

Comparison of partial coherence interferometry and ultrasound for anterior segment biometry

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PURPOSE: To assess the performance of a partial coherence interferometry (PCI)-based device for the determination of anterior segment biometry.

SETTING: Clínica Centrofama, Cartagena, Murcia, Spain.

METHODS: Central corneal thickness (CCT), anterior chamber depth (ACD), and lens thickness (LT) were measured with the ACMaster PCI anterior segment biometer and an Echoscan US-1800 ultrasound (US) biometer/pachymeter with and without cycloplegia. To determine the precision of the instruments, the same examiner took 30 consecutive CCT, ACD, and LT measurements in a single subject under the same conditions and with and without cycloplegia. The same measurements were performed in additional subjects.

RESULTS: Twenty-one eyes (16 subjects) were evaluated. Repeated measurements of the single subject yielded a standard deviation of 4.0 μm for CCT, 106.0 μm for ACD, and 323.0 μm for LT; there were many peaks, mainly in the last 10 readings. There was a high correlation between CCT measurements with both systems with and without cycloplegia ($r^2 > 0.93$), with the US system giving higher values. Differences were significant ($P < .001$), but not consistent, throughout the range of corneal thicknesses and were greater for thicker corneas. Differences in ACD and LT measurements were similar. Agreement between systems in ACD and LT measurements was considerably lower than for CCT measurements.

CONCLUSIONS: The PCI biometer provided precise CCT measurements. The ACD and LT measurements had a higher variance. Differences in CCT measurements between the 2 systems were greater for thicker corneas, with higher values with the US system.

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Measurements of central corneal thickness (CCT), anterior chamber depth (ACD), lens thickness (LT), and axial length (AL) of the eye are very useful in current ophthalmology practice due to their relevance to refractive surgery and cataract surgery. The 2 main types of instruments for measuring intraocular distances between different surfaces are ultrasound (US) biometers and optical biometers; each is based on a different physical principle.

Ultrasound biometers detect the areas of discontinuity within the ocular globe by means of ultrasonic waves with a typical frequency of 10 MHz. The waves are sent directly into the eye. They are partially reflected by the interfaces as echoes, are captured, and then are processed when leaving the eye. Optical biometers are a type of interferometry that is based on the incidence of a light beam (normally within the near infrared range typically 780 nm) partially coherent on the eye that interferes with itself

due to the reflection of part of the incident light on the interphases that separate refractive index discontinuities. Superposition of reflected beams is then captured by a photodetector. Partial coherence interferometry (PCI) has been regarded as a highly reliable method for AL determination.¹ Ultrasound biometry has been used and marketed since the 1970s, whereas optical biometry was developed in the early 1990s.

Measurement of ACD, LT, and AL are fundamental for intraocular lens selection in cataract surgery, and PCI technology has been shown to be useful in that field.^{2–4} In glaucoma patients, knowledge of CCT is essential to avoid continuous misinterpretation of the applanation tonometry measures.^{5–9} It is equally important to know the corneal thickness in candidates for laser refractive surgery because its value helps determine the feasibility of the surgery, the best type of surgery, and the surgical plan.

Because of the many applications of the technology, it is essential to know the accuracy and precision of biometric instruments. Several studies have analyzed the reliability of biometers and have compared results between different instruments. However, most studies were of CCT and ACD measurements.

Ultrasound pachymetry has been the gold standard for corneal thickness measurement for many years and has been extensively used to test new techniques for ocular biometry.¹⁰⁻¹⁹ One such device is the Echoscans US-1800 (Nidek, Inc.), a US A-scan/pachymeter that provides CCT, AL, ACD, and LT measurements.

Until recently, the most widely marketed laser PCI biometer was the IOLMaster (Carl Zeiss Meditec). This instrument is mainly used for AL measurements, although corneal radii and ACD can also be measured.²⁰⁻²² A newer instrument, the ACMaster (Carl Zeiss Meditec), came on the market approximately 2 years ago; it is based on the same principle as the IOLMaster but was designed specifically for anterior segment biometry. Although the instrument does not allow AL measurements, it provides a wide range of measurements including central and peripheral corneal thickness (range 200.0 to 800.0 μm), ACD (range 1.5 to 6.5 mm), and LT (range 0.1 to 9.5 mm).²³ These parameters can be measured under accommodative demands up to 3.00 diopters. There are few studies of the performance of the ACMaster, although the IOLMaster has been shown to provide accurate AL and ACD measurements.^{20,24,25}

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The goals of the present study were to evaluate the precision of the ACMaster biometer (PCI biometer) and compare the results with those obtained with the Echoscans US-1800 biometer (US biometer) and to assess the potential effect of cycloplegia on the measurements.

SUBJECTS AND METHODS

All subjects in the study read and signed an informed consent form before enrollment in the study. The study followed the tenets of the Declaration of Helsinki.

To determine the precision of the PCI biometer and US biometer, 30 measurements of CCT, ACD, and LT were obtained with both instruments in a single subject under the same conditions and without cycloplegia. The same experienced examiner took the readings. In addition, CCT, ACD, and LT measurements with and without cycloplegia were obtained with both instruments in a cohort of subjects.

Measurements

The default settings of the PCI biometer were used. The refractive index was 1.3851 for the cornea, 1.3454 for the aqueous and the vitreous, and 1.4065 for the lens. The US device was operated in automatic mode during acquisition. The velocity for acquisition was 1532m/s for ACD and vitreous depth and 1641m/s for crystalline lens thickness.

All measurements with both biometers were free of artifacts. Three measurements were taken in each subject with both biometers with and without cycloplegia to assess the effect of possible accommodative changes on the results. The measurements were performed under the same conditions by the same experienced examiner.

Statistical Analysis

Data were analyzed using an Excel spreadsheet (Microsoft Corp.) Paired *t* tests were used to determine significant differences in measurement values between the PCI and US instruments and to assess the differences between measurements obtained with each instrument with and without cycloplegia. Regression plots and Bland-Altman plots were used to assess the agreement and possible trends for the differences between the values obtained with both instruments.²⁶ Statistical significance was set at an α level of 0.05.

RESULTS

Measurements of CCT, ACD, and LT with and without cycloplegia were obtained with the PCI biometer and US biometer in 48 eyes of 24 subjects. Seventeen eyes were excluded because LT measurements with or without cycloplegia were not possible, and 10 were excluded because complete biometry, including LT, could not be obtained without cycloplegia. The resulting sample for analysis consisted of 21 eyes (7 right, 14 left) of 16 subjects (6 women and 10 men) with a mean age of 31.85 years \pm 5.29 (SD) (range 24 to 40 years).

Figure 1 and Table 1 show the results of the 30 consecutive measurements of the same subject by both

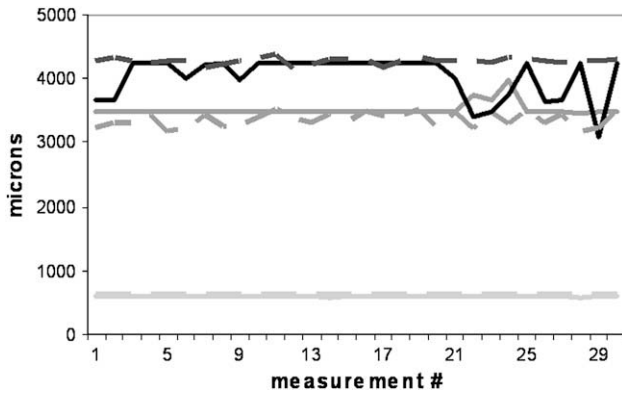


Figure 1. Results of 30 measurements in the same subject with the PCI biometer (solid lines) and US biometer (dashed lines). The CCT (light gray), ACD (dark gray), and LT (black) values are shown.

biometers. The CCT values were consistent, whereas the ACD and LT measurements, especially LT with the PCI biometer, showed variability.

A high correlation was found between CCT measurements with and without cycloplegia with both systems ($r^2 > 0.93$); under both cycloplegia conditions, the values obtained with the US biometer were higher. Although significant differences between measurements were observed, the difference was not consistent throughout the range of CCTs, being greater for thicker corneas and therefore showing poorer agreement (Figure 2). Differences in ACD and LT were similar regardless of the actual value measured, and agreement was poor for both parameters with and without cycloplegia (Figures 3 and 4).

Table 2 show the measurements with and without cycloplegia as well as the *P* values comparing the differences between the 2 biometers. There were significant differences in CCT measurements between the 2 biometers with and without cycloplegia. The difference in CCT between measurements taken with cycloplegia and measurements taken without cycloplegia were also statistically significant with both biometers (mean difference between 2.0 μm and 4.0 μm).

Table 1. Thirty consecutive measurements of the same subject.

Biometer	Mean \pm SD		
	CCT (μm)	ACD (mm)	LT (mm)
PCI	593 \pm 4	3.51 \pm 0.11	4.03 \pm 0.32
US	629 \pm 2	3.35 \pm 0.12	4.27 \pm 0.05

ACD = anterior chamber depth; CCT = central corneal thickness; LT = lens thickness; PCI = partial coherence interferometry; US = ultrasound

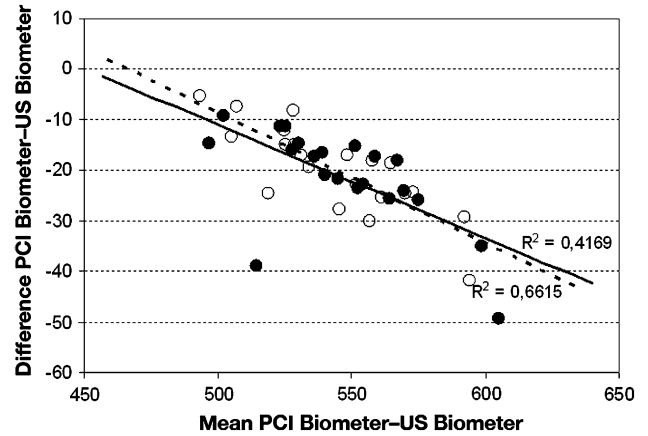


Figure 2. Bland-Altman plots of the difference versus the mean and the trend line between the PCI biometer and US biometer for CCT with cycloplegia (solid circles, solid line) and without cycloplegia (empty circles, dashed line) (PCI = partial coherence interferometry; US = ultrasound).

DISCUSSION

There are few reports in the peer-reviewed literature of the performance of the ACMaster PCI biometer. However, many studies have compared CCT and ACD measurements between contact and noncontact biometers and anterior segment analysis systems. The ACMaster uses the same principle as the IOLMaster biometer, which has been studied extensively and shown to be a highly precise and reliable noncontact method to determine AL and ACD.^{2,20,21,24,25,27,28} Furthermore, some authors suggest that this method is the new gold standard for ocular biometry.²⁷

Contact and noncontact biometers both have advantages and limitations. One advantage of noncontact PCI is that no anesthesia is needed, making it easier

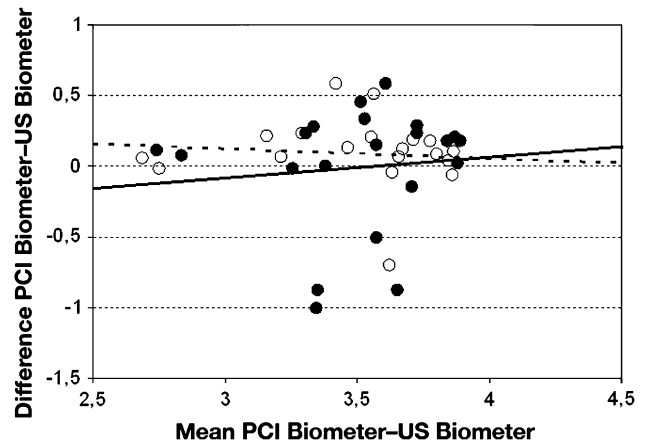


Figure 3. Bland-Altman plots of the difference versus the mean and the trend line between the PCI biometer and US biometer for ACD with cycloplegia (solid circles, solid line) and without cycloplegia (empty circles, dashed line) (PCI = partial coherence interferometry; US = ultrasound).

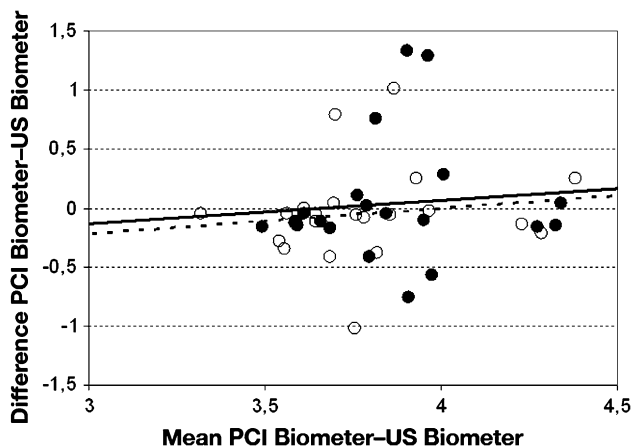


Figure 4. Bland-Altman plots of the difference versus the mean and the trend line between the PCI biometer and US biometer for LT with cycloplegia (solid circles, solid line) and without cycloplegia (empty circles, dashed line) (PCI = partial coherence interferometry; US = ultrasound).

to use in certain populations, in particular in children.²⁷ Contact biometry is more aggressive and depends on the examiner’s ability to locate the correct position on the eye and to gently apply the probe. Nevertheless, some practitioners find that is difficult to obtain valid measurements of the 3 parameters simultaneously (CCT, ACD, and LT) with the ACMaster biometer, mainly because of the difficulty in obtaining LT measurements.

In the present study, the ACMaster biometer gave very precise CCT measurements (SD 4.0 μm), quite precise ACD measurements (SD 106.0 μm), and not as precise LT measurements (SD 323 μm); many peaks appeared, mainly in the last 10 readings. The Echoscan US-1800 biometer gave very precise CCT measurements (1.73 μm SD) and quite precise ACD and LT measurements (SD 116 μm and 50 μm, respectively).

The CCT values obtained with the PCI biometer were systematically lower (approximately 36.0 μm on average) than those with the US biometer with and without cycloplegia. Agreement was high, although the differences were statistically significant; values were a mean of 23% lower with the PCI biometer than with the US biometer. Bland-Altman plots showed that differences were not consistent across the whole range of thickness and were greater with thicker corneas. The apparent variation in the differences in thickness measurements between the systems can be explained on the basis that the CCT in Table 1 (repeated measures) was considerably higher than the averaged CCT measurement in Table 2. Therefore, according to the regression equation obtained from the mean values from Figure 2, a 629.0 μm CCT measurement with the US biometer would be 591.1 μm when measured with the PCI biometer (Table 1), which was close to the value actually obtained (593.0 μm).

In contrast, the ACD measurements were similar between the 2 instruments. The LT measurements were

Table 2. Comparison of measurements with the 2 biometers with and without cycloplegia.

Setting	Measurement		
	CCT (μm)	ACD (mm)	LT (mm)
With cycloplegia			
PCI biometer (mean ± SD)	536 ± 25	3.50 ± 0.40	3.87 ± 0.37
US biometer (mean ± SD)	557 ± 31	3.51 ± 0.36	3.83 ± 0.34
Mean difference ± 95% CI	-21 ± 6	-0.07 ± 0.27	0.34 ± 0.33
P value	<.001*	.947	.765
Without cycloplegia			
PCI biometer (mean ± SD)	534 ± 24	3.56 ± 0.34	3.77 ± 0.35
US biometer (mean ± SD)	554 ± 31	3.47 ± 0.36	3.81 ± 0.31
Mean difference ± 95% CI	-20 ± 7	0.91 ± 0.21	-0.46 ± 0.44
P value	<.001*	.108	.616
With vs without cycloplegia			
PCI biometer			
Mean difference	2	-0.058	0.101
P value	.012*	.418	.223
US biometer			
Mean difference	4	0.040	0.021
P value	.034 *	.185	.694

ACD = anterior chamber depth; CCT = central corneal thickness; CI = confidence interval; LT = lens thickness; PCI = partial coherence interferometry; US = ultrasound

*Statistically significant, paired t test

approximately 240.0 μm higher with the US biometer, with great variability across the range of thicknesses. The results of the comparison between biometers seem logical because the higher ACD values with the PCI system correspond to the lower LT values than those obtained with the US system. The correlation between values obtained with the 2 systems was much lower for ACD and LT with and without cycloplegia. However, the differences in the mean values were far from significant.

Much and Haigis²⁹ compared CCT measurements in 104 eyes of 56 patients with 4 pachymeters; 3 were PCI technology biometers (OLCR, Haag Streit; OCP, 4optics AG; ACMaster), and 1 was an ultrasound biometer (Tomey AL2000, Tomey Corp.), which was used as the gold standard. Reproducibility of measurements was 2.0 μm with the PCI biometers and 3.4 μm with the US biometer. The CCT values with the ACMaster were a mean of 0.12 ± 5.88 μm thinner than those obtained with the US biometer.

Buehl et al.³⁰ compared measurements of thickness at the corneal center and 4 peripheral points and of ACD between 3 instruments: ACMaster, Orbscan I (Bausch & Lomb), and Pentacam (Oculus). Results in 88 eyes of 44 subjects showed lower values for the ACMaster than for tomography (7.9 μm lower than Pentacam; 17.6 μm lower than Orbscan I). Correlation was very high in both cases, implying good agreement and agreeing with previous reports of overestimation of corneal thickness values by tomography systems.^{10,31}

Sacu et al.²³ assessed intersession and intrasession repeatability of corneal thickness, ACD, and LT measurements in 10 eyes of young healthy volunteers and 10 eyes with cataract using the ACMaster device; 5 of the volunteers were examined under cycloplegia. The authors reported 99.9% reproducibility of corneal thickness and ACD measurements. The LT reproducibility was not estimated due to the large amount of data lost in the cataract group. The mean of the intersession variance (SD) was 1.9 μm for corneal thickness, 7.5 μm for ACD, and 10.6 μm for LT. The mean of the intrasession variance (SD) was 1.6 μm for corneal thickness, 10.8 μm for ACD, and 8.7 μm for LT. Variance was lower with cycloplegia than without cycloplegia. The authors concluded that although reliable, the instrument showed limitations in measuring eyes with cataract. Because the authors discarded the outliers before analysis, their results cannot be directly compared with those reported here.

Nemeth et al.³² compared 5 CCT measurements in 136 eyes of 70 patients obtained with the ACMaster biometer and Tomey AL-200 US pachymeter. The authors found that the PCI measurements were more reliable than the US measurements.

Meinhardt et al.³³ measured ACD in 50 phakic eyes using the IOLMaster, ACMaster, Pentacam, and Jaeger pachymeter/biometer (Haag-Streit, Mason, OH). Values obtained with the ACMaster were, on average, lower than the values obtained with the other systems and had the lowest variance (± 5.4 μm); the variance was ± 12.7 μm with the Pentacam, ± 24.5 μm with the IOLMaster, and ± 41.2 μm with the Jaeger device. The authors mention the possible contribution of inherent differences in the principles of the devices, examiner experience, and patient collaboration to explain the differences between devices. Based on their findings, the authors conclude that the ACMaster biometer offers advantages over the other devices because of its accurate measurements and high reproducibility.

The present study confirmed a finding common to all studies of the ACMaster; that is, that corneal thickness values are always lower with PCI technology than with other pachymetry systems.

In the present study, agreement in CCT measurements with the PCI biometer and US biometer was very high, with a mean difference of approximately 20.0 μm . This difference varied by actual CT value but was greater with thicker corneas. Precision was very good and similar for both systems.

A surprising finding was the difference in ACMaster CCT measurements with cycloplegia and without cycloplegia. This difference could be due to a shift in the location of the entrance pupil under cycloplegia; in addition, because the central location is based on patient fixation, the 2 measurements are not taken at the same corneal location.

In conclusion, the ACD and LT results with the ACMaster device in this study were less reliable than those obtained by other authors.^{23,34} Although the PCI biometer gave precise CCT measurements, the ACD and LT measurements showed much higher variance, possibly as a result of accommodation fluctuations during the acquisition process without cycloplegia. The theoretical higher resolution of the optical method should be reflected in a lower intrasubject standard deviation. However, the results always showed an increase higher than twice the mean intrasubject standard deviation for the PCI biometer compared with the US biometer. Our results are not as positive as those previously reported; therefore, it could be concluded that the precision of our corneal thickness measurements is relatively similar to that reported by others. However, the measurements of other biometric parameters were not as good; this finding, coupled with the difficulty we had measuring LT in some subjects, implies that the ACMaster biometer does not provide satisfactory ACD and LT measurements.

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