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Comparison of the biometric measurements obtained using noncontact optical biometers LenStar LS 900 and IOL Master V.5

Porównanie wyników pomiarów biometrycznych uzyskanych za pomocą bezdotykowych optycznych biometrów LenStar LS 900 i IOL Master V.5

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Summary: Purpose: Evaluation of the measurement accuracy using a new optical biometer LenStar LS 900 (Haag Strait) and comparison according to the IOL Master V.5 (Zeiss) device.
Methods: In a prospective clinical study biometric measurements along with artificial lens power calculation using the LenStar LS 900 device were performed. A total number of 106 patients qualified for a cataract extraction procedure were included in the study. Measurements along with lens power calculation were repeated using the IOL Master V.5. device. Results were elaborated using Pearson's correlation and Bland-Altman plot.
Results: Measurements were performed in 204 eyes of 106 patients. Mean values and ranges of biometry results were as follows: 23.46 ± 2.81 mm [20.79-29.80] for IOL Master, and 23.47 ± 2.83 mm [20.79-29.86] for LenStar LS 900. In keratometry for flat meridian (K1) the following data was obtained: mean 43.24 ± 3.22 D [range 38.27-47.94] for IOL Master and 42.44 ± 3.15 D [38.27-47.94] for LenStar LS 900. For steep meridian (K2) the data obtained were 44.14 ± 3.40 D; [39.29-49.13] and 43.27 ± 3.34 D [38.61-48.4] respectively. The obtained calculation results for each eye were as follows: mean 21.23 ± 8.07, [range 3.25-28.99] for Hagis formula, 21.14 ± 6.90; [4.83-27.6] for SRK II, 21.04 ± 7.78; [3.05-28.05] for SRK/T, 21.09 ± 8.13; [2.43-28.61] for Holladay using IOL Master and 21.41 ± 8.23; [2.99-29.15] for Haigis; 21.24 ± 7.00; [4.6--27.71] for SRK II, 21.13 ± 7.90; [2.76-28.18] for SRK/T; 21.09 ± 8.13; [2.16-28.76] for Holladay using LenStar LS 900.
Conclusions: The LenStar LS 900 device enables to perform accurate and repetitive biometric measurements and implant power calculations. Implant calculation results obtained using the LenStar LS 900 device are comparable to those achieved using the IOL Master V.5 device, which has been commonly accepted as standard for over a decade. The use of both devices is limited by significant lens opacification and posterior capsule calcification. In such cases, additional ultrasound biometry should be performed.
Keratometry results obtained using both devices should not be used alternatively because of the different measurement methods and different refraction indexes. The LenStar LS 900 device comparing to the IOL Master additionally enables pachymetry, macular retinal thickness, lens thickens and pupil diameter measurement. Accuracy of those measurements should be studied in the future.
Słowa kluczowe: IOL Master, LenStar, biometria, keratometria, obliczanie mocy soczewki wewnątrzgałkowej.
Key words: IOL Master, LenStar, biometry, keratometry, IOL power calculation.

Introduction

A very accurate ocular biometric measurements along with precise intraocular-lens (IOL) power calculation decide of the refractive target achievement following cataract extraction procedure (1). For quite a long time, implant power calculation was based on the previous golden standard – ultrasound biometry. Devices based on partial coherent interferometry introduction were a huge progress in the process of ocular biometric parameters determination (2,3). The first device based on that technology that became available on the market was IOL Master (Carl Zeiss Meditec AG), introduced in 1999. Biometry, keratometry and anterior chamber depth measurement using only one device reduced the time necessary to perform an examination, and significantly increased the patient's comfort. Noncontact measurement course reduced development of corneal erosions or occurrence of infections. Significantly higher resolution of the device enabled to achieve more accurate measurements and more accurate implant power calculation (4,5). The IOL Master introduction significantly improved outcomes of cataract extraction procedures.

IOL Master uses partial coherent interferometry only for axial length measurement, however the other measurements are based on other imaging techniques (6). A new device for ocular biometric measurements – LenStar LS 900 (Haag Streit), uses optical reflectometry of low coherence for axial length, corneal thickness, lens thickness and anterior chamber depth determination. While analyzing image obtained during measurement, the LenStar device simultaneously measures corneal curvature, horizontal iris width (white-to-white) and pupil width.

The present study compared values obtained using the LenStar device with values obtained using the IOL Master device.

Methods

A total number of 106 patients (34 males, 72 females), 204 eyes qualified for a cataract extraction procedure were included in the study. All measurements were performed for each eye on both devices by one researcher.

During the axial length measurement LenStar and IOL Master use an action rule similar to that used in optical coherence tomography. In IOL Master, a laser diode was used, while in LenStar a superluminescent diode of Gauss curve shape which allows achieving a higher axial resolution. Due to that difference in action, the LenStar device was described as optical low coherent reflectometry.

During the examination performed with the LenStar device, the patient has to be concentrated on a flashing light. The researcher adjusts the device based on the eye image visible on the computer monitor. The device was placed approximately 7.0 cm from the patient's eye. During one measurement the LenStar device performed 16 scans. Examination was repeated 3 times according to the manufacturer's indications. During the axial length measurement the device used 820 μm wavelength light. The LenStar device uses two circles analysis for keratometry (16 light points each) of 1.65 cm and 2.3 cm diameter.

During the examination performed with IOL Master (V.5) device, the patient also has to be concentrated on a flashing light while the researcher adjusts parameters on the eye image visible on the monitor. The device was placed in a distance of approximately 5.5 cm. During the axial length measurement IOL Master uses 780 μm wavelength infrared light. The corneal curvature was evaluated via computed analysis of the distance between three pairs of the opposite light points which are placed in the apexes of the hexagon of 2.3 cm diameter (6).

Following the measurements, IOL power calculation was performed using Haigis, SRK II, SRK/T and Holladay algorithms.

The obtained results were processed based on Bland-Altman plot and Pearson's correlation (R = [0-1]).

Results

A total number of 204 eyes in 106 patients were examined (in 8 patients a fellow eye examination was not performed due to medical reasons). All measurements were conducted by one researcher. No technical difficulties occurred during examinations.

Mean results and values ranges for AL, steep and flat keratometry meridian (K1,K2) and average keratometry values are presented in Table I.

Biometry results in the conducted study were as follows: mean 23.46 $\pm$ 2.81 mm, [range 20.79-29.80] for IOL Master and respectively 23.47 $\pm$ 2.83 mm, [20.79-29.86] for LenStar LS 900. The difference between the results (IOL Master vs LenStar) was -0.01 $\pm$ 0.07, p$\leq$0.05 [-0.28-0.08] (Tab. II, Fig. 1).

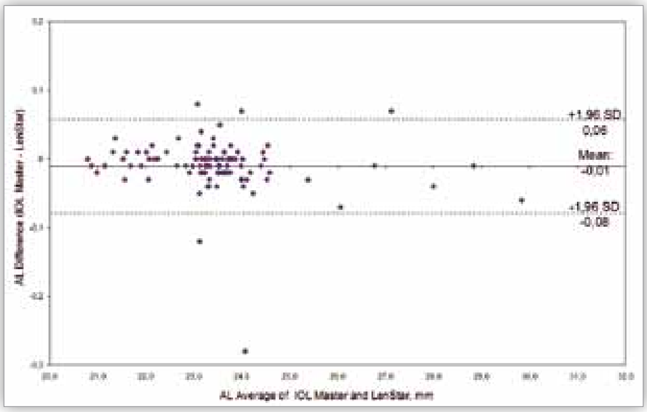

Fig. 1. The Bland-Altman graph showing the difference in axial length values in measurements performed using IOL Master and LenStar LS 900 (IOLMaster vs Lenstar) devices. The horizontal continuous line presents the value of average difference in measurements performed using both devices. The horizontal dashed lines determine the 95% confidence interval.

Ryc. 1. Wykres Blanda-Altmana przedstawiający różnicę wartości pomiarów długości gałki ocznej wykonanych za pomocą aparatów IOL Master i LenStar LS 900 (IOLMaster-Lenstar). Pozioma ciągła linia prezentuje wartość średniej różnicy pomiarów wykonanych za pomocą obu aparatów. Poziome przerywane linie wyznaczają 95% przedział ufności.

Pearson's analysis (Tab. III) showed almost complete conformity in the results of measurements conducted using both devices (0.996; p$\leq$0.01). The range analysis conducted did not show a statistically significant deviation (p$\leq$0.05). The Bland-Altman differences analysis showed that in eight cases the difference between the results was placed outside the 95% confidence interval. In those patients lens opacification or posterior capsule calcification caused reported abnormal result occurrences. In those patients, additional ultrasound biometry was conducted.

In keratometry for a flat meridian (K1) the mean values obtained were as follows: mean 43.24 $\pm$ 3.22 D; [range 38.27-47.94] for IOL Master and 42.44$\pm$3.15 D, [37.66-46.83]

Device	AL (mm)	K1 (D)	K2 (D)	Avg K (D)
IOL Master	23.46 $\pm$ 2.81 [20.79-29.8]	43.24 $\pm$ 3.22 [38.27-47.94]	44.14 $\pm$ 3.40 [39.29-49.13]	43.69 $\pm$ 3.24 [38.87-48.29]
LenStar LS 900	23.47 $\pm$ 2.83 [20.79-29.86]	42.44 $\pm$ 3.15 [37.66-46.83]	43.27 $\pm$ 43.27 [38.61-48.40]	42.86 $\pm$ 3.18 [38.22-47.61]

Tab. I. Average measurement values in 95% confidence interval and value ranges [ ] from minimum to maximum, obtained during IOL Master and LenStar LS 900 device measurements.

Tab. I. Średnie wartości pomiarów w 95% przedziale ufności oraz zakres wartości [ ] od najmniejszej do największej uzyskane podczas pomiarów aparatami IOL Master oraz LenStar LS900.

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	AL (mm)	K1 (D)	K2 (D)	Avg K (D)
Difference in values (IOL Master) – (LenStar LS 900)	-0.01 ± 0.07 [-0.28-0.08]	0.79 ± 0.50 [-0.14-2.02]	0.86 ± 0.48 [-0.01-1.81]	0.83 ± 0.41 [0.36-1.92]

Tab. II. Mean differences in measurements for each eye in the 95% confidence interval and range values [ ] from minimum to maximum.
Tab. II. Średnie różnic pomiarów dla każdego oka w 95% przedziale ufności oraz zakres wartości [ ] od najmniejszej do największej.

		AL_2	K1_2	K2_2	Avg_K_2	Haigis_2	SRKII_2	SRKT_2	Holladay_2
AL_1	Pearson Correlation	,996(**)	-,404(**)	-,380(**)	-,399(**)	-,905(**)	-,937(**)	-,934(**)	-,920(**)
	Sig. (2-tailed)	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
	N	102	102	102	102	102	102	102	102
K1_1	Pearson Correlation	-,433(**)	,988(**)	,929(**)	,977(**)	0,025	0,097	0,087	0,053
	Sig. (2-tailed)	0,000	0,000	0,000	0,000	0,801	0,330	0,385	0,598
	N	102	102	102	102	102	102	102	102
K2_1	Pearson Correlation	-,415(**)	,909(**)	,990(**)	,970(**)	0,018	0,085	0,074	0,041
	Sig. (2-tailed)	0,000	0,000	0,000	0,000	0,855	0,398	0,460	0,684
	N	102	102	102	102	102	102	102	102
Avg_K_1	Pearson Correlation	-,432(**)	,966(**)	,979(**)	,992(**)	0,022	0,092	0,082	0,047
	Sig. (2-tailed)	0,000	0,000	0,000	0,000	0,826	0,355	0,414	0,636
	N	102	102	102	102	102	102	102	102
Haigis_1	Pearson Correlation	-,893(**)	-0,013	-0,029	-0,022	,995(**)	,991(**)	,994(**)	,995(**)
	Sig. (2-tailed)	0,000	0,898	0,775	0,827	0,000	0,000	0,000	0,000
	N	102	102	102	102	102	102	102	102
SRKII_1	Pearson Correlation	-,928(**)	0,074	0,051	0,063	,988(**)	,998(**)	,996(**)	,994(**)
	Sig. (2-tailed)	0,000	0,457	0,609	0,527	0,000	0,000	0,000	0,000
	N	102	102	102	102	102	102	102	102
SRKT_1	Pearson Correlation	-,925(**)	0,062	0,038	0,050	,992(**)	,997(**)	,999(**)	,997(**)
	Sig. (2-tailed)	0,000	0,535	0,704	0,616	0,000	0,000	0,000	0,000
	N	102	102	102	102	102	102	102	102
Holladay_1	Pearson Correlation	-,910(**)	0,024	0,000	0,012	,993(**)	,996(**)	,997(**)	,998(**)
	Sig. (2-tailed)	0,000	0,809	0,998	0,907	0,000	0,000	0,000	0,000
	N	102	102	102	102	102	102	102	102

Tab. III. Pearson's correlation for AL, K1, K2, Avg K values and IOL power calculated values.
Tab. III. Korelacja Pearsona dla wartości AL, K1, K2, Avg K oraz dla wartości skalkulowanej mocy implantu.
** Correlation is significant at the 0.01 level (2-tailed).

for LenStar LS 900. The difference between the results (IOL Master vs LenStar) was 0.79 ± 0.50; $p \leq 0.05$; [-0.14-2.02] (Tab. II, Fig. 2) Pearson's analysis (Tab. III) showed almost complete conformity in the average results of measurements conducted using both devices (0.988; $p \leq 0.01$). The ranges analysis showed differences in ranges from 40.01 to 41.00 D ($p > 0.05$) and from 44.01 to 45.00 D ($p > 0.05$). In the range between 40.01-41.00 D the results obtained using the LenStar LS 900 device were higher than those obtained with IOL Master. In the range between 44.01 and 45.00 D results obtained using the LenStar LS 900 device were lower than those obtained with IOL Master.

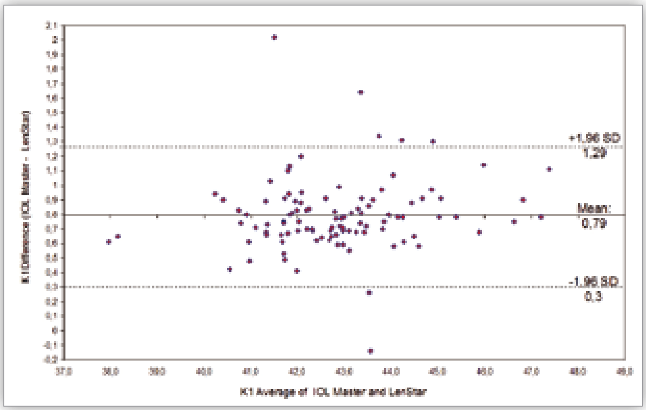

Fig. 2. A Bland-Altman graph showing the difference in keratometry measurements on the steep meridian (K1) conducted using IOL Master and LenStar LS 900 devices (IOLMaster vs Lenstar]. The horizontal continuous line presents the value of the mean difference in measurements conducted using both devices. The horizontal dashed lines determine the 95% confidence interval.

Ryc. 2. Wykres Blanda-Altmana przedstawiający różnicę wartości pomiarów keratometrii na stromym południku (K1) wykonanych za pomocą aparatów IOL Master i LenStar LS 900 (IOLMaster--Lenstar). Pozioma ciągła linia prezentuje wartość średniej różnicy pomiarów wykonanych za pomocą obu aparatów. Poziome przerywane linie wyznaczają 95% przedział ufności.

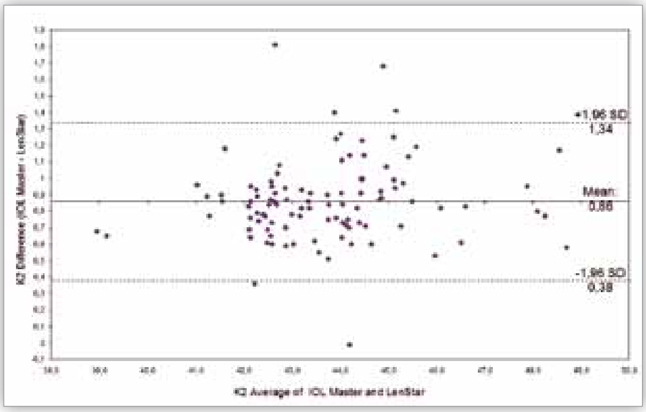

Fig. 3. A Bland-Altman graph showing the difference in results of the keratometry measurements on the steep meridian (K2) conducted using IOL Master and LenStar LS 900 devices (IOL Master vs Lenstar). The horizontal continuous line presents the value of the mean difference in measurements conducted using both devices. The horizontal dashed lines determine the 95% confidence interval.

Ryc. 3. Wykres Blanda-Altmana przedstawiający różnicę wartości pomiarów keratometrii na stromym południku (K2) wykonanych za pomocą aparatów IOL Master i LenStar LS 900 (IOL Master--Lenstar). Pozioma ciągła linia prezentuje wartość średniej różnicy pomiarów wykonanych za pomocą obu aparatów. Poziome przerywane linie wyznaczają 95% przedział ufności.

Device	Haigis	SRK II	SRK/T	Holladay
IOL Master	21.23 ± 8.07 [3.25-28.99]	21.14 ± 6.90 [4.83-27.60]	21.04 ± 7.78 [3.05-28.05]	21.09 ± 8.13 [2.43-28.61]
LenStar LS 900	21.41 ± 8.23 [2.99-29.15]	21.24 ± 7.00 [4.6-27.71]	21.13 ± 7.90 [2.76-28.18]	21.21 ± 8.26 [2.16-28.76]
Difference	-0.18 ± 0.85 [-1.92-1.31]	-0.10 ± 0.42 [-1.18-0.34]	-0.10 ± 0.45 [-1.35-0.55]	-0.13 ± 0.58 [-1.71-0.54]

Tab. IV. Mean values of the IOL power calculation and mean differences in measurements for each eye in the 95% confidence interval and range values [ ] from minimum to maximum.

Tab. IV. Średnie wyniki kalkulacji mocy implantu oraz średnie różnice pomiarów dla każdego oka w 95% przedziale ufności oraz zakres wartości [ ] od najmniejszej do największej.

The Bland-Altman differences analysis showed that the difference in the results was outside the 95% confidence interval only in 14 cases.

For a steep meridian (K2) the following mean values were obtained: 44.14 ± 3.40 D; [range 39.29-49.13] for IOL Master and 43.27 ± 3.34 D [38.61-48.40] for LenStar LS 900. The difference between the results (IOL Master vs LenStar) was 0.86 ± 0.48; $p \leq 0.05$; [-0.01-1.81] (Tab. II, Fig. 3) Pearson's analysis (Tab. III) showed almost complete conformity in the mean results of measurements conducted using both devices (0.990; $p \leq 0.01$). The range analysis showed differences in ranges from 41.01-42.00 D ($p > 0.05$) and 45.01-46.00 D ($p > 0.05$). In the range between 41.01 and 42.00 D results obtained using the LenStar LS900 device were higher than those obtained using IOL Master. In the range between 45.01 and 46.00 D results obtained using the LenStar LS 900 device were higher than those obtained in the case of IOL Master.

The Bland-Altman differences analysis showed that the difference in results was placed outside the 95% confidence interval only in 12 cases.

Rated differences in measurements for each eye for AL, K1, K2 and AvgK values are presented in Table II.

Calculation results obtained for each eye were (Tab. IV): mean 21.23 ± 8.07; [range 3.25-28.99] for Haigis formula, 21.14 ± 6.90 [4.83-27.60]) for SRK II, (21.04 ± 7.78 [3.05-28.05]) for SRK/T and (21.09 ± 8.13 [2.43-28.61]) for Holladay using IOL Master and 21.41 ± 8.23; [2.99-29.15]) for Haigis; 21.24 ± 7.00; [4.6-27.71]) for SRK II, 21.13 ± 7.90; [2.76-28.18]) for SRK/T and 21.09 ± 8.13 [2.16-28.76]) for Holladay using LenStar LS 900. The confidence analysis performed using Pearson's correlation (Tab. III) showed almost complete conformity of the results in all algorithms.

Discussion

Ultrasound biometry and manual keratometry have been the golden standard in IOL power calculation for a long time. The introduction of biometry based on partially coherent interferometry and automated keratometry marked a great progress in cataract surgery (2,3,7). It allowed for a significant improvement of the measurement accuracy and more precise implant power determination. The first device which combined biometry based on partially coherent interferometry with automated keratometry and anterior chamber depth measurement (based on slit of light analysis) was

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IOL Master (8). Its accuracy and superiority to ultrasound biometers were proven in many studies (9-11).

Implant power calculation used during cataract extraction procedure is performed using appropriate algorithms. According to the algorithm used axial length, keratometry or additionally anterior chamber depth is required (12). However, new algorithms (IV, V generation), often used during accommodative and pesudoaccommodative implants power calculation require a greater number of parameters. The LenStar LS 900 device is an instrument that allows determining the majority of them during one measurement, while IOL Master requires performing a lot of measurements.

The present study showed high conformity of the results obtained using IOL Master and LenStar LS 900 device in the case of biometry and keratometry. The mean biometry difference of 0.01mm reflects a very high correlation between the measurements obtained ($R = 0.996$). That difference is clinically insignificant (<0.03 D). That result proves the very high accuracy of LenStar biometry compared to IOL Master V.5. In keratometry value range analysis (K1, K2) statistically significant differences were shown. Those differences can however be a result of different refraction indexes ($n = 1.3375$ for IOL Master, and $n = 1.332$ for LenStar). Those differences did not influence the very high correlation of the mean K1 values ($R = 0.988$), K2 ($R = 0.990$), and also average keratometry values AvgK ($R = 0.992$). Because of the difference, it is impossible to alternatively use keratometry results obtained using both devices.

Implant power calculation accuracy was analyzed in Haigis, SRK II, SRK/T, Holladay algorithms treating results obtained using IOL Master as reference values (12,13). The analysis of the implant power calculation results conducted using Pearson's correlation showed almost complete conformity of the results obtained using LenStar LS 900 with results obtained using IOL Master.

LenStar LS 900 is a new useful tool for ocular biometrical measurements and implant power calculation. It enables to perform quick examination, which is not onerous for the patient.

The present study showed high accuracy of the measurements and precise implant power calculation. In the case of biometry and keratometry, LenStar LS 900 can be equivalent to IOL Master V.5. However, it enables to conduct significantly greater number of measurements which cannot be conducted with the IOL Master device. Accuracy of those measurements should be further studied.

Conclusion

1. LenStar LS 900 enables to quickly conduct precise and repeatable biometrical measurements and IOL power calculation.
2. Implant power calculation results obtained using LenStar LS 900 are comparable to those obtained using IOL Master V.5, which has been commonly recognized as a standard for over a decade.
3. The use of both devices is limited by significant lens opacification and posterior capsule calcification. In such cases, an additional US biometry should be performed.
4. Keratometry results obtained using both devices should not be used interchangeably due to the different measurement methods and different refraction indexes.
5. Compared to IOL Master, the LenStar LS 900 device additionally enables to perform pachymetry, retinal thickness measurement within macula, lens thickness and pupil diameter measurement. However, accuracy of those measurements should be further studied.

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