Comparative Study of Axial Length Estimation using A-Scan Ultrasound and Carl-Zeiss IOI Master in Benin City, Edo State, Nigeria

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Abstract

Axial length of the human eye is the distance from the anterior pole of the cornea to the posterior retina pole. It is an important element in evaluating the eye's power of refraction. Innovations and advances in technology have greatly increased accurate measurements of axial length in the previous two decades. This study compared axial length measurements using A-scan ultrasound and the Carl Zeiss IOL master's in human eyes in order to ascertain their repeatability and reliability. This research employed a cross-sectional design to study 80 eyes of participants aged 40 -- 80 (63+/-10.1) years selected using purposive random sampling techniques in two ophthalmology clinics located in Benin City, Edo State, Nigeria. SPSS version 23.0 was used to analyze the data. The independent-sample T-test and Pearson's correlation coefficient were used to compare axial length and determine relationship between both instruments, respectively. Statistically significant level was taken as probability values $P < 0.05$. The average axial length recorded by A-scan Ultrasound was 23.54mm ± 1.25 SD, and Carl Zeiss IOL Master was 23.62mm ± 1.25 SD. There was no significantly remarkable difference between average axial-length recorded with both instruments ($p = 0.7$). Both Carl Zeiss IOL Master biometric instrument and the A-scan ultrasound biometric instrument could be used to measure axial length interchangeably only when there are no factors that negatively affect any of the instrument's results.

Keywords: A-Scan, Axial Length, Biometry, Carl-Zeiss IOL Master, Refractive Error.

Introduction

Axial length of the human eye refers to the distance from the anterior pole of the cornea to the posterior retina pole, and it is an important element in evaluating the eye's power of refraction. Axial length elongation is a structurally significant aspect of myopia progression, especially in children.[1,2] The axial length measurement refers to a combination of three individual elements, namely; vitreous chamber depth, lens thickness, and anterior chamber depth.[3,4] Axial length measurement has been established as a crucial estimation in IOL biometry, due to its usefulness in calculating the ideal intraocular lens power for implant. Measuring axial length of the eyes has been proven to provide a more accurate indicator of intraocular lens and avoidance of postoperative errors, particularly where the patient is undergoing intraocular lens implant. For instance, just a 1 mm shift in axial length can cause a significant shift in intraocular lens power, ranging from 2.5 to 3.0D in emmetropic eyes and greater in myopic eyes.[5]

Axial length of the eye is often measured either by A-Scan Ultrasound or by Carl-Zeiss IOL Master biometric instrument which utilizes the principle of partial-coherence interferometry (PCI).[6] Research estimated axial length at birth to be 17 mm, and grows to approximately 24 mm at adulthood[6]. It is usually longer than 24 mm in myopic subjects, and shorter than 24 mm in hyperopic subjects [6]. Every millimeter change in axial length of the eye results in corresponding change of approximately 2.5D.[7]

The Carl-Zeiss IOL Master is the universal gold standard for calculating intraocular lens (IOL) power in clinical operations.[5] It utilizes an automated non-invasive method for measuring the anatomical parameters of the eye.[8] Precise measurements are hypercritical for evaluating the accurate power of an intraocular lens prior to implant during cataract surgery[9].

Meanwhile, A-scan ultrasound biometric instrument utilizes an invasive technique that involves direct contact with the corneal surface. Topical anesthetics are used, and can be uncomfortable for subjects being examined. Moreover, this technique of measuring axial length requires skillful training to reduce errors due to excessive compression of the ultrasound probe on the cornea by the practitioner. This instrument also needs regular ultrasound speed adjustment in different ocular media[10].

Traditionally, prior to invention of Zeiss IOL master which is also known as the optical biometry, A-scan ultrasound was earlier regarded as the gold standard in axial length estimation following its quick measurement when handled by skilled practitioners.[6,7] However, with the invention of Carl Zeiss IOL master, the applanation A-scan ultrasound has been faulted with few limitations such as variation and unreliability in axial length measurement due to corneal compression by the instrument probe[11].

A probe guides an ultrasonic beam into the eye during A-scan ultrasound biometry. The beam evenly distributes across the tissues of the eye, creating a peak-wave recording that, in a healthy eye, indicates the cornea, anterior portion of the lens, posterior lens-capsule, and retina in that order. The analysis provides a two-dimensional representation of the eye's structures, and the total of these images enables the determination of the eye's axial length[12].

In Carl Zeiss IOL Master, the instrument produces two co-axial 780nm infrared-light beams. The two beams cause the eyes to be sensitive to longitudinal movements. Meanwhile, the A-scan ultrasound device measures axial-length from the cornea surface to internal limiting membrane, Carl Zeiss IOL master device measures axial-length from cornea surface to retinal pigment-epithelium, having variation estimated to be 130 µm. Although, there are no direct device to cornea contact with the patient's eye in the Carl Zeiss IOL master biometry technique, it can be occasionally challenging to measure axial length, most especially if there are media opacities, hemorrhages and lens cataracts, as well as wrong measurements in pseudophakic eyes, up to 4.00 mm, due to intraocular lens reflection[8].

Previous researchers have conflicting opinions on both instruments being used interchangeably with diverse results that the optical biometry tends to give a higher axial length than the non-optical biometry. The purpose of this research survey was to compare the axial length estimation of the A-scan ultrasound to that of Carl Zeiss IOL Master in order to ascertain their repeatability and reliability.

Materials and Methods

This was a cross-sectional study

Sampling Technique

Random selection technique was used for this study in which each sample or participants had an equal probability or chance of being chosen or selected.

Sampling Location

This study was carried out in prime opticals Benin City and Claire eye Clinic

Study Population

The study population were patients from the study location who meet the criteria for the research experiment

Sample Size

The study size for the research experiment was calculated using Charan and Biswas formula and a total of 80 eyes were used for this study. This study was carried out within a period of 4 months

Study Materials

The following materials were used for the study: A-scan ultrasound (Contact biometry), Carl zeiss IOL master (optical biometry), slit lamp (Bausch & Lomb), and a 4. Tetracaine hydrochloride 0.5% eyedrop (Anaesthesia)

Inclusion Criteria

Patients who had no ocular disease/abnormalities, systemic diseases and who gave their consents were included in the study.

Exclusion Criteria

Patients with total vision loss, who had eye surgery, ocular infections, and patients with ocular trauma were excluded from the study

Procedure for Data Collection

Visual acuities (VA) at far were evaluated with Snellen's chart placed at 20 feet in a standard lighted clinic room.[13] Only subjects' eyes with 20/20 visual acuity were enrolled into the study. Pen-torch, and Keeler-ophthalmoscope were used to assess the external and internal eye structures respectively. Fasting blood sugar test and blood pressure were measured prior to the study. Subjects with fasting blood sugar greater than 120mg/dl,[14] and blood pressure greater than 140/90mmHg were excluded from the study.[15]

Optical biometry was performed first on the selected eyes using the Carl Zeiss IOL Master, followed by the A-Scan ultrasound measurement with 15min time interval between both measurements. This was done to avoid measurement errors that could arise from potential corneal abrasion.

Using the IOL Master axial length measurement mode, magnification ratio automatically become smaller, thereby making the reflection of the vertical line alignment of the eye under examination visible. The subjects were told to maintain fixation at the red signal located on the center of the instruments in order for the examiner to visualize the encircle-crosshair displayed on the screen. The corresponding displayed field on the screen indicates the axial length of that eye. Measurement was taken three consecutive times and the mean values were recorded as the axial lengths of the eyes.[7,16]

Meanwhile, the procedure for measuring axial length using the applanation A-scan ultrasound requires topical anaesthesia. A single drop of Proparacaine hydrochloride, 0.5% was used to anaesthetize the selected eye of the patient to avoid sensitivity from the instrument probe. The instrument probe was sterilized with 70% alcohol, and allowed to touch the subject's cornea in order for the A-scan ultrasound to produce modifiable sound waves. The readings appeared as spikes on the visual monitor screen. Ocular structures can be matched to both the appearance of the spikes and relative distances between them. The probe was positioned on the center of the cornea surface, making sure that the probe slightly touched the cornea, and aligned with the eyes optical axis. Once the probe aligns with the optical axis, retina spikes were displayed on the A-scan graph, and this indicates the axial length of that eye. This procedure was repeated three consecutive times and the mean value was taken as the axial length of that eye.[16,17]

The data collected were analyzed with version 23.0 of IBM-SPSS. Results were presented in tables and charts. Mean and standard deviation were used to describe numeric variables e.g., age and axial length while frequencies and percentages were used to describe the categorical variable, gender. The independent-sample T-test was used to compare axial lengths, while Pearson's correlation coefficient was used to determine relationship between both instruments. Probability value of $P < 0.05$ was regarded as a statistically significant level.

Ethical Committee of the Faculty of Optometry University of Benin approved the study with protocol number FLS/2023/016. Prime Optical and Claire Eye Clinic granted permission for the use of their clinics, and each enrolled subject signed informed consent form for the study.

Results

The 80 participants examined consisted of 44 males (55.0%) and 36 females (45.0%), and the average age of all participants was 63.0 ± 10.1 years (Figure 1).

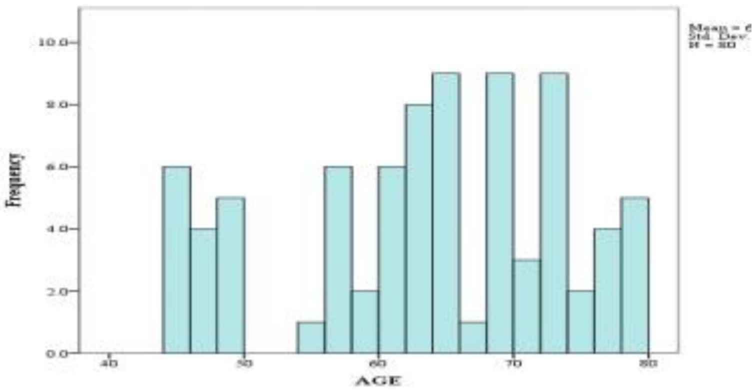

Figure 1: Histogram Showing Age Distribution

Figure 2a and 2b compared the axial length measurements of both instruments and the average axial length of the instruments respectively. Most of the participants in both groups had an axial length of approximately 23.0mm. The average axial length recorded by A-scan Ultrasound was 23.5 ± 1.2mm, while that of Zeiss IOL Master was 23.6 ± 1.2mm (figure 2a). There was no significant difference between the average axial length recorded by the two instruments (P = 0.7) (figure 2b).

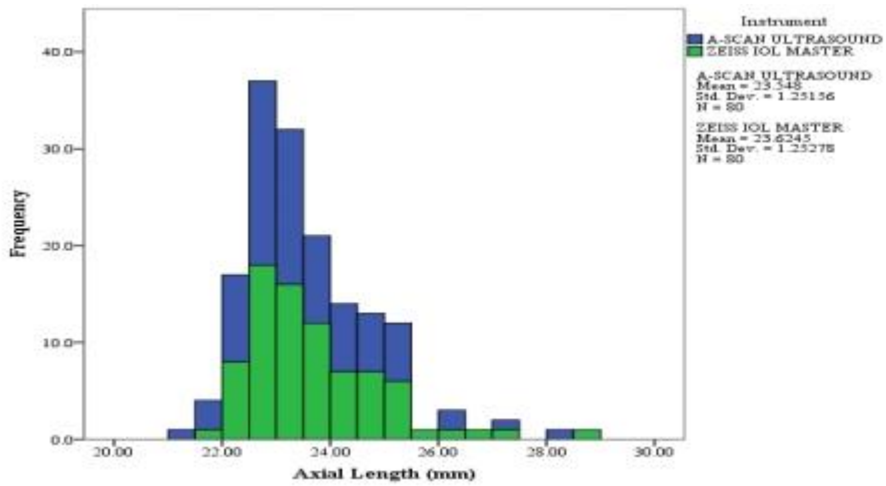

Figure 2a: Distribution of axial length measurements recorded by A-Scan Ultrasound (Blue) and Zeiss IOL Master (Green)

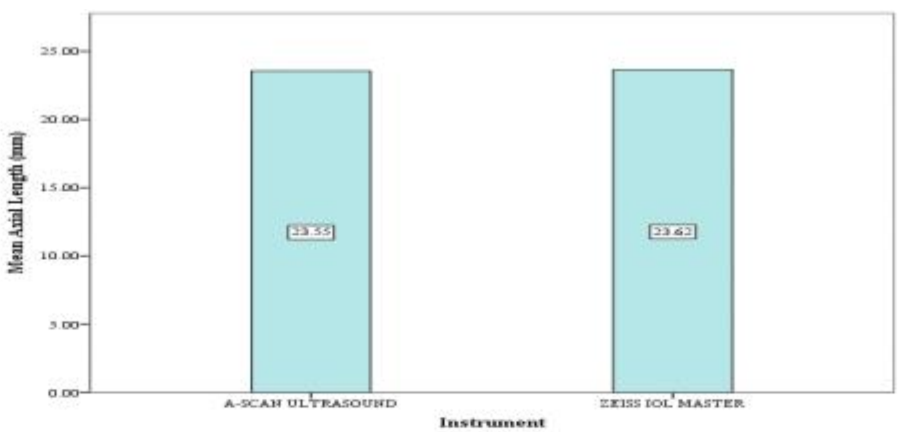

Figure 2b: Average Axial Length of Both Instruments

In Figure 3, the plot showed the relationship between A-scan Ultrasound and Zeiss IOL Master using Pearson's correlation coefficient. A strong positive and remarkable correlation existed between them ($r = 0.998$, $p = 0.000$). This implied that there was no difference in the axial lengths measured by both A-scan Ultrasound and Zeiss IOL Master, showing that both could be used interchangeably.

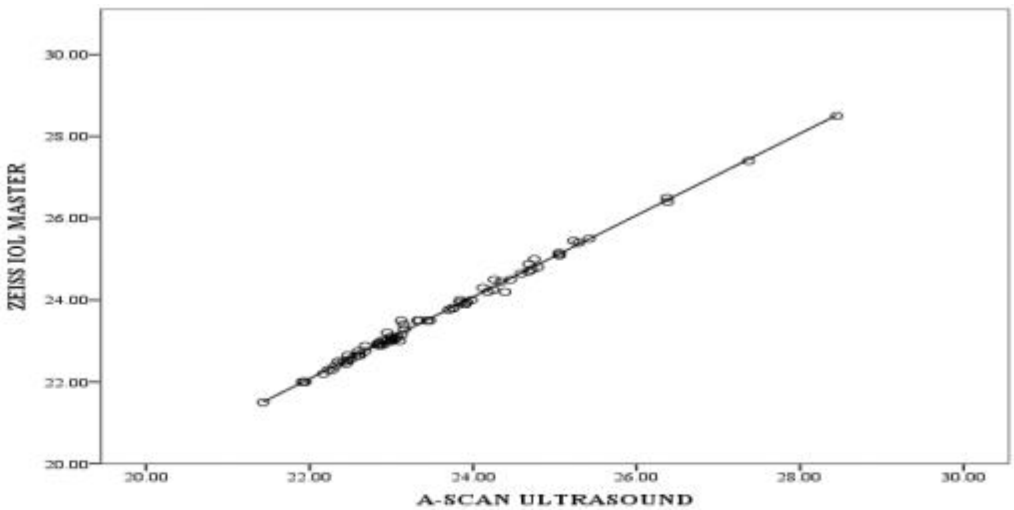

Figure 3: Correlation between the Axial Lengths of A-scan Ultrasound and Zeiss IOL Master

Results of this study also showed that age and gender had influence on mean difference of axial length between A-scan Ultrasound and Zeiss IOL Master. Difference between the axial length measurements (computed as A-scan Ultrasound minus Zeiss IOL Master) as shown in Figure 4 was significant positively with relation to age (r = 0.28, P = 0.012).

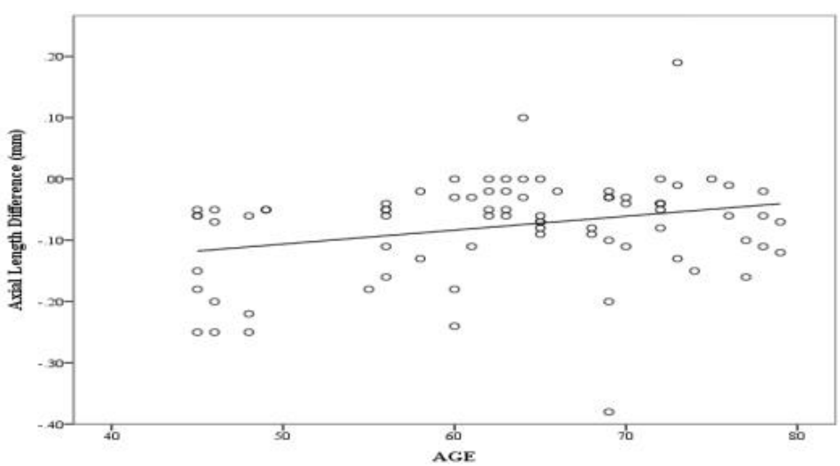

Figure 4: Relationship between Age (years) and the Axial Length Difference (mm)

This implied that, as the age of the participants increases, difference in axial length measurement increases also. In males and females, A-scan ultrasound had smaller values than Zeiss IOL Master as depicted by the negative sign of the mean (Table 1). The axial length difference in females were significantly longer than those in males (p = 0.002).

Table 1: The Average Axial Length Difference in Males and Females

	Gender	N	Mean	Std. Deviation	Std. Error Mean
Axial length difference	Male	44	-.0509	.06954	.01048
	Female	36	-.1078	.08629	.01438

Discussion

This study was carried out with two biometric instruments- Carl Zeiss IOL Master which is also referred to as the non-contact biometric instrument and A-scan ultrasound instrument which is also called contact biometric instrument. The study and analysis were centered on axial length measurement in connection with age and gender. In this study we calculated the mean difference, as well as the correlation of axial length between Carl Zeiss IOL Master and A-scan Ultrasound Biometric instruments to see if both instruments can be used interchangeably. A total of 80 eyes of males and females with age range 40-80 years were used for the survey. Most subjects were between 55 and 75 years with average age of 63.0 ± 10.1 years. There were 44 (55.0%) male eyes and 36 (45.0%) female eyes. Findings showed that majority of the participants had an axial length of approximately 23.0mm which is within the normal range (22 to 24.50) of axial length for adults,[18] with no significant mean deviation from both instruments. Our study revealed that the mean axial length obtained with the A-scan ultrasound (mean of 23.548mm ± 1.25156 standard deviation) where lower than the axial length (mean of 23.6245mm ± 1.25278 standard deviation) obtained from the Zeiss IOL Master with no statistically significant differences ($p = 0.7$) recorded between the axial length of both instruments. The outcome of this current study are similar to previous publications which compared applanation ultrasound and optical biometry, and reported no difference or better outcomes with optical biometry.[7,10,17,18] This implies that both instruments can be used interchangeably. In other words, Carl Zeiss IOL Master and A-scan ultrasound biometry have a strong repeatability. On the contrary, research done by Alabi *et al.*in South-west Nigeria showed a statistically significant difference in comparison of axial lengths measured with both Carl Zeiss IOL Master and A-scan ultrasound instruments.[19] Outcomes of this study further showed that axial length measurements of both instruments were highly (strong positive) correlated ($r = 0.998$, $p = 0.000$). This implies that the axial length of both instruments increased together. Axial lengths measured with the A-scan ultrasound (mean 23.548mm, SD 1.25mm) were lower than values measured with the Carl Zeiss IOL Master (mean 23.6245mm, SD 1.25mm). Similar outcomes were documented in previous studies.[19–21] The variation in those results could probably be due to the properties and limitations of both techniques such as compression of cornea may result in shorter axial length, while using A-scan ultrasound biometry, media opacities like corneal scar and vitreous hemorrhage may lead to inaccurate measurements while using optical biometric instrument.[18,22]

The difference between the axial length measurement was positively related to age (r = 0.28, p = 0.012). This implies that as the age of the participants increase, the difference along the axial length measurement increases. Our study was in consonance with Roy *et al.* .[23] remarks that age correlated positively with axial length. In both males and females, the A-scan ultrasound had shorter values than Zeiss IOL Master as depicted by the negative sign of the mean (-0.509 and -1078) Table 1. The axial length difference in females was significantly longer than those in males (0.002). Similar findings of longer axial length in females were reported by Roy *et al.*in Saudi Arabia.[24] On the contrary, Mashige and Oduntan reported longer axial length in males and females among black South Africans.[25]

Conclusion

Although the operating principles of the two axial length measuring devices are different, it is clear that the results of the measurements coincide to a great extent. Axial length estimation in normal eyes using the two biometry techniques (A-scan ultrasound biometrics and IOL Master optical biometrics) do not differ statistically from each other. It shows a good correlation and agreement, therefore both instruments can be used interchangeably for axial length estimation. Nevertheless, findings in this survey may not be generalized to other types of biometric instruments without further study. Another limitation was that factors such as keratometry and intraocular lens power which may affect the biometry evaluation were not considered.

Acknowledgement

A profound gratitude to Prof. (Mrs) F.K Idu, Dean, Faculty of Optometry, University of Benin for her excellent leadership. May God bless every Optometry lecturers and non-academic staff of the Department who has made this study a success.

Conflict of interest

All authors have no conflict of interest to declare

Funding

Authors received no grant for the research

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