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ORIGINAL RESEARCH

# Agreement and relationship between ultrasonic and partial coherence interferometry measurements of axial length and anterior chamber depth

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**Purpose:** To find the relationship between axial length (AL) and anterior chamber depth (ACD) measurements, using partial coherence interferometry (PCI) and A-scan ultrasonography (US).

**Setting:** National Eye Hospital, Cairo, Egypt.

**Method:** Retrieving and comparing biometric data from the files of 163 consecutive patients seeking cataract extraction by PCI (IOLMaster) and US (Sonomed).

**Results:** AL measured using US range from 20.93 to 33.17 mm (mean ± SD = 24.45 ± 2.73 mm). AL measured by PCI range from 20.90 to 33.27 mm (24.05 ± 2.76 mm). The range of ACD measured by US was 2.09 to 4.48 mm (3.32 ± 0.46 mm). The range of ACD measured by PCI was 2.15 to 4.29 mm (3.31 ± 0.45 mm). There is very high agreement between both methods; the intraclass correlation coefficient = 0.999 for AL, and 0.966 for ACD measurements. A linear regression model of two formulae fits the AL values (one for eyes longer than 29 mm, and the other for the shorter eyes), with no significant departure from linearity ($P > 0.1$). One formula fits the ACD values with significant departure from linearity ($P < 0.05$).

**Conclusion:** Both US and PCI methods for measurements of AL and ACD are highly correlated. Therefore, the value of AL measured by one method can be predicted, with high accuracy, from the other method.

**Keywords:** axial length, anterior chamber depth, A-scan US, partial coherence interferometry

## Introduction

New intraocular lenses (IOLs) such as accommodative, multifocal, and aspheric models need accurate ocular biometry for accurate IOL power calculations. Otherwise, the patients may be left with a significant refractive error.[1] Accurate axial length (AL) measurement has been shown to be the most important parameter for IOL power determination.[2] On the other hand, anterior chamber depth (ACD) measurement is required by several newer theoretical IOL power formulas to fine-tune the effective lens position; therefore, its accurate measurement is essential to minimize the risk of unwanted refractive outcomes.[1] Several noncontact biometry devices compare favorably to older ultrasonic biometric and keratometric techniques.[3] A-scan US measurement of the AL has a longitudinal resolution of 200 µm and an accuracy of 100–200 µm.[4] An error of 100 µm in AL measurements leads to about 0.28 diopter (D) of postoperative refractive error.[5]

In 1999, Carl Zeiss Meditec (Jena, Germany) introduced a noncontact partial coherence laser interferometer PCI (IOLMaster) as an alternative technique to measure the AL.[1] The PCI provides three different measurements: the AL, the phakic ACD,

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and the keratometric (K) readings. This set of measurements is sufficient to predict IOL power. The measurement of the AL is based on PCI using a laser diode in the near infrared spectrum (780 nm). This technique is able to measure AL with a high resolution of 12 μm and very high precision of 0.3–10 μm along the fixation line of the eye.[6–8] Advantages over conventional ultrasound (US) include: high precision (reproducibility), contact-free measurement, and observer independence of the measurements.[9,10]

Moreover, the AL measurement is performed through the visual axis since the patient is asked to fixate on the laser spot. In highly myopic or staphylomatous eyes, this can be of particular advantage since it can sometimes be difficult to measure the true AL through the visual axis with an ultrasonic probe. Optical biometry is also superior to US in the measurement of the pseudophakic and silicone oil-filled eye because the correction factor needed is much smaller than in ultrasonic biometry.[11]

The aim of this study was to investigate the agreement between contact A-scan US and PCI measurements of AL and ACD. In addition, we tried to find a formula with high accuracy to convert data between the two methods.

## Materials and methods

This retrospective study included 163 eyes for AL measurements and 104 eyes for ACD measurements of patients asking for cataract surgery at the National Eye Hospital (Cairo, Egypt). Data were collected retrospectively from patients' files including age, gender, history, clinical findings, PCI examination, and contact A-scan US results. All candidates were examined by the same ophthalmologist.

Exclusion criteria included patients with corneal opacification, previous corneal surgery, corneal edema, previous documented trauma cases, anterior segment inflammation, clinically diagnosed keratoconus and a history of glaucoma. In addition, patients were excluded if they had factors that could cause questionable measurement by PCI as a result of retinal detachment, silicone oil-filled eye, dense cataract, etcetera. Preoperatively, all candidates underwent PCI by IOLMaster (with software v4.08) and a contact A-scan ultrasound by Sonomed A/B Scan 5500 (Sonomed, Lake Success, NY) using the contact (applanation) technique to determine AL, K readings and ACD.

## Statistical analysis

Data were collected, revised, and analyzed using Microsoft Office Excel (2007; Redmond, WA), IBM SPSS Statistics (v19; Armonk, NY), and MedCalc (v11.1.1.0; Medcalc Software bvba, Ghent, Belgium). The following were calculated: the mean, standard deviation (SD), standard error of the mean (SEM), intraclass correlation coefficient, cusum test, *t*-test, Welch test, ANOVA test, post hoc test, and the linear regression. A *P*-value of less than 0.05 indicated statistical significance.

A scatter graph and Pearson's correlation coefficient were used to investigate the linear relationship between the AL and ACD by PCI versus those by contact A-scan ultrasound.

The agreement between the two methods was investigated using a Bland–Altman plot, which is a graph of the ratios between readings measured by the two methods plotted against the means for the pairs of measurements. The upper and lower limits for the 95% confidence interval for the mean differences are connected with horizontal straight lines, thus providing a band that helps to visualize the extent of agreement between the two methods.

## Results

### Demographic data: (Table 1)

163 measurements of AL, and 104 measurements of ACD:

- The mean age of the patients was 64.3 ± 10.9 years (ranging from 35–87.5 years).
- The mean IOL power was 18.1 ± 7.5 diopters (ranging from −5 to 30 diopters).
- The right eye to left eye ratio was 80:83.
- The male to female ratio was 64:99.

### AL measurements: (Table 2)

(a) By contact A-scan US:
- Range: 20.93–33.17 mm
- Mean ± SD: 24.45 ± 2.73 mm

(b) By PCI:
- Range: 20.90–33.27 mm
- Mean ± SD: 24.05 ± 2.76 mm.

There was a highly significant intraclass correlation coefficient between the PCI and contact A-scan US measurements for AL with the average for absolute agreement = 0.999 (Pearson Correlation = 0.998) (Figure 1).

Bland–Altman plots were created to assess the difference in individual measurement as a function of the mean

**Table 1** Demographic data

| | Mean ± SD | Range |
|---|---|---|
| Age | 64.3 ± 10.9 y | 35–87.5 y |
| IOLs power | 18.1 ± 7.5 D | −5–+30 D |
| **Numbers** | | |
| Side | 80 right | 83 left |
| Gender | 64 male | 99 female |

**Abbreviations:** IOLs, intraocular lenses; SD, standard deviation; y, years.

**Table 2** Mean AL and ACD measurements by both US and PCI

| | US (in mm) | PCI (in mm) |
|---|---|---|
| AL | | |
| Range | 20.93–33.17 | 20.90–33.27 |
| Mean ± SD | 24.45 ± 2.73 | 24.05 ± 2.76 |
| ACD | | |
| Range | 2.09–4.48 | 2.15–4.29 |
| Mean ± SD | 3.32 ± 0.46 | 3.31 ± 0.45 |

**Abbreviations:** AL, axial length; ACD, anterior chamber depth; US, ultrasound; PCI, partial coherence interferometry; SD, standard deviation.

of the two measurements for that subject. The two methods showed good agreement, 95% of the differences in the readings between them lay between 0.992 mm and 1.017 mm (Figure 2).

The difference between AL measurements with PCI and that with US:

- There was a mean difference in the measured AL obtained with PCI and contact A-scan US of 0.11 mm (range –0.47 to 0.72 mm).
- It doesn't depend on gender ($t = -0.033$, $P = 0.903$) by Welch test.
- It doesn't depend on laterality ($t = 1.374$, $P = 0.172$) by Student *t*-test.
- It doesn't correlate with age ($r = -0.010$, $P = 0.090$) by Pearson's correlation coefficient.
- It correlates with AL itself ($r = 0.0230$, $P = 0.003$) by Pearson's correlation coefficient.
- The ANOVA analysis showed significant differences (*F*-ratio = 9.965, $P < 0.001$). The Student–Newman–Keuls test for all corresponding comparisons showed that the long AL group is different from both the short and medium AL groups, which showed no significant difference between them (Table 3).

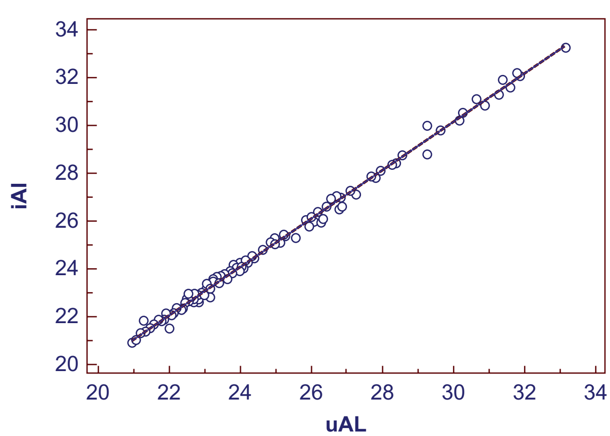


**Figure 1** Intraclass correlation coefficient between the PCI and contact A-scan ultrasonograph measurements for AL
**Abbreviations:** iAl, AL by partial coherence interferometry; uAL, AL by ultrasonography; PCI, partial coherence interferometry; AL, axial length.

Therefore, by linear regression we can only adopt two formulae:

1. For eyes with AL less than or equal to 29 mm by PCI:
   Equation: AL (PCI) = 0.2824 + 0.9919 AL (US)
   $R^2 = 0.9938$, $P < 0.001$
2. For eyes with AL more than 29 mm by PCI:
   Equation: AL (PCI) = 2.6108 + 0.9238 AL (US)
   $R^2 = 0.9564$, $P < 0.001$

Cusum test for linearity: there is no deviation from linearity ($P > 0.1$).

## ACD measurements: (Table 2)

(a) By contact A-scan US:

- Range: 2.09–4.48 mm
- Mean ± SD: 3.32 ± 0.46 mm

(b) By PCI:

- Range: 2.15–4.29 mm
- Mean ± SD: 3.31 ± 0.45 mm

There was a highly significant intraclass correlation coefficient between the PCI and contact A-scan US measurements for ACD, with the average for absolute agreement = 0.968 (Pearson's correlation coefficient = 0.938) (Figure 3).

From the Bland–Altman analysis, the two methods showed good agreement. Ninety-five percent of the differences in the readings between them lay between 0.91 and 1.10 (Figure 4).

The difference between ACD measurements with PCI and measurements with US:

- There was a mean difference in the measured ACD obtained with PCI and contact A-scan US of 0.01 mm (range –0.53–0.56 mm).
- It doesn't depend on gender ($t = 0.000$, $P = 1.000$) by Student *t*-test.
- It doesn't depend on laterality ($t = 0.495$, $P = 0.622$) by Student *t*-test.
- It doesn't correlate with age ($r = -0.079$, $P = 0.424$) by Pearson's correlation coefficient.
- It correlates poorly with AL ($r = 0.185$, $P = 0.060$) by Pearson's correlation coefficient (Table 4).
- The ANOVA analysis showed no significant differences (*F*-ratio = 1.250, $P = 0.291$).

Therefore, by linear regression we can adopt one formula only:

- Equation: ACD (PCI) = 0.2788 + 0.9208 ACD (US) $R^2 = 0.8734$, $P < 0.001$
- Cusum test for linearity: there is a significant deviation from linearity ($P < 0.05$).

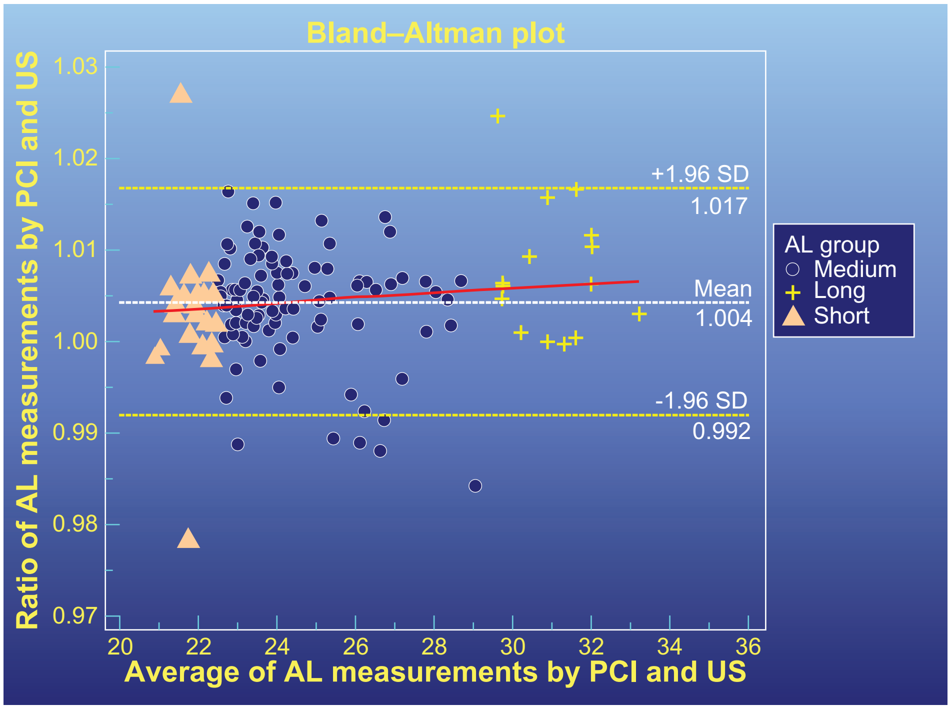


**Figure 2** Bland–Altman plot between the PCI and contact A-scan ultrasonograph measurements for AL.
**Abbreviations:** AL, axial length; PCI, partial coherence interferometry; US, ultrasound; SD, standard deviation.

## Discussion

This study showed good agreement, with a mean difference in the measured AL obtained with optical biometry and contact biometry of 0.10 mm (range −0.47–0.72 mm). Hitzenberger et al[12] found that the ALs measured by optical biometry were 0.18 mm longer than those measured by the immersion technique, and 0.47 mm longer than those measured by the contact technique. Kiss et al[13] reported a mean difference in the measured AL obtained with optical biometry and immersion biometry of 0.22 mm (range −0.24–0.57 mm).

Németh et al found that, for 208 eyes, the AL values measured by A-scan ultrasound and by PCI were significantly correlated ($r = 0.985$, $P = 0.001$); however, the PCI values were significantly higher than those of the A-scan US (mean difference = 0.39 ± 0.36 mm).[8]

In the previous studies including the present study, the ALs measured by the optical method were significantly longer than those measured by US; however, the values obtained by the two methods were closely correlated. The IOLMaster software is calibrated so that the optically measured value is adjusted using a regression model to the value measurable by the immersion US method.[14]

The longer eyes tend to be more compressible in contact A-scan US. This suggests a linear relationship between the magnitude of compression and the AL. Our study found the linear formulas describing the relationship between both methods of AL measurement with a good agreement. Therefore, the IOLMaster software could be

**Table 3** The difference between AL measurements with PCL and that with US

| | Total | Short AL | Medium AL | Long AL |
|---|---|---|---|---|
| Sample size | 163 | 32 | 115 | 16 |
| Range (in mm) | −0.47–0.72 | −0.47–0.58 | −0.46—0.37 | −0.01–0.72 |
| Mean ± SD (in mm) | 0.11 ± 0.16 | 0.06 ± 0.14 | 0.10 ± 0.14 | 0.27 ± 0.24 |

**Abbreviations:** AL, axial length; SD, standard deviation.

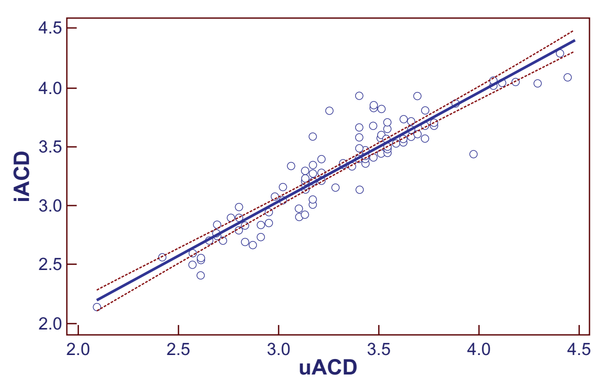


**Figure 3** Intraclass correlation coefficient between the PCI and contact A-scan ultrasonograph measurements for ACD.
**Abbreviations:** ACD, anterior chamber depth; iACD, ACD by partial coherence interferometry; uACD, ACD by ultrasonography; PCI, partial coherence interferometry.

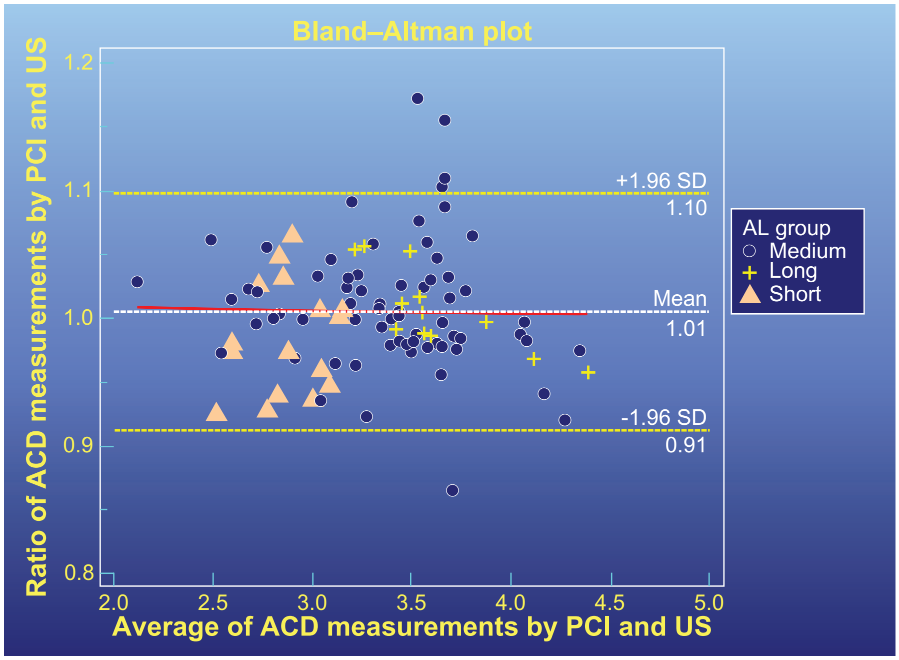


**Figure 4** Bland–Altman plot between the PCI and contact A-scan ultrasonograph measurements for ACD.
**Abbreviations:** ACD, anterior chamber depth; PCI, partial coherence interferometry; US, ultrasound; AL, axial length; SD, standard deviation.

modified to accept A-scan measured AL to calculate the IOL power. The present study reported a good agreement with a mean difference in the measured ACD obtained with optical biometry and contact biometry of 0.014 mm but with significant deviation from linearity. Németh et al reported that the ACD values with the IOLMaster in 252 eyes were significantly higher (by 0.28 mm) than the US values with no correlation between the two sets of values.[8]

Reddy et al[15] found that contact US measured ACD is 13% shorter, while the Orbscan and IOLMaster showed good correlation.

Decentration and misalignment with the visual axis in case of contact A-scan US made the difference between both measurements dependent upon the pupil diameter and accommodative state of the lens. These cause pronounced differences in ACD measurement and could explain the deviation from linearity in the ACD formula.

**Table 4** The difference between ACD measurements with PCI and ACD measurements with US

| | Total | Short AL | Medium AL | Long AL |
|---|---|---|---|---|
| Sample size | 104 | 18 | 74 | 12 |
| Range (in mm) | –0.53–0.56 | –0.2–0.19 | –0.53–0.56 | –0.19–0.18 |
| Mean ± SD (in mm) | 0.01 ± 0.16 | –0.04 ± 0.13 | 0.027 ± 0.17 | 0.02 ± 0.12 |

**Abbreviations:** ACD, anterior chamber depth; PCI, partial coherence interferometry; US, ultrasound; AL, axial length; SD, standard deviation.

In conclusion, although PCI is generally more accurate, we still need US measurements in some situations (eg, tear film abnormalities, corneal pathology, mature and dense posterior subcapsular cataracts, vitreous opacities, maculopathy, or retinal detachment).[1,16] It is better to combine US measurements with PCI capabilities. In order to do this, we need AL and ACD measurements to be convertible from one method to the other. This is fulfilled with the linear regression conversion formulae obtained with 99% accuracy for the AL, and 87% accuracy in ACD.

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