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Axial biometry of the entire eye using ultra-long scan depth optical coherence tomography

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Abstract

Purpose—To assess the repeatability of axial biometry of the entire eye using ultra-long scan depth optical coherence tomography (ultra-long scan depth-OCT) and to investigate the agreement with IOLMaster.

Design—Prospective, observational case series.

Methods—There were 37 adult subjects enrolled in Group 1 and 12 adult subjects in Group 2. Using ultra-long scan depth-OCT, the left eyes of these groups were measured in two separate sessions. The images were processed by a manual method and custom-developed automatic software. A model eye was imaged for verification. The subjects of Group 2 were imaged using ultra-long scan depth-OCT and using the IOLMaster for axial length measurement comparison.

Results—All measured parameters of the model eye matched the geometric parameters. In Group 1, there were no significant differences in all measured parameters using automatic and manual segmentation methods (paired t-test, $P > .05$). The CoR% of segments ranged from 0.3% to 3.9%. The corresponding inter-class correlation coefficients (ICC) ranged from 0.946 to 0.999. The correlation between the results using automatic and manual segmentation methods appeared strong ($R^2 = 0.999$, $P < .05$). In Group 2, the axial length of the eye measured by the IOL Master matched the results obtained by ultra-long scan depth-OCT with the automatic method ($R_1^2 = 0.987$, $P < 0.05$) and the manual method ($R_2^2 = 0.988$, $P < .05$).

Conclusions—Automatic axial biometry using ultra-long scan depth-OCT successfully measured each segment of the entire eye with good repeatability. With further development of

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C. Contributions of the authors

Design of the study (JZ, JW, YS, AT, HJ, CL, HZ); data collection (JZ, YS, AT, JW), analysis and interpretation of the data (JZ, JW, YS, AT, HJ, CL, HZ), preparation, review and approval of the manuscript (JZ, JW, YS, AT, HJ, CL, HZ).

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automatic segmentation, ultra-long scan depth-OCT appeared to be a promising tool in the axial biometry of the entire eye.

INTRODUCTION

Accurate, rapid and safe axial biometry of the entire eye, including measurements of axial length (AL) and crystalline lens thickness, is important for the power calculation of intraocular lens (IOL)¹ and refractive error research.^{2–4} Many diseases, such as myopia,^{2–4} hyperopia,^{2, 3} and glaucoma,^{5, 6} can affect the axial biometry of the entire eye. Accommodation induces the dimensional changes of the anterior segment, resulting in altered segments in the eye. Traditional methods for axial biometry include ultrasound and optical low coherence reflectometry (OLCR) based devices, such as the IOLMaster (Carl Zeiss Meditec, Dublin, CA)^{7, 8} and the Lenstar (Haag-Streit USA, Mason, OH).^{9–11} These methods use a single axial measurement like the A-scan. Real-time imaging may be difficult with these traditional methods. With advances in optical coherence tomography, it is now possible to image the entire eye in two or three dimensions.^{12–15} With the advantages of high speed scanning and high resolution, full eye axial biometry may provide an alternative method of axial biometry. However, the precision of full eye biometry remains untested. The goal of the present study was to determine the repeatability of axial biometry of the entire eye using ultra-long scan depth OCT (ultra-long scan depth-OCT). Also, we tested and validated our custom software for processing the ultra-long scan depth-OCT images and providing axial biometry data of entire eye.

METHODS

This protocol was prospectively approved by the institutional review board for human research at the University of Miami. The study was in accordance with HIPAA regulations. All subjects were treated in accordance with the tenets of the Declaration of Helsinki and were given the written informed consent to participate in this study after they were informed about the nature, risks and possible adverse consequences of the procedure. In this prospective study, there were 37 adult subjects (17 males and 20 females) enrolled in Group 1 for ultra-long scan depth-OCT measurements. Their mean age was 36.0 ± 14.4 years (range 19 to 76 years) and their mean refraction was -2.8 ± 1.9 diopters (range +2.00 to -7.00 diopters). In addition, there were 12 adult subjects (6 males and 6 females) from the Group 1, enrolled in Group 2 for the measurements of ultra-long scan depth-OCT and IOLMaster. Their mean age was 35.2 ± 1.9 years (range 26 to 48 years) and their mean refraction was -2.50 ± 1.9 diopters (range -0.25 to -7.00 diopters). All subjects were recruited from the University of Miami. Exclusion criteria were anterior or posterior segment pathology, systemic disease, or history of laser treatment, trauma, or eye surgery.

Subjects in Group 1 were imaged twice with ultra-long scan depth-OCT. The parameters included central corneal thickness (CCT), anterior chamber depth (ACD), lens thickness (LT), vitreous length (VL) and axial length (AL). Subjects in Group 2 were imaged with ultra-long scan depth-OCT and IOLMaster (Carl Zeiss Meditec, Dublin, CA) for the AL measurement. The measurements with both instruments were taken twice at one visit. All measurements were performed on the left eyes. OCT imaging was conducted by the same researcher (YS).

The ultra-long scan depth-OCT system was improved from our previous prototype of long scan depth OCT by adding a switchable reference arm for improving the scan depth range.^{16, 17} The improvement included the implementation of a complementary metal-oxide-semiconductor (CMOS) camera and a four-mirror switchable reference arm for enhancing the scan speed and scan depth. The system consisted of five key elements: a light

source, reference arm, sample arm, spectrometer and computer. The light source was a superluminescent diode (SLD, InPhenix, IPSDD0808, Livermore, CA, USA). Its center wavelength was 840 nm and full-width at half maximum bandwidth was 50 nm. The measured axial resolution was 7.7 μm . The measured scan depth was 12.57 mm. The power of incident light on the corneal surface of the human eye was 1.25 mW, which was below the ANSI Z136.1 cut-off value for safety.¹⁸ The beam was split into the sample arm and the reference arm with a 50:50 fiber coupler. From information derived from our previous prototypes, we incorporated a special switchable reference arm in the OCT system to increase the signal-to-noise (SNR) and the effective imaging depth. There were 4 mirrors in the reference arm. A galvanometer, controlled by a computer, turned the light among the 4 mirrors in the reference arm, which increased the scan depth. This approach was also used in scanning the anterior segment and retina by Ruggeri et al., who used a 3-mirror switchable reference arm.¹⁵ In our prototype, the two images from the first two mirrors were used to scan the anterior segment with the zero-delay lines placed at the top of the cornea and the posterior surface of the crystalline lens, similar to the set-up used in our previous study.^{16, 17} Overlaying these two images resulted in the enhancement of image quality.¹⁶ The 3rd and 4th mirrors were set to scan the vitreous and retina. The optical path difference between 1st mirror and 3rd mirror was 25.14 mm. The optical path difference between 3rd mirror and 4th mirror was 12.57 mm. The total scan depth was 37.71 mm, which was sufficient to image the entire eye without gaps (Figure 1). The sample arm was mounted on a modified slit-lamp microscope. The x-y galvanometer pair scanned the horizontal and the vertical meridians. The target was a white Snellen letter “E” on a black background displayed by the liquid-crystal display (LCD) screen, which was 10 cm from the tested eye. The spectrometer was composed of four parts: a collimating lens ($f = 50$ mm, OZ Optics, Ottawa, Canada), a 1,800 lines/mm volume holography transmission grating, an image enlargement lens with a focal length of 240 mm (Schneider Optics, $f = 240$ mm, Hauppauge, NY), and a line array CMOS camera with a high scan speed of up to 70,000 A-lines/s (Basler Sprint spL4096-140k; Basler AG, Germany). We set the exposure time at 44 μs , and the scan speed to 17,500 A-lines/s in order to scan the entire eye. The image size obtained with each mirror was $2,048 \times 4,096$ pixels per scan segment and the reconstructed image was $2,048 \times 12,288$ pixels.

One model eye (OEMI-7, Ocular Instruments Inc., Bellevue, WA, Figure 2) was imaged with ultra-long scan depth-OCT to validate OCT full eye biometry. The model eye was made from polymethyl methacrylate (PMMA) with a cornea, crystalline lens and retina. The anterior chamber and vitreous chamber were filled with saline solution. The anterior segment, included cornea, anterior chamber and crystalline lens, was detachable from the posterior segment. The geometry of the model eye was measured using a digital caliper (Tresna, Guilin Guanglu Measuring Instrument Co. Ltd., Guangxi Province, China) and a digital thickness gauge (ID-C1012EBS, Mitutoyo Corp., Takatsu-ku, Kawasaki, Kanagawa, Japan). CCT (Figure 2, A) and the length from the anterior of the cornea to the posterior of the crystalline lens (Figure 2, C) were measured using the digital thickness gauge, LT (Figure 2, B) was measured using the digital caliper, then ACD was calculated as $C - (A+B)$. The length of the model eye (Figure 2, E) was measured using the digital caliper, the length between the posterior of the model eye and the apex of the retina (Figure 2, D) was measured using the digital thickness gauge, then AL was calculated as $E \text{ minus } D$. VL was calculated as $AL - (CCT + ACD + LT)$. Using the refractive index of PMMA (1.485 at a wavelength of 840 nm) and saline solution (1.336 at a wavelength of 840 nm), axial biometry of the model eye was determined with ultra-long scan depth-OCT. The measurement obtained with ultra-long scan depth-OCT highly correlated with the geometry of the model eye with regard to all measured parameters (Figure 3).

Custom software was developed to automatically register the two images obtained with the first two mirrors and to create an overlaid image. The common features of the iris and the

anterior segment of the crystalline lens were used to register these two images. A full eye image was subsequently reconstructed (Figure 1). After removal of the central specular reflex (50 A-scans), hundreds of A-scans in the center were used to create a longitudinal reflectivity profile. The software automatically searched the peaks corresponding to each boundary, which were marked on the reflectivity profile. Inspection of the detected boundary location was conducted by comparing the peak locations and the reconstructed two-dimensional image (Figure 1). Corrections were made if the detected peak did not correspond to the boundary in the image. After the locations of the boundaries were confirmed by the inspection, the apparent distances of the central cornea, anterior chamber, crystalline lens and vitreous chamber were measured along the central axis. At a wavelength of 840 nm, the refractive indices of the cornea, aqueous humor, crystalline lens, and vitreous were 1.387,¹⁹ 1.342,²⁰ 1.408,^{20, 21} and 1.341,²⁰ respectively. Using the refractive index, the geometrical lengths of the central corneal anterior chamber, lens and vitreous were calculated. The axial length of the entire eye was the sum of the geometrical lengths of the cornea, aqueous, lens and vitreous. The software saved all measurements into an Excel spreadsheet.

To validate software generated results, the manual method for defining the boundaries was performed in Adobe Photoshop CS (San Jose, CA) by obtaining the boundary pixel in each image. The marking was taken on the right side of the central specular reflex. The two images obtained with the first two mirrors were manually registered and overlaid. Manual markings were then made on the overlaid image. The location of each boundary was then determined and used to calculate full eye biometry with the set of refractive indices used in the software.

A statistical software package (SPSS for Windows 17.0, SPSS Inc., Chicago, IL) was used for descriptive statistics and data analysis. All data were presented as the mean $\pm$ standard deviation. Paired t-test was used and $P < 0.05$ was considered a significant difference between two methods. The coefficient of repeatability (CoR) was defined as 2 standard deviations (SDs) of the difference between two measurements made by the same observer in different sessions for the same subject.²² The percentage of coefficient of repeatability (CoR %) was calculated as CoR divided by the average of each pair of measurements. The interclass correlation coefficients (ICC) were calculated. Bland-Altman plots were used to determine the agreement between the two measurements of entire eye axial biometry.

RESULTS

All of the parameters from the images obtained with ultra-long scan depth-OCT were successfully processed with the automatic and manual methods. In Group 1, there were no significant differences in the measured parameters between automatic and manual methods and between the first and second measurement ($P > .05$, Table 1, Figure 4). There was a strong correlation between the results using automatic and manual segmentation methods ($R^2 = 0.999$, $P < .05$, Figure 5). The difference between the two measurements for each parameter was plotted using the Bland-Altman Plot (Figure 6). The CoRs of CCT, ACD, LT, VL and AL were 0.021 mm, 0.067 mm, 0.071 mm, 0.084 mm and 0.075 mm, respectively, using the automatic method (Table). The CoR% ranged from 0.3% to 3.9% and ICC ranged from 0.946 to 0.999 (Table). Using the manual method, the CoR ranged from 0.011mm to 0.073mm, and the corresponding CoR% ranged from 0.3% to 2.0% (Table). The ICC ranged from 0.986 to 0.999 (Table). In Group 2, axial length measured by ultra-long scan depth-OCT was 25.441 ± 1.071 mm with the automatic segmentation method, 25.444 ± 1.073 mm with the manual segmentation methods, and 25.342 ± 1.096 mm with the IOLMaster. There was a significant difference of 0.09 mm between two repeated measurements ($P < .05$). The results from both automatic and manual methods correlated

with the results measured by the IOLMaster ($R_1^2 = 0.987$ and $R_2^2 = 0.988$, respectively, $P < .05$, Figure 7).

DISCUSSION

There are traditional methods for axial biometry of the entire eye *in vivo*. A-scan ultrasound is the gold standard for the determination of eye length, but the best precision of A-scan ultrasound is only 0.1 mm.^{23–26} The measurement requires contact with the eye for measuring AL, which requires topical anesthesia and increases the risk of corneal abrasions and infection.^{23–26} There are other techniques that have been used to assess the shape of the entire eye *in vivo*, such as X-ray,²⁷ magnetic resonance imaging (MRI),²⁸ and computed tomography (CT).²⁹ X-ray and MRI have low resolutions, which may limit their use in the eye.²⁸ MRI is relatively time-consuming, making it difficult to obtain dynamic images. Optical techniques, such as partial coherence interferometry (PCI),^{7, 8} laser Doppler interferometry (LDI),³⁰ and OLCR,³¹ can be used. They offer a precision ranging from 3 μm to 20 μm and do not require contact with the eye. These methods are used by the IOLMaster (Carl Zeiss Meditec, Dublin, CA)^{7, 8} and Lenstar (Haag-Streit USA, Mason, OH); these imaging modalities can only make axial measurements in a single dimension, similar to the A-scan ultrasound.^{9–11} Most of the devices do not have a fixation target and use the group index for converting optical length to geometrical length.^{10, 32–34} These measurements of axial length may thus be influenced by changes due to accommodation during measurement.^{34–37} This may explain some of the measurement errors in the calculation of IOL power.³⁷

Optical coherence tomography (OCT) has been used in ophthalmology for approximately 20 years with the benefit of noninvasive, cross-sectional imaging of the eye.^{38, 39} OCT is mainly used for imaging the posterior segment of the eye, including the retina, macula, and optic nerve head.^{40–43} OCT can also be used in imaging the anterior segment of the eye, including the cornea, anterior chamber, chamber angle and crystalline lens.^{44, 45} Commercially available OCT instruments are not able to image the entire eye, due to limited scan depth range and signal drop-off. With recent advances in the OCT field, the scan depth range of OCT can be long enough to image the entire eye. An approach with two spectrometers or two scanning channels in the OCT system has been demonstrated to be useful in imaging the anterior segment and the retina.^{12, 14} Ruggeri et al¹⁵ demonstrated that the full eye could be imaged with a switchable reference arm. These OCT approaches could be used to obtain axial biometry of the entire eye, but only a portion of the eye was imaged (anterior segment and the retina). Three-dimensional (3D) scanning has been demonstrated for imaging the entire anterior segment.⁴⁶ Quantitative 3D OCT biometry of the anterior segment will be helpful in the correction of eye motion and the measurement of the geometric structure of the eye, which will be beneficial for IOL calculation, although it involves complicated image processing, reconstruction and optical correction. Full eye scanning along the axial axis has been performed, and all portions of the eye, including the vitreous, can be imaged. Grulkowski et al¹³ demonstrated that swept source OCT (SS-OCT) utilizing vertical-cavity surface emitting laser (VCSEL) technology can be used for *in vivo* imaging of the full eye. These advances indicated that OCT could be employed for full eye biometry, with the added benefit of two or three dimensional scanning. In the present study, the ultra-long scan depth-OCT system demonstrated the ability to image the cross-section of each segment of the eye through the axial axis at a high speed. Further analysis crystalline lens shape change can therefore be conducted with this system. High speed scanning is also possible with our system, which can be used in real-time scanning to track the changes in all segments during accommodation.¹⁵ The implementation of a fixation target and the tracking of iris planes in the horizontal and vertical meridians may further improve repeatability. As demonstrated, the retinal image had no detailed layer information, making it impossible to

determine if the center was aligned with the fovea. Further improvement with the two-channel scanning probe may be explored.¹⁴

In addition to our prototype ultra-long scan depth-OCT with the switchable reference arm for scanning the entire eye, there are several reported OCT instruments with the ability to image the entire eye that present their own advantages and disadvantages.^{12–15} Some OCT systems have two spectrometers or two scanning channels for imaging the anterior segment and the retina.^{12, 14} In these systems, the anterior segment imaging may not be satisfactory because the division of light into the two channels results in 50% attenuation of the reflected light. The advantage of these systems is the simultaneous scanning of both anterior and posterior segments. The disadvantage seen in the two-channel approach has been overcome by using SS-OCT with a robust light source, resulting in *in vivo* imaging of the full eye.¹³ However, the light source used by Grulkowski et al¹³ is currently not commercially available, and the system appears to be complex. Ruggeri et al¹⁵ described full eye imaging with a switchable reference arm of three mirrors. All key elements of the eye were imaged successfully. However, an un-scanned gap remained in the vitreous chamber. The last mirror may need to be adjusted for accommodating some subjects with extremely short axial lengths. In the present study, we used the 4 mirror switchable reference arm, which was sufficient to image the entire eye without gaps. The use of the CMOS camera with 4,906 pixels made it possible to have high resolution and high speed scanning in the OCT system.

Repeatability is a very important parameter that needs to be evaluated before the method is widely used in clinic and research.²² There is currently no information available about the repeatability of the other methods for axial biometry of entire eye.^{12–15} In the present study, the CoR ranged from 0.014 to 0.079 mm, indicating excellent repeatability. The CoRs of CCT and ACD were the same as that reported by the IOLMaster and Lenstar. However, the CoR of AL was higher than that obtained by the IOLMaster and Lenstar.^{9, 10} In the present study, rather than using of group refractive index, AL was the sum of CCT, ACD, LT and VL. The bias of each element may affect the AL measurement. The IOLMaster and Lenstar perform 10 readings for each measurement and averaging these 10 readings may help the repeatability.

As the hardware develops, developing software to process images and to automatically yield results will be a challenge. Measuring OCT images with manual measurements is a time-consuming process and is subject to human error. In the present study, custom software was used to automatically register and reconstruct the full eye image. The results from both automatic and manual methods showed strong correlation. All data pertaining to axial biometry of entire eye obtained by the automatic algorithm matched the results obtained by the manual method. The results indicated that it is feasible to automatically process the data. Full eye axial biometry could therefore be fully automatic. In the present study, human inspection was performed and adjustment of the peak detection was conducted. Although the data matched the manual results, further improvement of the automatic algorithm will be needed to optimize the automatic process.

There were some limitations in this study. First, the sample size was relatively small. For clinical application, a large sample size, including subjects with cataracts or implanted IOL, may be necessary to test the reliability of our method. Second, because all OCT imaging was conducted by the same researcher, the reproducibility between operators was not tested. Third, the image of retinal structure was not as clear as the image obtained by posterior segment OCT. As a result, the software was not fully automatic and adjustments needed to be performed.

In conclusion, axial biometry using ultra-long scan depth-OCT successfully measured each segment of the entire eye with good repeatability. With further development of automatic segmentation, ultra-long scan depth-OCT appears to be a promising tool in the axial biometry of the entire eye. The system may have clinical applications like calculation of IOL power and tracking lens shape alteration during accommodation.

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Biographies

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Dr. Zhong's current research interests include full eye biometry measurement and slit-lamp functional imaging.

Figure 1.

Representative image of axial biometry of the entire eye using ultra-long scan depth optical coherence tomography. The full eye image (left) was obtained from the left eye of a 43-year-old subject with myopia (−1.0 diopter). The right side shows the longitudinal reflectivity profiles produced by the custom-developed software. The profile has peaks from the boundaries of the cornea, crystalline lens and the retina that allows determination of intraocular distances. Bar = 1 mm.

Figure 2.

Schematic of model eye (left) used for calibration and its engineering drawing (right) was illustrated. The central corneal thickness (Figure 2, A) and the length from the anterior of the cornea to the posterior of the crystalline lens (Figure 2, C) were measured using the digital thickness gauge, the lens thickness (Figure 2, B) was measured using the digital caliper, then the anterior chamber depth was calculated as $C - (A + B)$. The length of the model eye (Figure 2, E) was measured using the digital caliper, the length between the posterior of the model eye and the apex of the retina (Figure 2, D) was measured using the digital thickness gauge, then the axial length was calculated as E minus D . The vitreous length was calculated as $E - D$. Bar = 10 mm.

CCT: central corneal thickness; **ACD:** anterior chamber depth; **LT:** lens thickness; **VL:** vitreous length; **AL:** axial length.

Figure 3.

Correlation between the actual parameters of the model eye and the axial biometry of entire eye measured by ultra-long scan depth optical coherence tomography. Correlation was showed strong ($R^2 = 0.999$, $P < .05$). The solid line represents the equality.

CCT: central corneal thickness; **ACD:** anterior chamber depth; **LT:** lens thickness; **VL:** vitreous length; **AL:** axial length.

Figure 4.

Inter-session variations in automatic (red) and manual (blue) methods of full eye axial biometry in 37 adult subjects. No significances were found among sessions and between the first and second measurement. The results showed strong correlations. Bars = standard deviation.

CCT: central corneal thickness; **ACD:** anterior chamber depth; **LT:** lens thickness; **VL:** vitreous length; **AL:** axial length.

Figure 5.

Correlation between manual and automatic segmentation methods of full eye axial biometry in 37 adult subjects. Automatically segmented results were compared to the manually segmented results. Both results showed strong correlations ($R^2 = 0.999$, $P < .05$). The solid line represents the equality. Bars = standard deviation.

CCT: central corneal thickness; **ACD:** anterior chamber depth; **LT:** lens thickness; **VL:** vitreous length; **AL:** axial length.

Figure 6.

Bland–Altman plots of the difference between the two repeated measurements using both automatic (red) and manual method (blue) of full eye axial biometry in 37 adult subjects. The full eye axial biometry included the central corneal thickness, the anterior chamber depth, the lens thickness, the vitreous length and the axial length. Values on the horizontal axis correspond to the mean of the two measurements. Values on the vertical axis correspond to the difference of two measurements. Solid lines and dashed lines indicate mean differences and 95% limits of agreement.

CCT: central corneal thickness; **ACD:** anterior chamber depth; **LT:** lens thickness, **VL:** vitreous length; **AL:** axial length.

Figure 7.

Correlations of the axial lengths obtained with ultra-long scan depth optical coherence tomography and IOLMaster. The data were obtained from the 12 subjects of Group 2. Strong correlation of axial length was obtained by ultra-long scan depth optical coherence tomography using the automatic method and by IOLMaster (Red, $R_1^2 = 0.987$, $P < .05$). Strong correlation of axial length was obtained by ultra-long scan depth optical coherence tomography using the manual method and by IOLMaster (Blue, $R_2^2 = 0.988$, $P < .05$).

Table
Axial biometry of the entire eye using ultra-long scan depth optical coherence tomography (n = 37)

	CCT	ACD	LT	VL	AL
Manual Method					
Measure 1 (mm)	0.531 ± 0.032	3.156 ± 0.280	3.887 ± 0.330	17.193 ± 1.057	24.767 ± 1.039
Measure 2 (mm)	0.530 ± 0.032	3.157 ± 0.284	3.888 ± 0.331	17.188 ± 1.067	24.763 ± 1.047
Difference (mm)	0.001 ± 0.005	0.001 ± 0.015	0.001 ± 0.018	0.005 ± 0.037	0.004 ± 0.036
CoR (mm)	0.011	0.029	0.037	0.073	0.072
CoR %	2.0	0.9	0.9	0.4	0.3
ICC	0.986	0.999	0.998	0.999	0.999
Automatic Method					
Measure 1 (mm)	0.529 ± 0.032	3.155 ± 0.276	3.898 ± 0.345	17.181 ± 1.064	24.763 ± 1.036
Measure 2 (mm)	0.528 ± 0.031	3.157 ± 0.271	3.884 ± 0.339	17.189 ± 1.062	24.757 ± 1.033
Difference (mm)	0.002 ± 0.030	0.002 ± 0.033	0.014 ± 0.035	0.008 ± 0.042	0.006 ± 0.037
CoR (mm)	0.021	0.067	0.071	0.084	0.075
CoR %	3.9	2.1	1.8	0.5	0.3
ICC	0.946	0.993	0.995	0.999	0.999
Average Manual Measurement vs. Average Automatic Measurement					
Manual Method (mm)	0.531 ± 0.032	3.156 ± 0.281	3.888 ± 0.330	17.190 ± 1.062	24.765 ± 1.043
Automatic Method (mm)	0.529 ± 0.032	3.156 ± 0.273	3.891 ± 0.342	17.185 ± 1.063	24.760 ± 1.034
Pair t-test P value	0.079	0.466	0.373	0.271	0.232

CCT: central corneal thickness, ACD: anterior chamber depth, LT: lens thickness, VL: vitreous length, AL: axial length, CoR: coefficients of repeatability, ICC: intraclass correlation coefficients.