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Accuracy of a new partial coherence interferometry analyzer for biometric measurements

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Background/aims: Precise biometry is an essential preoperative parameter for refractive as well as cataract surgery. A new device based on partial coherence interferometry technology was tested and evaluated in regards to accuracy of measurements.

Methods: In a prospective clinical study 200 eyes of 100 healthy phakic volunteers were measured with a functional prototype of the new ALLEGRO BioGraph (Wavelight AG) / LENSTAR LS 900 (Haag Streit AG) biometer and the IOLMaster V.5 (Carl Zeiss Meditec AG). Repeated measurements as recommended by the manufacturers were performed with both devices and compared using Spearman Correlation calculations (WinSTAT).

Results: Spearman Correlation revealed a high correlation for axial length and keratometry measurements between the two devices tested. Anterior chamber depth, however, had a lower correlation between the two biometry devices. Also the mean values of the anterior chamber depth differed (IOLMaster 3.48 ± 0.42 mm versus BioGraph/LENSTAR 3.64 ± 0.26 mm, respectively), however this was not statistically different ($p>0.05$, t-test).

Conclusion: The new biometer provided results that correlated very well to those of the IOL Master. The ALLEGRO BioGraph / LENSTAR LS 900 is a precise new device that contains additional features which are a helpful tool for any cataract or refractive surgeon.

Precise biometric measurements of the eye as well as intraocular lens (IOL) calculation are a crucial step for successful outcomes of refractive and cataract surgery. While ultrasound axial length measurements have been the gold standard for a long period of time, the introduction of partial coherence interferometry based biometry was a big step towards more precise and reliable measurements.(1,2) The first commercially available device using this technology for biometric measurements was the IOLMaster (Carl Zeiss Meditec AG) which was introduced in the year 1999 and set new standards.(3) Especially since keratometry and anterior chamber depths measurements are included in the same machine the time needed for complete biometry is minimized and patient comfort is improved due to the non-contact measuring mode. Several studies have already proven the accuracy and advantage of partial coherence interferometry and the IOLMaster in comparison to ultrasound biometry.(4-9) Over the past years the IOLMaster has been improved several times and the current version V.5 is the most user friendly and fastest one. The purpose of this study was to evaluate and compare in a cohort of volunteers with healthy eyes a functional prototype of the new partial coherence interferometry biometer, ALLEGRO BioGraph (Wavelight AG) / LENSTAR LS 900 (Haag Streit AG) to the IOLMaster V.5. This new biometry device uses partial coherence interferometry not only for axial length but also for anterior chamber depth, pachymetry, lens and retinal thickness measurements. Additionally further biometric parameters like pupil size as well as corneal radius and consequently corneal power are evaluated and IOL power calculated using different formulas.

Material and Methods

In a prospective study 200 eyes of 100 healthy volunteers with a mean age of 27.25 ± 10.32 years (range 18-53 years) were measured without having received any eye drops or contact exams prior to the measurements using the IOLMaster V.5 and a functional prototype of the ALLEGRO BioGraph (Wavelight AG) / LENSTAR LS 900 (Haag Streit AG) biometer (figure 1). While the IOLMaster uses partial coherence interferometry only for axial length measurements the BioGraph / LENSTAR uses this technology also for pachymetry, anterior chamber depth as well as lens and retinal thickness measurements. In order to compare the two devices, axial length, anterior chamber depth as well as flattest and steepest corneal meridian were analyzed. All exams were performed by a doctor who did not use the devices before and who was trained according to the manufacturer's recommendations regarding number of repeated measurements needed as well as focusing patients' eyes. All participants were informed about the nature of this IRB approved study and gave their informed consent to perform the measurements and analyze the data. With the IOLMaster five consecutive measurements of axial length as well as anterior chamber depth and three consecutive keratometry measurements were performed. The ALLEGRO BioGraph / LENSTAR LS 900 requires five consecutive measurements, however, with one measurement several parameters are analyzed in one step. Among these are axial length, keratometry, anterior chamber depth and others. Anterior chamber depth was defined as the distance from the corneal epithelium to the anterior surface of the crystalline lens in order to be able to make comparisons to the measurements provided by the IOLMaster. The order regarding which machine was used first was randomly assigned.

Additionally all eyes were analyzed using an autorefractometer (AR-660A, NIDEK) in order to validate the biometric measurements with the patient's refraction. The mean values and standard deviations of all parameters measured were entered into an Excel (Microsoft Inc.) file. Statistical analysis was performed using WinSTAT software and Spearman correlation as well as t-test analysis.

Results

All 200 measurements were performed by one investigator without any problems and all exams were included in the evaluation. The mean spherical equivalent refraction was -0.42 ± 1.43 diopters (D) (range -6.00 to +6.38 D). The mean values and standard deviations for axial length measurements, keratometry readings for flattest and steepest meridian (K1 and K2) as well as anterior chamber depth (ACD) are shown in table 1. While the mean values and standard deviations for axial length measurements and keratometry readings between IOLMaster and ALLEGRO BioGraph / LENSTAR LS 900 biometer showed similar values, mean anterior chamber depth and its standard deviation differed (3.48 ± 0.42 mm versus 3.64 ± 0.26 mm, respectively), however, this was not statistically different ($p>0.05$, t-test).

	Axial length (mm)			K1 (D)			K2 (D)			Anterior chamber depth (mm) (*from epithelium)*		
	IOL Master	**ALLEGRO / LENSTAR**	**R**	**IOL Master**	**ALLEGRO / LENSTAR**	**R**	**IOL Master**	**ALLEGRO / LENSTAR**	**R**	**IOL Master**	**ALLEGRO / LENSTAR**	**R**
Mean	23.57	23.58	0.9992	42.45	42.41	0.9957	43.37	43.33	0.9929	3.48	3.64	0.4456
Std. Dev.	0.91	0.92		1.48	1.48		1.49	1.48		0.42	0.26	

Table 1: Comparison of mean axial length, keratometry and anterior chamber depth measurements of both devices tested. R = Correlation coefficient (Spearman Correlation, WinSTAT), refractive index of 1.322 used; n=200 eyes

Spearman correlation analysis revealed a high correlation for axial length (R=0.9992) and keratometry measurements (R=0.9957 and R=0.9859, respectively). Anterior chamber depth, however, had a moderate correlation between the two biometry devices (R=0.4456). Therefore the ACD analysis was repeated following exclusion of eleven eyes with IOLMaster ACD measurements of ≤ 2.6mm which most probably where related to incorrect detection of the anterior lens surface. Even then the correlation was slightly lower (R=0.9297) than that for axial length or keratometry measurements. The data analysis with Bland-Altman plots (figures 2-4) visualizes also these findings. Out of 200 axial length measurements only four showed a difference ≥ 0.1 mm (between 0.1 and 0.24 mm difference). 14 measurements of flattest meridian showed a difference of ≥ 0.25 D (between 0.25 and 0.88 D) and 25 measurements of steepest meridian showed a difference of ≥ 0.25 D (between 0.25 and 1.24 D). 13 measurements of the anterior chamber depth showed a difference of ≥ 0.5 mm (between 0.66 and 2.07 mm). The differences in axial length, flattest and steepest meridian as well as anterior chamber depth occurred in different eyes and were equally spread between all eyes without any specific trends. None of these eyes had any severe conditions that would explain these differences.

Discussion

While ultrasound axial length and manual keratometry measurements have been the gold standard for many years in ophthalmology, the introduction of partial coherence interferometry biometry and automated keratometry measurements was a very important step in cataract and refractive surgery.(1,2,10) Especially in the field of refractive surgery, but also in modern cataract surgery the requirements and patient demands for precise and accurate IOL power calculation are very high. The IOLMaster was the first device that combined the accurate partial coherence interferometry technology for axial length measurements with automated keratometry and anterior chamber depth measurements using slit illumination in one machine.(3) Depending on the IOL power calculation formula axial length and keratometry or additionally anterior chamber depth need to be known.(11) However, due to new intraocular surgical procedures like phakic IOLs or intracorneal implants and the increasing numbers of patients asking for individualized surgical refractive procedures, a machine that provides measurements for many kinds of refractive procedures would be a helpful tool during preoperative exams. The new ALLEGRO BioGraph (Wavelight AG) / LENSTAR LS 900 (Haag Streit AG) biometer is a good improvement towards this direction. It includes besides axial length, anterior chamber depth and keratometry measurements also corneal thickness, White-to-White distance and anterior chamber depth measurements from the endothelium which is very important for phakic IOL implantation.

The measurements performed in this study revealed a very good correlation for axial length and keratometry measurements between the ALLEGRO BioGraph / LENSTAR LS 900 biometer and the IOLMaster. For the anterior chamber depth measurements however, the correlation was lower with a higher standard deviation for the IOLMaster. This might be related to the difference in the measuring mode of the two devises. While the IOL Master uses a lateral slit illumination the new biometer also uses partial coherence interferometry technology to detect the anterior chamber depth. This allows the ALLEGRO BioGraph / LENSTAR LS 900 biometer to provide measurements of the corneal thickness from epithelium to endothelium and separately the distance from the endothelium to the anterior surface of the crystalline lens and therefore the correct anterior chamber depth. The cases where the IOLMaster showed shallow anterior chamber depth sizes whereas the new biometer measured a much deeper anterior chamber could be related to incorrect detection of the crystalline lens surface. The IOLMaster might have measured only the distance from the cornea to the iris or some light reflections of the clear lens surface in these young and healthy eyes lead to the incorrect measurements.

The advantage of partial coherence interferometry for precise anterior chamber depth has also been demonstrated in other studies. Meinhardt et al. compared the ACMaster (Zeiss Meditec), which uses this technology, to the IOLMaster as well as Pentacam and a slit-lamp attached device introduced by Jaeger and found that the ACMaster using partial coherence interferometry revealed the highest reproducibility and patient compliance.(12) Lavanya et al. compared the IOLMaster to the Visante anterior segment optical coherence tomography and found deeper anterior chamber measurements.(13). Other devices used to measure anterior chamber depth are corneal topography machines like Orbscan (Bausch & Lomb) or the Scheimpflug based analyzing systems Pentacam (Oculus) and Galilei (Ziemer).(14,15) Also modified and improved ultrasound technologies are recommended, however, their accuracy is still very much dependent on the skills of a trained examiner.(16) The advantage of partial coherence interferometry measurements in pseudophakic eyes has been demonstrated in a study by Kriechbaum et al. who compared anterior chamber depth measurements of phakic and pseudophakic eyes.(17) They found no difference in phakic patients if measured with the IOLMaster or partial coherence interferometry, however, pseudophakic eyes showed a higher difference and no correlation. Since our patient group had young and healthy eyes with a clear crystalline lens, this could have caused similar problems during the measuring mode of anterior chamber depth as seen in pseudophakic eyes. The ability of correct detection of the intraocular lens surfaces and consequently accurate measurement of anterior chamber depth in pseudophakic situations as well as correct measurements in cataract cases needs also to be proven for the new device. Therefore further studies should be performed evaluating these situations. The results so far confirm the high precision of the measurements in healthy eyes and suggest its use for exams in refractive surgery candidates and should also be a helpful tool in cataract cases.

Disclaimer: None of the authors has a financial or proprietary interest in any of the products mentioned.

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Legends to figures:

Figure1: Zeiss Meditec IOLMaster (A) and Wavelight ALLEGRO BioGraph / Haag Streit LENSTAR LS 900 (B) partial coherence biometers which were tested in the study.

Figure 2: Bland-Altman plot: Axial length (AL) comparison of IOLMaster and ALLEGRO BioGraph / LENSTAR LS 900 (biometer).

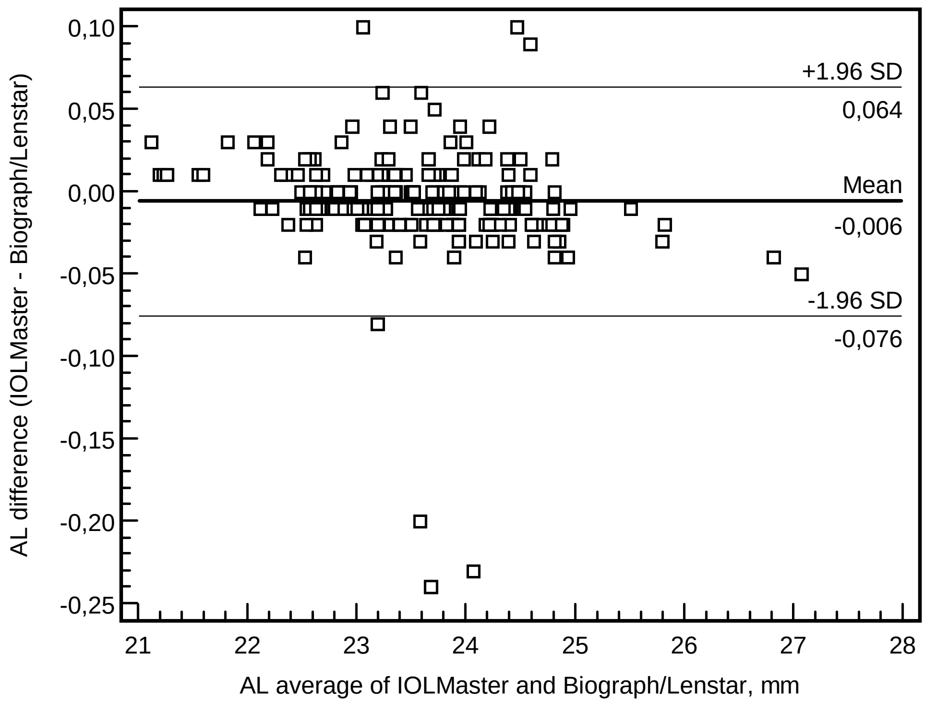
Figure 3: Bland-Altman plot: Comparison of flattest (A) and steepest (B) corneal meridian in diopters (D) measured with IOLMaster and ALLEGRO BioGraph / LENSTAR LS 900 (biometer).

Figure 4: Bland-Altman plot: Anterior chamber depth (ACD) comparison of IOLMaster and ALLEGRO BioGraph / LENSTAR LS 900 (biometer).

Figure 1A

Figure 1B

Figure 2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-0,10
-0,15
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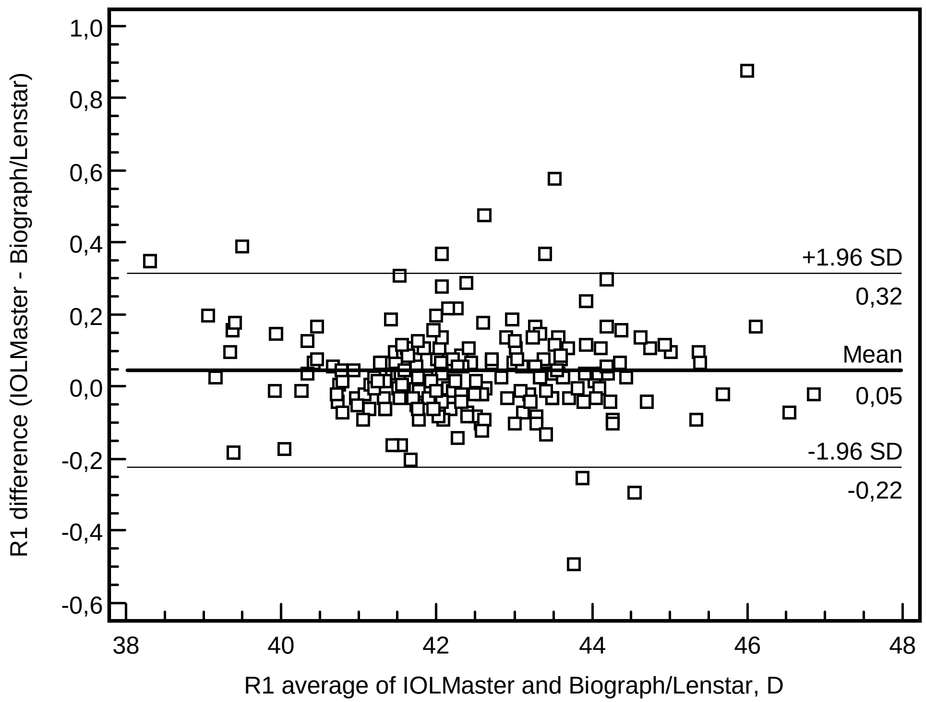
-0,25
+1.96 SD
0,064
Mean
-0,006
-1.96 SD
-0,076
21
22
23
24
25
26
27
28
AL difference (IOLMaster - Biograph/Lenstar)
AL average of IOLMaster and Biograph/Lenstar, mm

Figure 3A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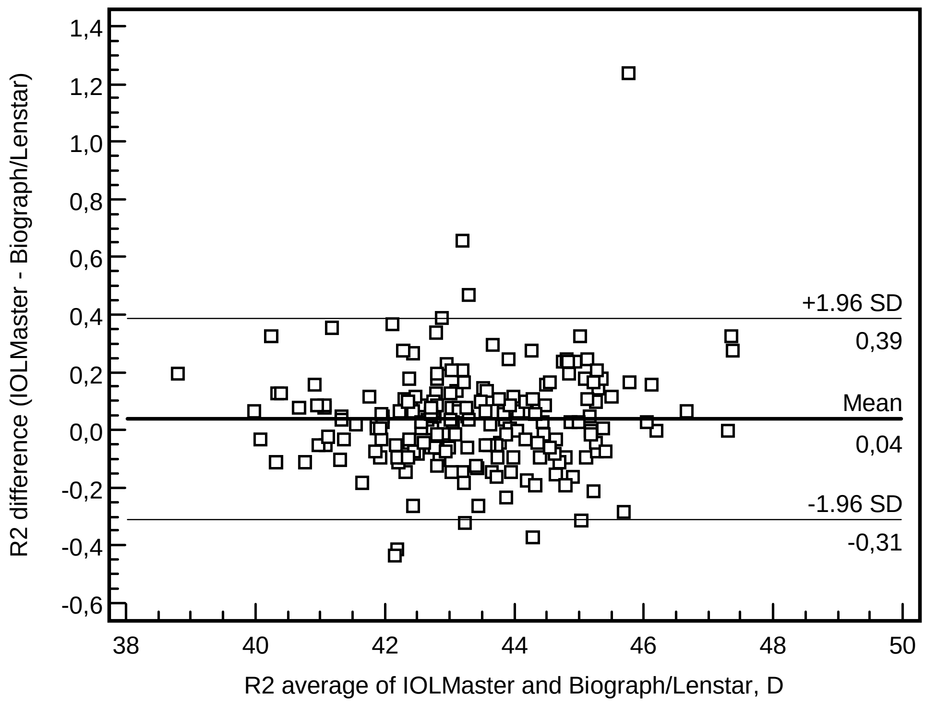
0,6
0,4
0,2
0,0
-0,2
-0,4
-0,6
38
40
42
44
46
48
+1.96 SD
0,32
Mean
0,05
-1.96 SD
-0,22
R1 difference (IOLMaster - Biograph/Lenstar)
R1 average of IOLMaster and Biograph/Lenstar, D

Figure 3B



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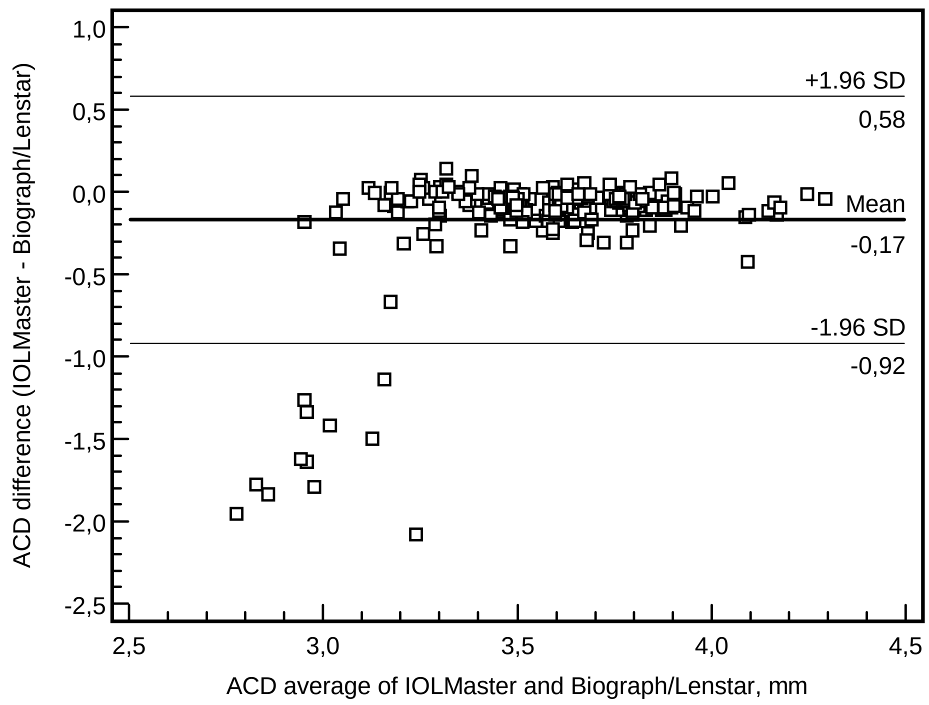
1,0
0,8
0,6
0,4
0,2
0,0
-0,2
-0,4
-0,6
R2 difference (IOLMaster - Biograph/Lenstar)
+1.96 SD
0,39
Mean
0,04
-1.96 SD
-0,31
38
40
42
44
46
48
50
R2 average of IOLMaster and Biograph/Lenstar, D

Figure 4



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0,0
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-1,0
-1,5
-2,0
-2,5
+1.96 SD
0,58
Mean
-0,17
-1.96 SD
-0,92
2,5
3,0
3,5
4,0
4,5
ACD difference (IOLMaster - Biograph/Lenstar)
ACD average of IOLMaster and Biograph/Lenstar, mm

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