%) and ***Group A2*** (AEL <25 mm): included 41 eyes (82%). ***Group B*** (Optical biometry): included 50 eyes. They were subdivided into ***Group B1:*** (AEL ≥25) mm included 18 eyes (36%) and ***Group B2***: AEL <25 mm included 32 eyes (64%). (Table 1)

Table (1). Axial length distribution in both groups

Group	**No.**	**%**
Group A1 (AL ≥25 mm/ Immersion US)	9	18
Group A2 (AL <25 mm/ Immersion US)	41	82
Group B1 (AL ≥25 mm/ Optical biometry)	18	36
Group B2 (AL <25 mm/ Optical biometry)	32	64

Distribution: The mean age in US group was 58.3 ±11 years, and in optical group it was 56.4 ± 9 years. In the US group 25 patients (54%) were males, 21 patients (54.7%) were females, while optical group included 23 males (52.3%) and 21 females (47.7%). Diabetic patients constituted 6.5% of US group and 22.7% of optical group. This difference was statistically insignificant.

Preoperative results: The mean AEL ± SD was 23.62 ±1.69 mm. For the US group, the mean ± SD was 25.17 ± 3.56 mm for the optical group. This difference was statistically significant (P value=0.007). In US group mean IOL power ± SD was 21.2 ± 5D. While in optical group it was 16.5 ±10 D. The difference was statistically significant (P- value = 0.02).

There was statistically insignificant difference between both groups as regards preoperative UCVA (P value 0.419) and BCVA (P value 0.396) (table 2).

Table (2): Comparison between 2 groups in pre operative UCVA&BCVA

	US (n=50)			Optical (n = 50)	
	Mean	± SD	Mean	± SD	P value
UCVA	0.12	0.08	0.11	0.08	0.419
BCVA	0.245	0.111	0.227	0.099	0.396

There was statistically insignificant differences between the 2 groups as regards the types and density of cataract. The median of nuclear cataract in group A was 3 (Range: 1-5), and was 3 (1-6) in group B . The median of cortical cataract was 2 ((Range:1-5) in group A and was 4 ((Range: 0-5) in group B . The median of cataract score was 8 ((Range: 5-13) in group A and was 8 ((Range: 4-12) in group B.

There was statistically insignificant differences between the 2 groups as regards mean K1 (P value was 0.421D), mean K2 (P value was 0.264 D) and mean cylinder (P value was 0.38) (table 3).

Table (3): K1, K2 , Cylinder in Both groups

		US (n = 50)	Optical (n = 50)	P value
K1 (D)	Mean ±SD	43.75 ±1.83	44.07 ±2.14	0.421
K2 (D)	Mean ±SD	44.92 ±2.09	45.43 ±2.43	0.264
Cylinder (D)	Median (range)	-0.93 (-4 - 0)	-1.07 (- 4.44 - -0.06)	0.381

Postoperative results: There was statistically insignificant differences between the 2 groups in UCVA (0.249) and BCVA (0.093) .Table(4).

Table(4): Comparison between 2 groups in post-operative UCVA&BCVA

		US (n = 50)		Optical (n = 50)	
	Mean	±SD	Mean	±SD	P value
UCVA	0.39	0.17	0.43	0.19	0.249
BCVA	0.9	0.1	0.9	0.2	0.093

In our study, 66 eyes (66%) achieved post-op BCVA 1.0 and 34 eyes (34%) achieved 0.5 or better.

There was insignificant statistical difference between subgroup A1 and subgroup B1(myopic eyes) as regards the median of post –operative SE (P value was 0.561). Also in eyes with axial length less than 25 mm subgroup A2 and subgroup B2 showed also insignificant statistical difference (p value was 0.115), Table (5):

Table (5): Post-operative SE in subgroups A1&B1 and subgroups A2 &B2

	Group A1			Group B1	
	Median	Range	Median	Range	P value
Post-op SE (D)	-1	(-1.875 – -0.25)	-0.813	(-2 - 1)	0.561
	Group A2			Group B2	
Post-op SE (D)	-1.25	(-4- 1.375)	-0.938	(-2.625 1.375)	0.115

Regarding the mean absolute error (MAE) (The Difference between the target refraction and the observed refraction). In US group the MAE median was -0.27 D (range -2.1 -2.33 D), while in Optical group was -0.14 D (Range: -1.84-1.79). The difference was statistically insignificant (P value 0.341).

There was insignificant statistical difference between subgroup A1 and subgroup B1(myopic eyes) as regards the median MAE (P value was 0.571). Also in eyes with axial length less than 25 mm subgroup A2 subgroup B2 showed insignificant statistical difference (p value was 0.341), Table (6).

Table (6): MAE in the two groups and the four subgroups

	Group A	Group B	P value
MAE: Median (Range)	-0.27 (-3.1 - 2.33)	-0.14 (-1.84 - 1.79)	0.341
	Group A1	Group B1	
MAE: Median (Range)	-0.08 (-0.93 - 1.03)	-0.09 (-1.13 - 1.79)	0.806
	Group A2	Group B2	
MAE: Median (range)	-0.41 (-3.1 - 2.23)	-0.4 (-1.84 - 1.15)	0.571

Correlations between the study variables:

There was statistically significant positive correlation (0.2622) between AL and post-operative SE within all study groups (P value was 0.0084).

Regarding correlation between MAE and pre operative BCVA,UCVA,K1,K2,IOL power, cataract score, and axial length and post operative BCVA , UCVA and SE within all study group (n=100 cases): There were statistically significant negative correlations between MAE and IOL power within all study groups (p.<0.05). There were statistically significant positive correlations between MAE and AL within all study groups (p.<0.05). There were a statistically significant positive correlations between MAE and post operative UCVA and SE within all study groups (Table 7).

Table 7: Correlation between MAE and other study variables.

Pre operative	MAE	
	Correlation (r)	P.value
BCVA	-0.0422	0.677
UCVA	0.00167	0.9868
K1	0.1173	0.2452
K2	0.1173	0.2451
IOL power	-0.3436	0.0005
Cataract score	-0.0327	0.7465
AL	0.2771	0.0053
Cylinder	-0.0222	0.8263
Post operative	MAE	
	Correlation (r)	P.value
BCVA	0.1442	0.1523
UCVA	0.4962	<0.0001
SE	0.8842	<0.0001

DISCUSSION

Ocular biometry is crucial to achieve satisfactory post-operative refraction following cataract surgery [11] . The fundamental points for accurate biometry include AEL, K readings, A-constant and post –operative effective lens position (ELP) [12] . Errors in predicted refraction after implantation of an intraocular lens (IOL) of calculated power is the sum of the random error in the measurement of the axial length (54%), the measurement of the corneal power (8%), and the estimation of the pseudophakic anterior chamber depth (ACD) (38%) [13]. In our study we compared immersion B scan ultrasound biometry versus optical biometry in achieving satisfactory post operative refraction.

One of the markers regarding quality of ocular biometry is the percentage of eyes achieving 0.5-1.0 D spherical equivalent of the target refraction In our study 66 (66%) eyes achieved Post-op BCVA 1.0 and 34 (34%) eyes achieved 0.5 or better, and the differences between the 2 groups were statistically insignificant .

The mean SE in the study group was 0.98 which is going with **Gale et al** [14] who stated that a benchmark of 85-90 % of patients undergoing routine cataract surgery should achieve a final spherical equivalent within 1 D of the target refraction **(**and this denotes the high degree of the 2 studied methods of biometry in achieving a good refractive outcome .

In our study, there was statistically insignificant differences neither between subgroup A1 and subgroup B1(myopic eyes) nor between subgroup A2 subgroup B2 (axial length less than 25 mm) in the median of post –operative SE.

In the current study the median of MAE was -0.14 (Range: -1.84-1.79) in the optical group which is better than the immersion group where the median of MAE was -0.27 (Range: -2.1 -2.33), but the differences were statistically insignificant .

Similar results were reported by **Fontes *et al.*** [15] who compared calculations performed by PCI (IOL Master; Carl Zeiss Meditec), with immersion US (Ultrascan; Alcon) and compared MAE. They found insignificant differences with the use of Holladay 1 formula (we used Haigis formula in our study).

Also Similar results were reported by ***Yang et al.*** [7] they evaluated the accuracy of AL measurement obtained from Immersion B-scan US compared to A-scan and IOL master for IOL power calculation. Patients were divided into two groups according to the AL: one containing patients with 22mm ≤AL< 26 mm (group A) and the other containing patients with AL ≥ 26 mm (group B). Immersion B-scan showed accuracy of measurements comparable to that of the IOL Master, and it was more accurate than the contact A-scan. Also they reported that, the standard deviation (SD) of the mean error (ME) of Immersion B -scan didn't differ significantly from those of IOL Master and contact A-scan. In group B, ALs measured by immersion B-scan didn't differ significantly from those of the IOL Master, but were significantly longer than those measured by Contact A-scan. Also the standard deviation (SD) of the mean error (ME) of immersion B -scan (-0.635 ±0.157 D) didn't differ significantly from those of the IOL Master, but differed significantly from those of contact A-scan.

Similar results were reported by **Naicker *et al.*** [16] who compared immersion A-scan ultrasound (US) and Lenstar LS 900(®) biometry and their results showed no significant differences between the target spherical equivalent (SE) and the post-operative SE value by the Lenstar LS 900(®) or immersion A-scan US biometry devices. The magnitude of differences between the two biometric devices were not significantly different (p value was 0.868). There was no significant difference in the predicted post-operative refractive outcome between immersion A-scan US biometry and Lenstar LS 900(®). They concluded that the immersion A-scan US technique is as accurate as LenstarLS 900(®) in the hands of an experienced operator. Also **Gaballa *et al*.**[17] stated that there is no significant difference between IOL master and A scan biometry. with the non -contact IOL Master being preferred by patients.

Different results were reported by ***Landers and Goggin*** [18] who reported that biometry performed using the IOL Master produces a more predictable refractive outcome than immersion ultrasound, with patients' spherical equivalent more likely to be closer to their target refraction, they used SRK-T formula. They found that final refractive outcome was more hyperopic than the target refraction when using the IOL Master and more myopic when using immersion ultrasound. Different results could be attributed to using different formulas for IOL power calculation.

Haigis formula differs from other formulas in a very important way. It uses three constants: $a0$, $a1$ and $a2$ to calculate the effective lens position (d) where $d = a0 + (a1 \times \text{ACD}) + (a2 \times \text{AL})$. Therefore, rather than using a single number, the Haigis formula recommends IOL power based on three-variable ($a0$, $a1$, and $a2$) function [19]. **Becker *et al*.** [20] found Haigis formula is superior to other formulas, the Haigis formula showed the lowest difference between target refraction and achieved postoperative refraction.

Also **Roessler**[21] and associates reported that Haigis provided the best predictability of postoperative refractive outcome than the Holladay 1 and SRK/T for 37 eyes with AL more than 26.5mm

Also opposite results were reported by ***Jasvinder* et al**.[22] They measured IOL power using four different methods: IOL Master, LENSTAR and A-scan applanation and immersion ultrasound biometry using SRK/T formula for IOL calculation with emmetropia as the target refractive outcome. They found that measurements of AL, and IOL power calculated using the SRK/T formula from LENSTAR are biometrically equivalent to those from IOL Master, but not with those from applanation and immersion ultrasound biometry. LENSTAR agreement with IOL Master is strongest, followed by those with immersion and applanation. Different results may be due to different formulas .Also optical biometry is easy to perform but ultrasound biometry needs operator experience.

Many authors compared AEL measurements assessed by U/S biometry and optical biometry. In their results, the optical biometry provided larger mean measurements than U/S biometry in eyes with cataract or clear crystalline lens, which was represented by a negative difference of 0.05 mm in AEL measurements, with higher measurements produced by optical biometry [23],[24]. But **Pongsachareonnont and Tangjanyatam** [25] found significant underestimation of AL measurement when using optical biometry in eyes with rhegmatogenous retinal detachment with macular involvement .

The main disadvantage of the optical method is its inability to obtain AL measurements in approximately 8-17 % of eyes, such as those with dens cataract, posterior subcapsular cataracts, vision worse than 6/60, and nystagmus[8].

In conclusion, the immersion B scan biometry and optical biometry gave comparative results with precise final post operative refractive outcome.

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