

# COMPARISON OF BIOMETRIC VALUES AND INTRAOCULAR LENS POWER CALCULATIONS OBTAINED BY ULTRASOUND AND OPTICAL BIOMETRY

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## POREĐENJE BIOMETRIJSKIH VREDNOSTI I KALKULACIJE JAČINE INTRAOKULARNOG SOČIVA DOBIJENIH ULTRAZVUČNOM I OPTIČKOM BIOMETRIJOM

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### ABSTRACT

*This study sought to compare the biometric values and intraocular lens (IOL) power obtained by standard ultrasound and optical biometry.*

*We examined 29 eyes in preparation for cataract surgery. None of the patients had refractive surgery or corneal anomaly. In all patients, the horizontal and vertical refractive power of the cornea was determined using a keratometer (Bausch&Lomb). The axial length of the eye was determined via A-scan ultrasound (BVI-compact-V-plus) using Holladay's formula. The IOL power and complete biometric measurements were obtained via an IOL Master-500-Zeiss using the Holladay-2 formula. All obtained values were compared and analysed using the statistical program SPSS 20.*

*The average age of treated patients was 71.21±1.68 years. In 16 patients with dense cataracts (55.17%), it was not possible to determine the IOL power by optical biometry. Optical biometry obtained significantly increased axial length values of 24.04±0.29 mm compared with those obtained with ultrasound biometry (23.89±0.28 mm,  $p=0.003$ ). The mean refractive cornea power values of the horizontal meridian measured using a keratometer (42.50±0.47 D) and an IOL Master (42.69±0.49 D) were not statistically different ( $p=0.187$ ). The mean values of the refractive cornea power of the vertical meridian obtained using a keratometer (42.62±0.48 D) and an IOL Master (43.36±0.51 D) exhibited a statistically significant difference ( $p=0.000$ ). The keratometer obtained statistically significant lower mean values of corneal refractive power (42.73±0.32 D) compared with those obtained with optical biometry (43.22±0.35 D,  $p=0.000$ ). Ultrasound biometry obtained significantly increased the mean values of IOL power (20.19±0.48 D) compared with those obtained with optical biometry (19.71±0.48 D,  $p=0.018$ ).*

*The large number of patients who receive an operation for dense cataracts indicate the need for representation of both biometric methods in our clinical practice.*

**Key words:** axial length, intraocular lens power, ultrasound biometry, optical biometry

### SAŽETAK

*Cilj je poređenje vrednosti biometrijskih podataka i jačine intraokularnog sočiva (IOL) dobijenih standardnom ultrazvučnom i optičkom biometrijom.*

*Pregledano je 29 očiju u okviru pripreme za operaciju katarakte. Niko od pacijenata nije imao refraktivnu operaciju, ni anomaliju rožnjače. Svim pacijentima je pomoću keratometra (Bausch&Lomb) određena horizontalna i vertikalna prelomna moć rožnjače, A-scan ultrazvukom (BVI-compact-V-plus) aksijalna dužina oka, pomoću Holladayeve formule jačina intraokularnog sočiva kao i kompletno biometrijsko merenje IOL Master 500- Zeiss uz upotrebu Holladay-2 formule. Sve dobijene vrednosti su poređene i obrađene statističkim programom SPSS 20.*

*Prosečna starost pacijenata je bila 71.21±1.68 godina. Kod 16 pacijenata sa gustom kataraktom (55.17%) nije bilo moguće odrediti jačinu intraokularnog sočiva optičkom biometrijom. Optičkom biometrijom se dobijaju statistički značajno više vrednosti aksijalne dužine 24.04±0.29 mm, nego ultrazvučnom biometrijom 23.89±0.28 mm,  $p=0.003$ . Između srednje vrednosti jačine prelamanja rožnjače po horizontalnom meridijanu izmerene keratometrom, 42.50±0.47 D i IOL Master-om, 42.69±0.49 D nije uočena statistički značajna razlika,  $p=0.187$ . Dobijene srednje vrednosti jačine prelamanja rožnjače po vertikalnom meridijanu određene keratometrom 42.62±0.48 D i IOL Master-om 43.36±0.51 D, pokazuju statistički značajnu razliku,  $p=0.000$ . Keratometrom se dobijaju statistički značajno niže srednje vrednosti prelamanja rožnjače, 42.73±0.32 D nego optičkom biometrijom 43.22±0.35 (38.34-46.62 D),  $p=0.000$ . Ultrazvučnom biometrijom dobija se statistički značajno viša srednja vrednost jačine IOL-a 20.19±0.48 D (17.0-23.0 D), nego optičkom biometrijom 19.71±0.48 D, (16.0-22.5 D),  $p=0.018$ .*

*Veliki broj pacijenata koji se operišu u stadijumu guste katarakte ukazuju na potrebu zastupljenosti obe metode biometrije u našoj kliničkoj praksi.*

**Ključne reči:** aksijalna dužina, jačina intraokularnog sočiva, ultrazvučna biometrija, optička biometrija



## ABBREVIATIONS

<b>IOL</b> - intraocular lens	<b>K1</b> - refractive power of the cornea by the horizontal meridian
<b>AL</b> - axial length of the eye	<b>K2</b> - refractive power of the cornea by the vertical meridian
<b>ACD</b> - anterior chamber depth	<b>US</b> - ultrasound
<b>K</b> - refractive power of the cornea, keratometric value	



## INTRODUCTION

Modern cataract surgery requires the achievement of ideal postoperative refractive results.

In addition to good operational techniques, intraocular lenses (IOL) quality and retina identification, a precise calculation of the intraocular lens power is of crucial importance to achieve good results after refractive cataract surgery (1, 2). Accurate calculations primarily depend on the accuracy of preoperative biometric data, including the axial length of the eye (AL), the anterior chamber depth (ACD), and the keratometry values (K), and the precision of the formula applied to calculate IOL power (3-6). Incorrect calculation of the lens power is the main reason for patient dissatisfaction and lens replacement in modern cataract surgery (7).

Intraocular lens power calculations are possible with standard ultrasound biometry and modern contactless optical biometry (IOL Master, Zeiss).

Optical biometry provides more comfort for the physician and the patient because it is a fast, non-invasive, non-contact approach that does not require local anaesthesia. In addition, there is no risk of trauma and infection of the cornea (3, 8, 9).

The purpose of this study is to compare the biometric values and IOL power obtained by standard ultrasound and optical biometry and to consider the advantages and disadvantages of optical and ultrasound biometry.

## MATERIALS AND METHODS

A comparative study was conducted. We examined 29 eyes of 29 patients in preparation for cataract surgery. Biometric measurement and IOL power calculation were performed for all patients by ultrasound (standard) and optical biometry. None of the examined patients underwent refractive surgery or exhibited corneal anomalies.

The horizontal and vertical refractive power values of the cornea were determined using a keratometer (Bausch and Lomb). The axial length of the eye was determined using A-scan ultrasound (BVI compact V plus), and the intraocular lens power was determined using Holladay's formula.

We did complete biometric measurements by optical biometry, IOL Master 500, Zeiss camera using coherent light

interference: the axial length, keratometry, anterior chamber depth and IOL power. We used Holladay-2 formula for calculating intraocular lens power.

Our study included a comparison of the axial length of the eye (Student's t-test), the refractive power of the cornea by the horizontal meridian K1 (Wilcoxon test), the refractive power of the cornea by the vertical meridian on K2 (Student's t-test), the refractive power by the cornea K (Student's t-test) and the intraocular lens power (Wilcoxon test) as obtained by a standard ultrasound and modern optical biometry.

For statistical data analysis, the statistical program SPSS 20 was used, and p-values <0.05 were considered statistically significant.

## RESULTS

The measurement was performed on one eye of 29 patients who were preparing for cataract surgery. Examined patients were 62 to 83 years of age, with a mean age of  $71.21 \pm 1.68$  years. The frequency of patients of a certain age was determined by the  $\chi^2$  test. Two patients (6.90%) in the age range of 50 to 59 years were examined, 5 (17.24%) patients in the age range of 60 to 69 years were examined, 15 (51.72%) patients in the age range 70 to 79 years were examined, and 7 patients (24.14%) in the age range 80 to 89 years were examined. Most patients were 70 to 79 years of age. No statistically significant differences were noted in the frequency of patients of a certain age ( $\chi^2=7.621$ ,  $p=0.974$ ).

In 16 patients (55.17%), it was not possible to determine the intraocular lens power using optical biometry. Of these patients, 2 were 50 to 59 years of age (100% of the patients examined at that age), 7 patients were 70 to 79 years of age (46.67% of the patients examined at that age) and 6 patients were 80 to 89 years of age (85.71% of the patients examined at that age). For all patients 60 to 69 years of age, the IOL power was determined using both apparatuses (Table 1).

The mean value of the axial length of the eye measured by ultrasound was  $23.89 \pm 0.28$  mm in the range 21.62-26.35 mm, and by optical biometry  $24.04 \pm 0.29$  mm in the range 22.52-26.67 mm, as measured by optical biometry. A statistically significant difference between the axial length



**Table 1.** Age of patients undergoing preoperative preparations for cataract surgery

Age range	Number of examined patients	% of examined patients	IOL Master calculation could not be performed	% of patients in the age range in whom IOL Master measurements could not be obtained
50 – 59	2	6.9	2	100%
60 – 69	5	17.24	0	0%
70 – 79	15	51.72	7	46.67%
80 – 89	7	24.14	6	85.71%
90 – 100	0			
Total	29	100	15 (51.72%)	

**Table 2.** The axial length of the eye measured by ultrasound and optical biometry

	Ultrasound biometry	Optical biometry	Statistical significance
Axial length of the eye ± SD (min-max)	23.89 mm±0.28 mm 22.43 mm-26.3 mm	24.04 mm±0.29 mm 22.52 mm-26.67 mm	p = 0.003 Student's T-test

of the eye measured by the standard ultrasound method compared to modern optical biometry via the IOL Master (t-test,  $p=0.003$ ) was observed. Optical biometry provided greater axial eye length values (Table 2).

The mean value of the refractive cornea power of the horizontal meridian (K1) as measured by the Bausch & Lomb keratometer was  $42.50 \pm 0.47$  D. The minimum measured value was 38.00 D, and the maximum value was 45.00 D. The mean value of the refractive cornea power of the horizontal meridian K1 as measured by the IOL Master was  $42.69 \pm 0.49$  D. The minimum value was 38.1 D, and the maximum value was 44.64 D. The obtained keratometric values of the horizontal meridian K1 as calculated by the Bausch & Lomb keratometer and IOL Master did not exhibit a statistically significant difference (the Wilcoxon test,  $p=0.187$ ) (Table 3).

The mean value of the refractive cornea power of the vertical meridian as assessed by the Bausch & Lomb keratometer was  $42.62 \pm 0.48$  D (minimum 38.01 D, maximum 44.75 D). The mean value determined by IOL Master was  $43.36 \pm 0.51$  D (minimum 38.66 D, maximum 45.67 D). Vertical refractive cornea power (K2) values as determined by these two apparatuses exhibited a statistically significant difference (Student's t-test,  $p < 0.01$ ) (Table 3).

The mean value of corneal refractive power (K) as determined by the Bausch & Lomb keratometer was  $42.73 \pm 0.32$  D (minimum 38.25 D, maximum 45.88 D). The mean value determined by the IOL Master mean value was  $43.22 \pm 0.35$  D (minimum 38.34 D, maximum 46.62 D). A statistically significant difference was noted between the obtained measurements. Measurements obtained with the

**Table 3.** Keratometric values

	Bausch&Lomb	IOL Master	Statistical significance
K1 Middle value ± SD (min-max)	$42.56 \pm 0.47$ D (38.0 D - 44.64 D)	$42.69 \pm 0.49$ D (38.1 D - 44.64 D)	$p = 0.187$ Wilcoxon test
K2 Middle value ± SD (min-max)	$42.62 \pm 0.48$ D (38.1 D - 44.75 D)	$43.36 \pm 0.51$ D (38.66 D - 45.67 D)	$p < 0.01$ Student's T-test
K Middle value ± SD (min-max)	$42.73 \pm 0.32$ D (38.25 D - 45.88 D)	$43.22 \pm 0.35$ D (38.34 D - 46.62 D)	$p = 0.000$ Student's T-test

**Table 4.** Intraocular lens power as determined by ultrasound and optical biometry

	Ultrasound biometry	Optical biometry	Statistical significance
Mean value of IOL power ± SD (min-max)	$20.19 \pm 0.48$ D 17.00 D-23.00 D	$19.71 \pm 0.48$ D 16.00 D-22.5 D	$p = 0.018$  $p < 0.05$ Wilcoxon test



Bausch & Lomb keratometer produce lower values (Student's t-test,  $p=0.000$ ) (Table 3).

The mean value of the intraocular lens power obtained by standard ultrasound biometrics was  $20.19 \pm 0.48$  D (minimum 17.0 D, maximum 23.0 D). The mean value of the intraocular lens power measured by optical biometry was  $19.71 \pm 0.48$  D (the minimum IOL power was 16.0 D, the maximum was 22.50 D). A statistically significant difference was noted between the intraocular lens power values observed by standard ultrasound compared to optical biometry (Wilcoxon test;  $p=0.018$ ,  $p < 0.05$ ) (Table 4).

## DISCUSSION

The axial length of the eye can be measured by ultrasound (contact and immersion techniques) and optical biometry (IOL Master or Lenstar). The study of preoperative and postoperative ultrasound biometry revealed that 54% of errors in predicting the refractive power after IOL implantation can be attributed to errors in measuring the axial length of the eye (10-12). Therefore, it is very important to carefully and accurately obtain measurements at this stage (13). An error of 100 micrometres in axial length can lead to postoperative refractive errors from 0.28 D (14).

Noncontact optical biometry has become the gold standard given its ease of performance, accuracy and reproducibility (14). In addition to high-precision, non-contact and non-invasive measurements, the advantages of optical biometry include speed and patient comfort. Given that IOL power calculations by optic biometry do not require anaesthesia, there is no risk of corneal trauma and infections (3, 8, 9). In addition, mydriasis is not required to perform this technique. The main drawback of this technique is the inability to measure the axial length in 10% of patients with dense posterior subcapsular cataract (15). In these patients, the contact ultrasonic method is the method of choice, and the immersion method is rarely used. It is also not possible to perform measurements in patients with severe corneal pathology, eyelid abnormalities, macular degeneration and eccentric fixation. In these patients, it is possible to obtain eye biometrics using ultrasound (16). Two main causes of errors when using applanation ultrasound biometry include mistakes in measuring axial length that arise from the indentation of the eyeball and axial measurements of axial length (13). The immersion ultrasonic technique avoids these drawbacks. Applanation ultrasound techniques achieve better refractive results (17). Compared with ultrasound biometry, where the IOL power calculation depends on the experience of the performer, optical biometry measures the axial length of the eye along the visual axis no indentacije eyeball. The measurement is less dependent on the person who is performing the measurement (13, 18). Optical biometry also has an advantage in patients with silicone oil and rear staphyloma (16).

A large number of authors suggest that measurements of AL and the IOL power using the IOL Master are comparable or more precise with respect to the use of the applanation ultrasound method in the normal population (3, 13, 19-21). In addition, numerous studies indicate that both methods exhibit high accuracy and reproducibility (22, 23). Modern optical biometry achieves optimal visual acuity after cataract surgery in 90% of patients  $\pm 1$  D and in greater than  $60\% \pm 0.5$  D of best corrected visual acuity (14).

Our results confirm previous research results and indicate the inability to use optical biometry on patients with dense cataracts. The percentage of patients in whom it was not possible to measure the axial length of the eye and intraocular lens optical biometry in our study was 51.72%. In all the patients, clinical examination revealed a dense cataract or dense posterior subcapsular cataract. Such a high inability to perform optical biometry is not consistent with data in the literature that range from 8% to 10% (20, 24), but it is possible to explain the results of studies by showing that the failure to execute biometric measurements correlates with the existence of last subcapsular cataracts (14, 16, 19). The results of our research are understandable if we consider the peculiarities of our environment, including a large number of patients who are waiting for cataract surgery. According to data for the month of July of the current year, the average wait for cataract surgery is 537.3 days. Given the long wait, a large number of patients have dense cataracts for whom surgery is not possible due to technical characteristics of the apparatus used to perform optical biometry measurements.

Our study confirmed previous findings that compared with optical biometry, contact ultrasound biometry provides a reduced axial length (14, 24-26). Previous studies demonstrate that contact ultrasound biometry provides reduced AL values compared with immersion ultrasound biometry (27). IOL power calculations depend on the precision of the applied formula. The most commonly used formulas for calculating IOL power lens (Hoffer Q (28), Holladay 1 (29), and SRK/T (30)) use two biometric measurements (axial length and keratometry) and an IOL constant (31). The conclusion of previous studies suggests that no single formula is suitable for all eyes (14). According to Aristodemou and associates who tested Hoffer Q, Holladay 1, and the SRK/T formulas in 8108 eyes, Hoffer Q is best for axial lengths below 21.5 mm, whereas SRK/T is ideal for those with axial lengths greater than 26.0 mm. For axial length values that fall between these values, no statistically significant differences were noted among the formulas. However, Holladay 1 has certain advantages (32). In our study, the axial length of the eye measured by ultrasound biometry was in the range of 21.62 to 26.35 mm; therefore, the Holladay formula was used. Based on optical biometry, the axial length was in the range of 22.52 to 26.67 mm, and the Holladay-2 formula was used for calculating the IOL power.



Although optical biometry exhibits high precision and reproducible measurements (22-23), unfortunately, the high equipment cost and the limited equipment availability explain the current preference for ultrasonic methods of biometrics.

## CONCLUSION

High patient expectations in terms of achieving good refractive results after cataract surgery indicate the need for continuous improvement of surgeons' operating techniques, the design of intraocular lenses and accurate biometric measurements.

In comparison with the standard biometry (Bausch & Lomb and ultrasound), optical biometry in our study showed significantly higher axial length of the eye, significantly higher refractive power of the cornea K and statistically significantly higher refractive cornea power by vertical meridian K2, and significantly lower power lenses that need to be implanted in the posterior chamber.

The peculiarities of our environment, including a long period of waiting for cataract surgery and a large number of patients with dense cataracts who receive an operation, indicate the need for the use of both methods in clinical practice.

## Declaration of interests

The authors declare no conflicts of interests.

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