A comparison of noncontact and ultrasound A-scan in the measurement of axial length in myopic subjects

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Abstract:

Introduction: Myopia is a common type of refractive error seen globally. As myopia increases, the axial length (AL) elongates and brings risks of vision impairment in later life. Therefore, AL measurement is an important indicator for myopia management and must be measured accurately. In this study, we compared the difference between AL measurements from two instruments available at the University Kebangsaan Malaysia (UKM) Optometry clinic for reference purposes. **Methodology:** A total of 90 healthy myopic subjects (14 males and 76 females) with a mean age of 22.03 ± 1.14 years were enrolled in this cross-sectional study. Clinical investigations that included visual acuity (VA), refraction and axial length measurement using optical and ultrasound biometry were carried out. **Results:** The mean spherical equivalent refractive error (SE), and axial length measured by optical biometry and ultrasound were found to be -3.04 ± 1.61 D, 24.74 ± 0.90 mm and 24.50 ± 0.86 mm respectively. Paired sample t-test showed that subjects' axial lengths measured by ultrasound A-scan were significantly lower than optical biometry ($p < 0.05$). Negative and strong correlations were found between the degree of myopia and axial length ($r_s = -0.609$, $p < 0.001$). Regression showed that axial length measurement accounted for a significant 33.5% of the degree of myopia, $R^2 = 0.335$, adjusted $R^2 = 0.328$, $F = (1, 88) = 44.38$, $p < 0.01$. **Conclusion:** This study concludes that AL measured using ultrasound is shorter than optical biometry. Measurements of AL should be done consistently with the same instrument to avoid any discrepancies during myopia management.

Keywords: myopia, axial length, refraction, ultrasound biometry, optical biometry

Introduction:

Myopia is a common refractive error that affects the majority of the population. Myopia, as defined qualitatively by Flincroft et al. (2019), is a refractive error in which, when ocular accommodation is relaxed, light rays entering the eye parallel to the optic axis are focused in front of the retina. This typically happens when the eyeball is too long from front to back, although it can also be brought on by an overly curved cornea or a lens with a higher optical power. By quantitative definition, myopia is a condition in which, when ocular accommodation is relaxed, an eye's spherical equivalent refractive error is ≤ -0.50 D. For many, visual disability of myopia is easily remedied with corrective devices (such as contact lenses or spectacles) but the risks of uncorrected visual impairment rise with increasing myopia. For some, during adulthood, myopia can result in permanent visual disability due to co-morbid conditions such as myopic macular degeneration, retinal detachment and glaucoma (Chen et al 2012; William et al 2015). Data from Japan and Taiwan suggest that myopic macular degeneration is already a major cause of blindness in both countries (Hsu et al 2004; Iwase et al 2006).

According to Holden et al. (2016), the prevalence of myopia and high myopia will rise globally by 2050, affecting almost 5 billion and 1 billion individuals, respectively. Myopia is associated with the elongation of the eyeball or AL. Axial length is defined as the distance from the corneal surface to the retinal pigment epithelial layer and is an important indicator of the refractive state of the eye. It is well established that AL elongates with myopia progression and provides a coordinated estimation of the overall ocular structure and changes in that structure in myopia and high myopia (Wang et al. 2016).

Two types of A-scan biometry are based on different working principles, namely optical biometry and ultrasound biometry. Optical biometry such as the Lenstar LS 900™ (Haag-Streit, Germany) is a non-contact, fast, precise and easy-to-use measurement device. Lenstar™, which uses the principle of Optical Low-Coherence Reflectometry (OLCR), can provide a lot of information about ocular parameters like central corneal thickness (CCT), lens thickness (LT), anterior chamber depth (ACD), axial length (AL), keratometry values, and corneal diameter in a single measurement. Ultrasound biometry, on the other hand, is an instrument that utilizes 10-MHz ultrasonic waves to get measurements of ocular characteristics such as the axial length of the eyeball (AL), lens thickness (LT), and the depth of the anterior chamber (ACD) (Wang et al. 2016). A study from Wang et al. (2016) also found that a contactless A-scan was able to measure the AL at a higher value when compared to measurements made with an ultrasound A-scan, as well as what has been reported in several other reports (Nakhli, 2014, Atwa et al. 2019, Goyal et al. 2003, Gopi et al. 2017). This is because ultrasound biometry requires placing the probe directly on the corneal surface, which might cause the corneal surface to be indented, resulting in lower and variable measurement findings compared to contactless biometry.

The Optometry Clinic, Faculty of Health Sciences, UKM recently purchased the Lenstar LS 900 ™ non-contact optical biometry for clinical use. Previously, ultrasound biometry was used to measure the AL for myopia management. The clinicians need to identify if there are any discrepancies in AL measurements between both instruments. Therefore, this study aimed to compare the AL measurements taken using optical biometry and ultrasound biometry in the clinic.

Methodology:

This study was conducted over a period of 9 months, starting from October 2021 until July 2022 among undergraduate students at the Universiti Kebangsaan Malaysia Kuala Lumpur campus. The inclusion criteria for the subjects were myope with a spherical equivalent of ≤ -0.50 D, aged between 19 to 25 years old with no ocular pathology, amblyopia and antimetropia. Only data on the right eye was presented in this study. This study was approved by the Universiti Kebangsaan Malaysia Research Ethics Committee UKM PPI/111/8/JEP-2022-125 and was conducted after acquiring subjects' written and informed consent.

This study was conducted at the UKM Optometry Clinic, Faculty of Health Sciences, Universiti Kebangsaan Malaysia, Kuala Lumpur. Subjects' history was taken including their previous ocular and systemic diseases, ocular trauma and history of contact lens wear. All subjects underwent a comprehensive eye examination which included visual acquity (VA) at distant and near using Snellen and near chart, retinoscopy, subjective refraction, measurement of AL using optical biometry (Lenstar LS 900™, Haag-Streit AG) and ultrasound A-scan

(VuPad Ultrasound™, Sonomed Escalon). To avoid corneal abrasion due to corneal indentation from A-scan probe, optical biometry was always done first followed by applanation ultrasound.

For optical biometry (Lenstar, LS 900™) the subjects were instructed to fix their gaze directly on the alignment beam to ensure that all measurements were obtained along the visual axis. Three consecutive measurements were taken on the right eye. For applanation ultrasound, the subjects were instilled with 0.5% proparacaine hydrochloride drops in the right eye. They were asked to look straight ahead, and the probe was placed at the center of the cornea perpendicularly without indenting it. Three consecutive measurements were taken on the right eye with a standard deviation of less than 0.1 mm for each subject.

The statistical analysis was performed using the IBM Statistical Package for the Social Sciences (SPSS) Statistics 21. The results were presented in mean ± standard deviation. The data normality assumption was tested with the Shapiro-Wilk test. The mean and standard deviation (SD) values for the AL were analyzed using descriptive tests. A paired sample t-test was used to analyze the value of the AL of the eyeball obtained by both methods. Spearman rho test was used to determine the relationship between the length of the eyeball and the degree of myopia in spherical equivalent refractive error. Regression analysis was performed to predict the degree of myopia from the AL measurement. All p values were 2-sided and a probability level of less than 0.05 was taken as statistically significant.

Results:

A total of 90 subjects (90 eyes) from 14 (15.6%) males and 76 (84.4%) females were included in the study with a mean age of 22.03 ± 1.14 years old. The mean spherical equivalent refractive error value for the right eye was -3.04 ± 1.61 D ranging from -0.50 DS to -6.75 DS.

The Shapiro-Wilk normality test for axial length measured by Lenstar and ultrasound A-scan showed the data were normally distributed since the significant values for both were more than 0.05. Statistical analysis showed that the mean AL measured using ultrasound A-scan was 0.24 mm less than the one measured using the optical biometer, 95% CI 0.17, 0.31]. This difference was statistically significant, $t(89) = 7.09$, $p < 0.001$. Table 2 summarizes the AL measurements obtained using optical biometry and ultrasound methods.

Table 1: Demographical data of the subjects

Variable	Frequency (Percent)	Mean ± SD
Gender		
Male	14 (15.6%)	
Female	76 (84.4%)	
Age		22.03 ± 1.14
Spherical Equivalent (RE)		-3.04 ± 1.61 D

Table 2: Mean of axial length measurements (SD) using both methods

	Mean axial length (SD) (mm)	dF	*t*	*p*-value
Ultrasound biometry	24.50 (0.86)	0.33	7.09	0.00
Optical biometry	24.74 (0.90)			

The Spearman's rho correlation coefficient was used to analyze the correlation between the degree of myopia and axial length measurement. This test indicated that there was a significant negative correlation between these two, $r_s = -0.609$, $p < 0.001$, N = 90. Figure 1 shows the correlation between the degree of myopia (D) and axial length (mm).

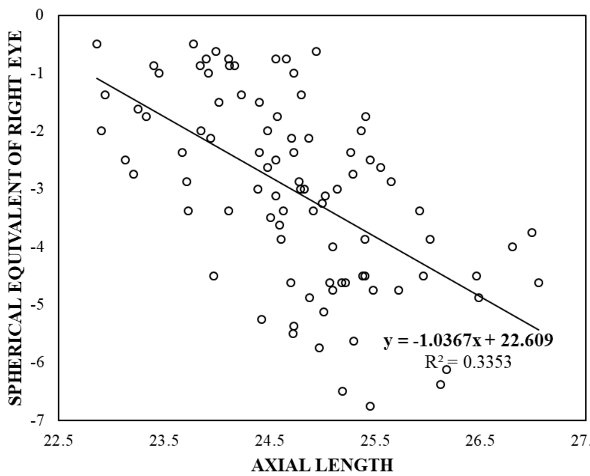

Figure 1: The correlation between the degree of myopia (D) and axial length (mm)

A simple linear regression was performed to predict the degree of myopia from AL measurement. Before interpreting the results of the simple linear regression, several assumptions were evaluated. First, the stem-and-leaf plots and boxplots indicated that each variable in the regression was normally distributed and free from univariate outliers. Second, inspection of the normal probability plot of standardized residuals as well as the scatterplot of standardized residuals against standardized predicted values indicated that the assumptions of normality, linearity and homoscedasticity of residuals were met.

In combination, the AL measurement accounted for a significant 33.5% of the degree of myopia, $R^2 = 0.335$, adjusted $R^2 = 0.328$, $F = (1, 88) = 44.38$, $p < 0.01$. Unstandardized (B) and standardized (β) regression coefficients and squared semi-partial correlations (sr^2) for the predictor in the regression model are reported in Table 3.

Table 3: Unstandardized (B) and standardized (β) regression coefficients and squared semi-partial correlations (sr^2) for the predictor in the regression model predicting the degree of myopia.

Variable	B [95% CI]	Β	sr^2
Axial length	-1.04 [-1.35, -0.73]	-0.58	0.34

Discussion:

This study investigated the comparison between axial length measurement between optical biometer (Lenstar 900™) and applanation ultrasound biometry in myopic subjects. From our findings, AL measured using the ultrasound biometry was significantly lower by 0.24 ± 0.33 mm than the measurement conducted using ultrasound ($p < 0.001$). Previous studies have demonstrated the differences in the AL measurements between non-contact A-scan and ultrasound A-scan. Wang et al. (2016) discovered that both Lenstar and IOL-Master non-contact biometry devices produced longer axial length values than the ultrasound device. A study from Atwa et al. (2019) demonstrated that, in eyes with a cataract or a clear lens, optical biometry produces longer mean measures than applanation ultrasound biometry, as represented by a difference of 0.05 mm in the AL measurement. Goyal et al. (2003) also reported that the average difference between the AL obtained using the non-contact interferometry method was higher by 0.20 mm than those measured using the ultrasound method.

The differences in the technique utilized to obtain the measurements and the variations in the system used by each instrument are the possible explanations for this difference in the AL measurement. Due to the need to position the probe directly on the cornea during ultrasound biometry, there is a chance that the cornea may be pressed inward. As a result, the measurements obtained are lower and more variable than with non-contact biometry (Wang et al. 2016). Additionally, the reflection of light provides another explanation. In ultrasound biometry, light is reflected on the ILM, while in optical biometry, Lenstar 900™, light is reflected on the retinal pigment epithelium (0.25 mm deeper than the ILM) (Atwa et al. 2019). Lenstar 900™ optical biometry instrument uses an 820 nm super luminescent diode (SLD) (Rohrer et al. 2009), which provides a higher resolution (O'Donnell et al. 2011), while ultrasound biometry produces a resolution of 200µm (Atwa et al. 2019). Furthermore, optical biometry uses light for measurement rather than using sound like ultrasound biometry, and this produces more accurate values (Pooja et al. 2018). Nakhli (2014) stated that resolution improves as wavelength decreases. Therefore, because light has a shorter wavelength than sound, laser light produces better resolution as used in contactless optical biometry. To monitor changes in axial length in patients, measurements of axial length should be conducted consistently using the same instrument in the clinic.

According to previous studies, non-contact biometry provides better repeatability and reliability compared to ultrasound biometry. Shen et al. (2013) reported that, in AL and ACD measurements in highly myopic eyes, the Lenstar LS 900 and IOLMaster biometry offered superior reproducibility and interchangeability than applanation ultrasound. Cruysberg et al. (2010) also mentioned that according to their study, Lenstar LS 900 provided excellent repeatability for CCT, ACD, LT, K values, and AL measurements. This is also supported by Rauscher et al. (2021) mentioning that in terms of CCT, AD, ACD, LT, and AL measurements, the Lenstar LS900 had outstanding repeatability. Thus, since non-contact biometry provides high resolution and low variability, it could result in more accurate measurements (Goyal et al. 2003).

The results of this study also found that there was a negative and strong linear correlation between axial length and degree of myopia in young adults. Similar findings were made by Chinawa et al. (2017) who reported a linear relationship between myopia and AL, indicating that AL increases with the degree of myopia. According to Chen et al. (2021), eyes with high myopia tend to have longer AL, shallower anterior spaces, thicker corneas, weaker lenses, and longer vitreous spaces. Xie et al. (2009) also reported that longitudinal studies showed that the depth of the anterior space increased in addition to the elongation of the vitreous with increased myopia. The AL measurements must be conducted during follow-up visits to monitor myopia progression in children.

The limitation of this study was that all AL measurements were carried out with undilated pupils, which made it easier for the subjects to fixate on the target during the examination. Nevertheless, without the use of cycloplegia, it is impossible to rule out the possibility that accommodation may have an impact on subsequent AL measurements. According to Gao et al. (2002), AL in myopic eyes is reduced following cycloplegia, contrary to studies by Cheng et al. (2014) and Bahar et al. (2021) which reported AL increases with cycloplegia. Future studies should be conducted on subjects with cycloplegia to determine the differences in measurements.

Conclusion:

This study concludes that there is a significant difference in the measurements of AL using optical and ultrasound biometry in myopic subjects, in which the AL measured using ultrasound is shorter than using optical biometry. Axial length measurements must be conducted during follow-up visits to monitor myopia progression in children and should be done consistently with the same instrument to avoid any discrepancies.

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