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ANALYSIS OF THE BIOMETRIC DATA FOR THE INTRA-OCULAR LENS (IOL) POWER CALCULATION: A COMPARISON BETWEEN THE HUNGARIAN, KOSOVAN, AND BRAZILIAN POPULATIONS

Ph.D. thesis

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LIST OF ABBREVIATIONS

Abbreviation	-	Full Term
IOL	-	Intraocular Lens
mm	-	Millimeters
D	-	Diopters
AL	-	Axial Length
ACD	-	Anterior Chamber Depth
LT	-	Lens Thickness
CCT	-	Central Corneal Thickness
K1, K2	-	Corneal Refractive Power
WTW	-	White-to-White Distance
ELP	-	Effective Lens Positioning
VCD	-	Vitreous Chamber Depth
RPE	-	Retinal Pigment Epithelium
MAE	-	Mean Absolute Error
SD	-	Standard Deviation
UCDVA	-	Uncorrected Distance Visual Acuity
BCDVA	-	Best Corrected Distance Visual Acuity
1 m. postop. UCDVA	-	1-month Postoperative Uncorrected Distance Visual Acuity
1 m. postop. BCDVA	-	1-month Postoperative Best Corrected Distance Visual Acuity

1. INTRODUCTION

Cataract is one of the most frequently encountered eye diseases, and its surgical treatment remains one of the most routinely performed operations in ophthalmology. Although widely practiced, cataract surgery requires meticulous preoperative evaluation, with particular emphasis on accurate biometric measurements, the selection of IOL calculation formulas, and the choice of the most suitable intraocular lens.

Continuous progress in ocular biometry and IOL power formulas has significantly improved refractive precision; nevertheless, differences in biometric characteristics between populations still make it challenging to achieve consistently optimal postoperative outcomes.

This study analyzes and compares the biometric characteristics relevant to IOL power calculation among Hungarian, Kosovan, and Brazilian populations, to contribute to the understanding of ethnic and regional variations in ocular biometry, and to assess how these differences may impact the accuracy of IOL power prediction and refractive outcomes.

1.1. Anatomy of the eye

Although the globe of the eye is often described as spherical, it does not form a perfect sphere. In adults, the anteroposterior diameter generally ranges from 23 to 25 mm. Structurally, the eye is divided into two main regions—the anterior and posterior segments—and contains three fluid-filled compartments: the anterior chamber, posterior chamber, and vitreous cavity.

The anterior segment includes the cornea, iris, ciliary body, crystalline lens, and both the anterior and posterior chambers. The anterior chamber, located between the corneal endothelium and the anterior surface of the iris, is filled with aqueous humor. Its depth, referred to as anterior chamber depth (ACD), varies among individuals and across ethnic groups, with an average of about 3.11 mm. The posterior chamber is the narrow space positioned between the iris and the lens.

The native intraocular (crystalline) lens is a transparent biconvex disc and has a diameter between 8-10 millimeters in adults; its refractive power is + 18 diopters (D). Its function is to focus the images onto the retina. The crystalline lens is composed of 3 main components: the capsule, the cortex, and the nucleus [1-3].

1.2. Cataract

A cataract is an eye condition defined by the loss of clarity in the crystalline lens, resulting in its clouding or opacification. Cataract is one of the leading causes of visual impairment and blindness worldwide [4-6]. From an etiological standpoint, cataracts may be classified as either congenital or acquired. The most common type of acquired cataract is the age-related cataract [7]. Age-related cataract, or senile cataract, is common in people older than 50 years old [4], findings from different studies show that its prevalence increases after the age of 60 years, and it is usually an inevitable cause of aging; however, it is also closely related to other risk factors such as: genetic and environmental factors, such as smoking, ultraviolet light exposure, and certain diseases, such as diabetes, uveitis, IOP-lowering medications/surgery, trauma and steroid usage [5,6,8-16].

1.3 Biometry

Biometry, a term originating from the Greek words bios (life) and metron (measure), denotes the application of mathematical methods to quantify and describe the anatomical features of living organisms. In ophthalmology, biometry refers to the anatomical and refractive properties of the human eye [17]. In 1905, Gullstrand's eye model served as a basis for quantifying the refractive power of the human eye, based on the refractive properties of the cornea, lens, ocular media, and the axial length of the eye [18].

1.3.1 Biometric parameters of the eye

Although cataract surgery and intraocular lens (IOL) implantation have advanced significantly, obtaining precise biometric measurements and calculating IOL power remain among the most demanding steps, as they are essential for achieving optimal postoperative visual outcomes. Following Harold Ridley's pioneering development and implantation of the first IOL in 1949, the challenge of accurately determining the refractive power of the artificial lens quickly emerged. The use of IOL power calculation formulas was first introduced by Fyodorov in 1967, where he introduced the vergence formula, using three variables: axial length (AL), corneal refractive power (K), and the calculated (postoperative) anterior chamber depth (ACD) [19-21].

The primary biometric parameters of the eye considered for IOL power calculation include: (AL), ACD, lens thickness (LT), central corneal thickness (CCT), corneal refractive power (K1, K2), white-to-white distance, pupil diameter, effective lens positioning (ELP) and vitreous chamber depth (VCD) [22-25].

Axial length is described as the measurement extending from the anterior corneal surface to the retinal pigment epithelium (RPE). In emmetropic adult eyes, the average axial length is 23.50 mm [26-30], whereas a newborn's eye has an AL of 16 mm, and it increases to up to 24–25 mm [31,32].

Anterior chamber depth refers to the distance measured from the cornea's anterior surface to the front surface of the lens. ACD is a very important biometric parameter, since it is an indicator of the axial position of the IOL postoperatively [33,34]. An accurate evaluation of the anterior chamber depth (ACD—the measurement from the anterior surface of the cornea to the anterior surface of the crystalline lens) is also critical when planning procedures utilizing either a phakic or pseudophakic intraocular lens (IOL) [35]. ACD is a key measurement utilized in intraocular lens power calculation formulas to help estimate the most suitable IOL power. It is also critically important for the Haigis formula, which only uses the axial length and the anterior chamber depth to predict the effective lens position [36-38].

1.3.2 Devices and measurement principles in ocular biometry

The formulas, instruments, and methodologies used for determining intraocular lens power are consistently evolving. The first available device for IOL power calculation was the A-scan ultrasound, which was used for the first time in the early 1970s [17]. A-scan ultrasonography works by transmitting an ultrasonic wave into the eye through a transducer, and as the sound wave reflects back from internal ocular structures, a series of spikes is generated on the display, representing tissues from the cornea to the orbital fat. This technique is used to measure the axial length, anterior chamber depth, and lens thickness [39].

Biometric values using the A-scan ultrasound can be obtained by using one of the two methods: the contact (applanation) method or the immersion method [40]. With the contact (applanation) technique, the probe touches the corneal surface directly, leading to unavoidable indentation of the cornea and anterior chamber, which in turn increases the likelihood of error in IOL power calculations. In contrast, the immersion ultrasound method prevents direct probe–cornea contact by using a liquid-filled shell, immersion gel, or even the closed eyelid to create a fluid interface between the probe and the cornea. The development of this immersion method has enabled more meaningful, accurate, and reproducible results than contact measurements [41]. As postoperative patient expectations continue to increase, the need for more accurate IOL power calculations remains. Therefore, the new generation of optical biometers provide more reliable IOL power calculations. Carl Zeiss Meditec introduced the first optical biometer, the “IOLMaster,” which later paved the way for more advanced devices, including Haag-Streit’s “Lenstar” and various Swept-Source Optical Coherence Tomography (SS-OCT)–based biometers (see Table 1).

Table 1. *Biometry techniques and variables*

Techniques	Measured variables	Advantages	Limitations	Best used
A-scan ultrasound (applanation)	AL, ACD, LT	Low-cost, portable	Compression error, operator skill dependent	Dense cataracts
A-scan ultrasound (immersion)	AL, ACD, LT	More accurate, no compression	More complex setup	Dense cataracts
Partial Coherence Interferometry (PCI) – IOL Master 500	AL, K, ACD	Fast, non-contact, accurate	Poor results in dense cataracts	Routine cataract cases

Optical Low-Coherence Reflectometry (OLCR) – Lenstar 900	AL, K, ACD, LT. WTW, CCT	Comprehensive, non-contact	Less effective in dense opacities	All cataracts, modern formulas
Swept-Source OCT (SS-OCT) – IOL Master 700	AL, K, ACD, LT, CCT, Retina	High-resolution, deep penetration	Expensive	Dense cataracts

1.4 IOL Power Calculation Formulas

Postoperative refractive results are the most important outcomes after cataract surgery. To meet patient expectations, several factors should be taken into consideration. Preoperative assessment and accurate biometry data, such as AL, K, ACD, and ELP, are very important [42]. It is estimated that the inaccuracy in AL measurements contributes to 36% of the error in the calculation of the IOL power and ELP estimation [43].

Intraocular lens power calculation formulas are the subject of ongoing research, in efforts to obtain the most precise postoperative refractive results, IOL power calculation formulas are divided into 5 generations of formulas: *1st generation formulas – regression formulas; 2nd generation formulas – improved regression formulas; 3rd generation formulas – theoretical/optical formulas; 4th generation formulas – multivariable theoretical formulas; 5th generation formulas – artificial intelligence-based formulas* [44-46].

Precise preoperative IOL planning depends on the axial length, corneal power, and anterior chamber depth ; a refractive error up to 3 diopters could result after a 1 mm error in the AL measurement, and a 1 D error in the corneal power alters the IOL power for 1 D [47]. Despite the refinement of the IOL power calculation formulas, inaccurate preoperative measurements account for most large refractive errors greater than 2 D [48]. Artificial intelligence (AI) has played a major role in the diagnosis, management, and treatment of cataracts, especially in biometry and IOL power calculation formulas [49]. 5th-generation, AI-generated IOL power calculation formulas have proven to be very promising in predicting postoperative refraction

[50]. The findings on the literature show that, of the AI formulas, the Kane formula, which focuses on improving the accuracy at the extremes of the various ocular dimensions, such as AL, K, and ACD, obtains the most accurate results, and its mean absolute error (MAE) was the lowest among the other AI-generated IOL power calculation formulas [51-54].

Table 2. *IOL power calculation formulas*

Generation	Formulas	Calculation principle	Biometric inputs	Advantages	Limitations	AI-based
1st	SRK (Sanders–Retzlaff–Kraff), Binkhorst I	Pure regression based on postoperative refractive outcomes; assumes fixed ACD	AL, K	Very simple; minimal measurement required	Inaccurate for short (<22 mm) and long (>26 mm) eyes; ignores true ELP	No
2nd	SRK II, Binkhorst II	Regression with empirical AL-based adjustments to improve accuracy in extremes	AL, K	Improved over 1st generation for extreme AL	Ignores real ACD; limited for irregular corneas	No
3rd	SRK/T, Holladay 1, Hoffer Q	Theoretical optics-based eye models; ELP predicted from AL & K	AL, K	Good accuracy in normal and moderately abnormal AL; well-validated	Less accurate for very short/long eyes; no LT or WTW in model	No
4th	Holladay 2, Haigis, Olsen, T2	Multivariable theoretical models; incorporate more anatomy to refine ELP prediction	AL, K, ACD, LT, WTW (varies by formula)	Improved performance across wider biometric ranges	Requires advanced biometers; less accurate in post-refractive eyes	
5th	Barrett Universal II, Barrett True-K, Hill-RBF, Kane, EVO, Pearl-DGS	Hybrid optics + AI (Kane, EVO) or pure AI/ML (Hill-RBF, Pearl-DGS); some remain purely advanced theoretical optics	AL, K, ACD, LT, WTW, ± posterior corneal power	Highest overall accuracy; good for post-refractive surgery eyes; adaptable to unusual corneal shapes	Requires advanced imaging; AI models depend on size/quality of training datasets	Yes

Table 2 provides a concise overview of the evolution of intraocular lens (IOL) power calculation formulas, illustrating a clear progression from simple regression-based methods to advanced hybrid and artificial intelligence–driven models. Early-generation formulas relied primarily on axial length and keratometry, assuming a fixed or empirically adjusted effective lens position (ELP), which limited their accuracy, particularly in eyes with extreme biometric values. Subsequent generations introduced theoretical optical models and progressively incorporated additional anatomic parameters—such as anterior chamber depth, lens thickness, and white-to-white distance—to improve ELP prediction and refractive precision. The most recent, fifth-generation formulas combine sophisticated optical modeling with artificial intelligence or machine learning approaches, enabling superior performance across a wide range of ocular anatomies, including post-refractive surgery eyes.

2. OBJECTIVES

2.1. Main objective

The main objective of this study was to analyze and compare the biometric data for IOL power calculation between three populations: Hungarian, Kosovan, and Brazilian. Biometric data and biometric evaluation play a crucial role in accurate IOL selection and IOL power calculation.

Being that the differences in biometric data are significant between different populations, evaluating these parameters and comparing them between our study populations would yield very important scientific results, which would contribute to the improvement of clinical practice in IOL planning and selection and in the improvement of postoperative results.

2.2. Other objectives

1. To compare the axial length between the Hungarian, Kosovan, and Brazilian patients.
2. To examine differences in anterior chamber depth among patients from Hungary, Kosovo, and Brazil.
3. To assess and contrast postoperative refractive results according to the intraocular lens selected.
4. To analyze and compare refractive outcomes following cataract surgery in relation to preoperative visual acuity.
5. To determine how the surgeon's level of experience influences postoperative results.

3. MATERIALS AND METHODS

The study was structured as a cross-sectional, observational investigation conducted across three international clinical sites, where biometric data were collected from cataract patients planned for phacoemulsification with IOL implantation. The participating centers included the Department of Ophthalmology at Semmelweis University (Budapest, Hungary), the University Clinical Center of Kosovo (Prishtina, Kosovo), and the Ophthalmology Service of the Faculty of Medicine of Ribeirão Preto (São Paulo, Brazil). To eliminate surgeon-related variability, each institution relied on a single experienced ophthalmic surgeon to perform all operations and postoperative examinations.

3.1. Patient selection

The study population consisted of 2,047 eyes from cataract patients scheduled for phacoemulsification with intraocular lens implantation. Out of 2047 eyes included in this study, 1001 were of Hungarian patients, 416 were of Kosovan patients, and 630 were of Brazilian patients.

Inclusion criteria

Patients of all age groups and both genders who had a confirmed diagnosis of cataract.

Exclusion criteria

We excluded all patients who were diagnosed with ocular surface disorders to avoid the influence of the corneal surface disorders on the accurate measurement of biometric data of each patient, and patients with retinal pathologies or glaucoma to avoid them as a confounding factor on the postoperative refractive outcomes.

Ethical considerations

All study activities were conducted in alignment with the ethical requirements set forth in the Declaration of Helsinki. The involvement of human subjects followed globally accepted guidelines for ethical clinical practice and biomedical research.

Ethical approval was granted by three independent committees: the Ethics Committee of the Kosovo Chamber of Doctors (No. 49/2022; 12 April 2022), the Regional Institutional Scientific and Research Ethics Committee at Semmelweis University (SE RKEB 82/2024; 14 May 2024), and the National Commission of Research Ethics of the University of São Paulo, Ribeirão Preto, Brazil (CAAE: 79011223.2.0000.5440; 26 August 2024).

3.2. Data collection

Patient information was obtained directly from the electronic Patient Data Management Systems of the respective institutions. Ocular biometry was carried out prior to surgery using the LenStar 900 optical biometer (Haag-Streit, Köniz, Switzerland), which served as the standard platform for all measurements. To maintain high measurement fidelity, exclusion criteria based on measurement variability were applied; eyes were not included if axial length variability exceeded 0.2 mm or if anterior chamber depth variability was greater than 0.13 mm.

The preoperative biometric evaluation included measurements of axial length, anterior chamber depth, corneal refractive power, lens thickness, and white-to-white corneal diameter. These measurements were used for automated intraocular lens power calculation. In addition, all patients underwent a full ophthalmic examination prior to surgery, which included assessment of uncorrected and best-corrected distance visual acuity and intraocular pressure measurement by tonometry.

All eligible patient records were compiled into a dedicated database and processed by a designated investigator at each study site. Biometric data were obtained from patients scheduled for cataract extraction via standard phacoemulsification, performed by the same experienced surgeon at each institution, each with a minimum of 10 years of surgical practice using this technique.

Phacoemulsification was carried out as the routine surgical approach for cataract removal and was performed under local anesthesia, administered either subconjunctivally or retrobulbarly, depending on the surgeon’s preference.

Patient follow-up

To evaluate the postoperative outcomes, the subjects were followed up in three different periods: 1 week post-operatively, 2 weeks post-operatively, and 1 month post-operatively. Post-operatively, we evaluated the uncorrected and corrected visual acuity.

3.3. Statistical analysis

Data analysis and figure generation were carried out using STATA software (version 18) and SPSS (version 27). Summary statistics were applied to describe mean values and variability within the dataset. The relationships between biometric variables were examined through Pearson's correlation index, and the effect of predictor variables on the dependent measure was estimated using multiple linear regression modeling. Comparisons among patient groups were performed via one-way analysis of variance, with Tukey's Honestly Significant Difference test used for post hoc pairwise evaluation.

ANOVA is a statistical technique that evaluates whether the mean values of multiple groups differ significantly from one another, allowing researchers to determine if observed variations are statistically meaningful. This method is widely applied to examine how various factors affect a specific outcome variable [55]. In the case of our study, it was first used to present the statistically significant differences according to 6 conditions, and then this analysis was also used to present the statistically significant differences of the study variables according to gender and age group.

Pearson's correlation coefficient (r) was applied to quantify the strength and direction of the linear association between two continuous variables. Correlation analysis is a statistical approach used to evaluate how two or more variables relate to one another. The relationship may be positive, negative, or absent. A positive correlation indicates that both variables change in the same direction—an increase in one is accompanied by an increase in the other. Conversely, a negative correlation signifies that the variables move in opposite directions—when one rises, the other declines. The magnitude of this association is expressed numerically through a correlation coefficient, with the Pearson coefficient being the most widely used index. Its values range from –1 to +1, where values approaching –1 represent a strong inverse relationship, values near +1 denote a strong direct relationship, and a coefficient of 0 reflects no linear correlation [56]. Three levels of statistical significance, 1% ($p < 0.01$), 5% ($p < 0.05$), and 10% ($p < 0.1$), were used to present the statistically significant differences; this enabled us to highlight not only the most robust results (at 1%) but also those that were moderately strong (at 5%), and suggestive trends (at 10%). This layered approach helped distinguish between varying degrees of evidence, making the results easier to interpret and offering a comprehensive view of the statistical significance across different thresholds.

4. RESULTS

4.1. Descriptive statistics of the sample of the study

This section summarizes the basic characteristics of the study population, including the number of participants per country and the distribution of operated eyes (right versus left).

Table 3. *Sample size by country*

Country	Sample Size	
	N	**%**
Hungary	1001	48.9
Kosovo	416	20.32
Brazil	630	30.78
Total	2047	100

Table 3 and Figure 1 present the sample size by country. According to the data shown, the study included a total of 2,047 participants across the three countries: Hungary, Kosovo, and Brazil. The highest number of patients is from Hungary, where 1001 patients, or 48.9% of the sample, belonged to this group. The second largest group of participants is from Brazil, with 630 patients or 30.78% and the lowest number of participants was from Kosovo with 416 patients or 20.32%.

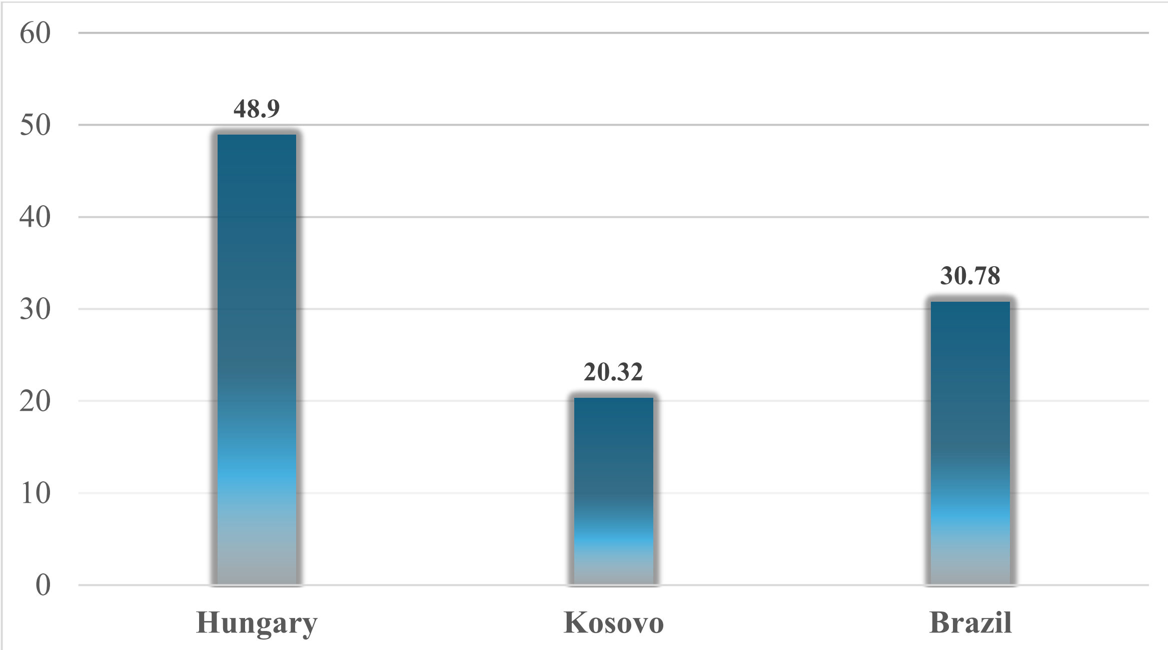

Figure 1. *Sample size by country*

Table 4. *Operated eye (right or left) by country*

Surgery	Hungary		Kosovo		Brazil		Total
	N	%	N	%	N	%	N
Right Eye	513	51.35	218	52.4	323	51.27	1054
Left Eye	486	48.65	198	47.6	307	48.73	991
Total	999	100	416	100	630	100	2045

Table 4 shows the results regarding the operated eye (right or left eye) by country. Based on the findings from Table 4, the right eye was operated on in 1054 cases, while the left eye was operated on in 991 cases.

Table 5. *Age of patients from Kosovo and Hungary*

Variables	Kosovo		Hungary		Brazil	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Age	70.4	9.23	68.97	12.35	-	-

As illustrated in Table 5, the two study populations differ slightly in terms of age distribution. The Kosovan participants had an average age of 70.4 ± 9.23 years, indicating a generally older cataract population when compared with the Hungarian group, whose mean age was 68.9 ± 12.35 years. Although the difference between the two means is modest, it may reflect demographic variations in the onset and progression of cataract pathology between the studied regions.

4.2. Results of Hungarian Patients

A total of 1,001 cataract patients operated with phacoemulsification and intraocular lens implantation at the Ophthalmology Department of Semmelweis University were included in the analysis. All procedures were performed under local anesthesia. Preoperative ocular biometry was obtained using the Lenstar 900 device, with axial length (AL), anterior chamber depth (ACD), keratometry (K), and lens thickness (LT) recorded as the primary biometric parameters. The Hungarian cohort showed a mean AL of 23.60 ± 1.84 mm and an average ACD of 3.14 ± 0.45 mm, as summarized in Table 6.

Table 6. *Age, axial length, and anterior chamber depth in Hungarian patients*

Variables	**Hungary**	
	Mean	**Std Dev**
Age	68.97	12.35
AL	23.6	1.84
ACD	3.14	0.45

Table 7. *Correlation between the age, axial length, and anterior chamber depth in Hungarian patients*

		Age	**AL**	**ACD**
Age	Cor	1	-0.116^{**}	-0.250^{**}
	Sig		0.000	0.000

	N	993	990	900
AL	Cor	-0.116**	1	0.351**
	Sig	0.000		0.000
	N	990	998	908
ACD	Cor	-0.250**	0.351**	1
	Sig	0.000	0.000	
	N	900	908	908

*Note: **. Correlation is significant at the 0.01 level (1%)*

The findings of this study indicate that age is associated with variations in both axial length and anterior chamber depth. Table 7 displays the correlation values between age and these two biometric parameters. A negative correlation was observed between age and axial length (r = –0.11), as well as between age and anterior chamber depth (r = –0.25). Both correlations reached statistical significance at the 1% level (P = 0.000). These results demonstrate that older individuals tend to have shorter axial length and shallower anterior chamber depth.

To assess the impact of refractive correction on the preoperative visual acuity in our patients, we have used the regression analysis.

In general, refractive correction using eyeglasses or contact lenses explained the change in the distance visual acuity of 33.2% of the patients (R-squared = 0.332). This regression was statistically significant based on the following: F-statistic = 5.36 and p = 0.001. (Table 8)

Table 8. *Regression analysis of the impact of refractive correction on visual acuity before surgery*

BCDVAPreop	Coef	St.Err.	t-value	p-value	[95% Conf]	[Interval]	Sig
Hypermetropic correction	0.01	0.005	3.03	0.006	-0.01	0.011	***
Myopic correction	0.01	0.002	0.57	0.571	-0.006	0.003	
Hyperopic astigmatism	0.02	0.02	0.12	0.903	-0.038	0.043	
Myopic astigmatism	0.12	0.012	2.45	0.017	-0.036	0.012	**
Constant	0.562	0.04	14.07	0	0.484	0.641	***
Mean dependent var	0.543	SD dependent var			0.291		
R-squared	0.332	Number of obs			820		
F-test	5.369	Prob > F			0.001		
Akaike crit. (AIC)	310.429	Bayesian crit. (BIC)			333.976		

*Note: *** p<0.01, ** p<0.05, * p<0.1*

Based on the coefficient results, the correction in the hyperopic patients had a positive impact on visual acuity (B = 0.01), which was statistically significant (p = 0.006). There was also a positive impact on the visual acuity in terms of myopic correction (B = 0.01); however, this was not statistically significant. In the patients with astigmatism, we obtained statistically significant results in cases of myopic astigmatism, where the correction had a high positive impact on visual acuity (B = 0.12) (p = 0.017). The impact of the correction on visual acuity was also positive in the cases of hyperopic astigmatism (B = 0.02); however, it was not considered statistically significant.

To analyze the postoperative results, we have analyzed and compared the preoperative uncorrected distance visual acuity (UCDVA) and the best corrected distance visual acuity (BCDVA), with the 1-month postoperative uncorrected distance visual acuity (1 m. postop.

UCDVA) and best corrected distance visual acuity (1 m. postop. BCDVA). The results of the preoperative and postoperative visual acuity are presented in Table 9.

Table 9. *Preoperative and 1-month postoperative uncorrected distance visual acuity and best corrected distance visual acuity*

Variable	Obs	Mean	Std. Dev.	Min	Max
Preop. UCDVA	911	0.247	0.22	0	0.9
Preop. BCDVA	828	0.544	0.291	0.1	1
1 m. postop. UCDVA	936	0.779	0.286	0.1	1
1 m. postop. BCDVA	948	0.852	0.258	0.1	1

**Note: Preop. UCDVA - preoperative uncorrected distance visual acuity; Preop. BCDVA—preoperative best-corrected distance acuity; 1 m. postop. UCDVA —1-month postoperative uncorrected distance visual acuity; 1 m. postop. BCDVA —1-month postoperative best-corrected distance visual acuity*

Table 9 indicates that prior to surgery, Hungarian patients had relatively poor distance visual acuity, with an average uncorrected value of 24.7% (0.25 decimal) and a best-corrected value of 54.4% (0.50 decimal). Following cataract surgery, a substantial improvement was recorded in both parameters. At the 1-month follow-up, uncorrected distance visual acuity increased to 77.9%, while best-corrected acuity reached 85.2% (0.85 decimal), confirming the effectiveness of phacoemulsification and IOL implantation in restoring visual function.

One of the most important factors in the IOL planning and postoperative refractive outcomes is the lens thickness. Lens thickness is correlated with post-operative visual acuity; therefore, using Pearson's correlation, we analyzed the correlation between lens thickness and the 1-month postoperative distance visual acuity. According to our findings, there was a negative correlation ($r = -0.096$), which is statistically significant at the 1% level ($p = 0.003$), between the lens thickness and the distance visual acuity after surgery; therefore, the greater the lens thickness before surgery, the lower the postoperative visual outcome. (Table 10)

Table 10. *Lens thickness and 1-month postoperative best-corrected distance visual acuity*

Variables		UCDVA preop.	BCDVA preop.	BCDVA 1m postop	Lens Thickness	IOL model
UCDVA preop.	Cor	1	0.477**	0.334**	0.019	0.084*
	Sig		.000	.000	0.565	0.012
	N	911	763	881	911	911
BCDVA preop.	Cor	0.477**	1	0.402**	-0.038	0.162**
	Sig	.000		.000	0.273	.000
	N	763	828	816	828	828
BCDVA 1m postop	Cor	0.334**	0.402**	1	-0.096**	-0.354**
	Sig	.000	.000		0.003	.000
	N	881	816	948	948	948
Lens Thickness	Cor	0.019	-0.038	-.096**	1	0.064*
	Sig	0.565	0.273	0.003		0.044
	N	911	828	948	1001	1001
IOL model	Cor	0.084*	0.162**	0.033	-0.048	-0.06
	Sig	0.012	.000	0.308	0.129	0.058
	N	911	828	948	1001	1001

*Note: ** Correlation is significant at the 0.01 level (1%).*

*Note * Correlation is significant at the 0.05 level (5%).*

The literature shows that with the ongoing advances in cataract surgery, the expectations of patients and surgeons remain on an increasing range. Therefore, the IOL model should be selected appropriately to fulfill the patients' needs. 14 different models of intraocular lenses were used to treat the Hungarian patients included in this study. Figure 3 presents the 14 IOL models implanted in Hungarian patients.

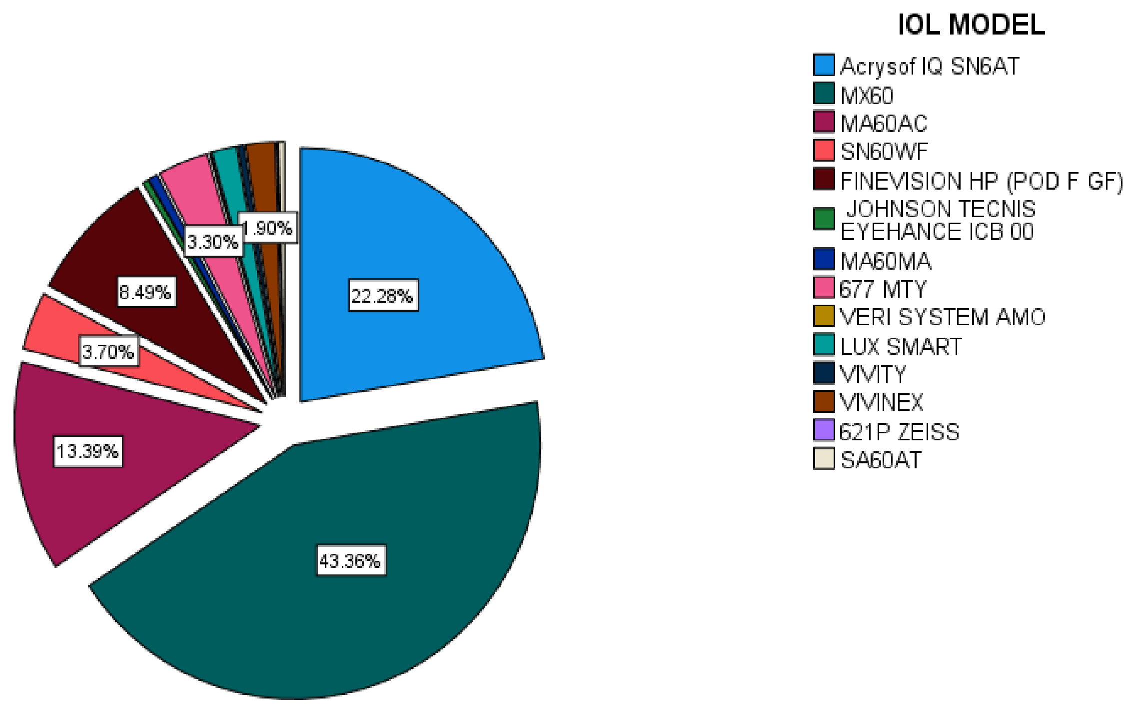

Figure 3. *IOL models in Hungarian patients*

From all available IOLs, enVista MX-60 (Bausch & Lomb, Bridgewater, NJ, USA) monofocal IOL was used in 43.36% of patients, the second most used IOL was AcrySof IQ toric SN6AT (Alcon, Fort Worth, TX, USA), 22.28%, MA60AC (Alcon, Fort Worth, TX, USA) was implanted in 13.39% of patients, while the other IOL models were implanted in less than 10 % of cases.

The IOL model plays a very important role in the postoperative results; therefore, using the regression analysis, we assessed the impact of the IOL model and the preoperative visual acuity on the postoperative uncorrected visual acuity and best-corrected visual acuity.

Based on the preoperative visual acuity, we divided our patients into three main groups: Group 1 - 0–33% (hand movement—0.33 preoperative visual acuity); Group 2—34–66% (0.34–0.66 preoperative visual acuity); Group 3—67–100% (0.67–1.0 preoperative visual acuity).

In Table 11, we have presented the results of the regression analysis on the impact of the IOL model and the preoperative visual acuity on the postoperative refractive outcomes.

Table 11. *Intraocular lens (IOL) model and postoperative visual acuity*

Lens Type	UCDVA 1 m postop.	UCDVA 1 m postop.	UCDVA 1 m postop.	UCDVA 1 m postop.
	0–33	34–66	67–100	Total
SN6AT	0.034 **	0.043 **	0.008 ***	0.16 **
	-2.67	-2.12	-4.53	-2.14
MX60	0.0428	0.136	0.115	0.0411
	-1.38	-1.38	-1.97	-1.81
MA60AC	−0.177 ***	−0.177	−0.223 **	−0.169 ***
	(−4.41)	(−1.77)	(−3.24)	(−5.44)
SN60WF	−0.0564	0.323	0.133	−0.073
	(−0.88)	-1.62	-1.4	(−1.51)
PODFGF PHYSIOL	0.164 **	0.323*	0.175 *	0.133 ***
	-3.24	-2.33	-2.49	-3.91
JOHNSON JOHNSON	−0.0184	0.323	0.204	0.145
TECNIS EYEHANCE ICB 00	(−0.06)	-1.62	-1.26	-1.1
MA60MA	−0.335 **			−0.397 ***
	(−2.74)			(−3.69)
677MTY	0.219 **	0.256	0.16	0.179 ***
	-2.83	-1.97	-1.85	-3.62
VERI SYSTEM AMO	−0.0184			
	(−0.06)			
LUX SMART	0.0482	0.223	0.144	0.184 *
	-0.28	-1.12	-1.33	-2.56
VIVITY	0.182			0.12
	-1.22			-0.91
VIVINEX	−0.0851	−0.527	−0.646 **	−0.0442
	(−0.84)	(−1.93)	(−2.88)	(−0.69)
621P ZEISS				−0.28
				(−1.85)
SA60AT	−0.218			−0.18
	(−1.28)			(−0.69)
Cons	0.718 ***	0.677 ***	0.796 ***	0.780 ***
	-28.27	-9.28	-17.4	-42.55
N	612	62	118	883

Lens Type	**BCDVA 1 m postop.**	**BCDVA 1 m postop.**	**BCDVA 1 m postop.**	**BCDVA 1 m postop.**
	0–33	**34–66**	67–100	**Total**
SN6AT	0.032	0.03 **	0.002 **	0.014 **
	-1.14	-2.22	-1.99	-2.85
MX60	0.0168	0.0521	0.0594	0.0245
	-0.58	-0.51	-1.03	-1.19
MA60AC	−0.0924 *	−0.0255	−0.08	−0.0852 **
	(−2.44)	(−0.25)	(−1.20)	(−3.04)
SN60WF	−0.0736	0.233	0.111	−0.0658
	(−1.24)	-1.1	-1.18	(−1.51)
PODFGF PHYSIOL	0.117 *	0.233	0.121	0.0914 **
	-2.44	-1.6	-1.71	-2.93
JOHNSON JOHNSON TECNIS EYEHANCE ICB 00	0.188	0.233	0.14	0.146
	-0.67	-1.1	-0.86	-1.21
MA60MA	−0.345 **			−0.388 ***
	(−2.97)			(−3.94)
677MTY	0.182 *	0.217	0.129	0.139 **
	-2.47	-1.59	-1.5	-3.09
VERI SYSTEM AMO				
LUX SMART	−0.0454	0.233	0.12	0.139 *
	(−0.28)	-1.1	-1.11	-2.11
VIVITY	0.088			0.0457
	-0.62			-0.38
VIVINEX	−0.0787	−0.167	−0.26	−0.0385
	(−0.82)	(−0.78)	(−1.60)	(−0.68)
621P ZEISS	−0.312			−0.354 *
	(−1.92)			(−2.56)
SA60AT				−0.254
				(−1.07)
Cons	0.812 ***	0.767 ***	0.860 ***	0.854 ***
	-34.14	-10.5	-19.42	-51.8
N	619	67	122	895

Our results showed that AcrySof IQ toric SN6AT (Alcon, Fort Worth, TX, USA) IOL, which was used implanted in 22.28% of the cases, had a statistically significant positive impact in all groups ($p < 0.05$), with the highest positive impact (B = 0.043) on the 1-month postoperative visual acuity of the second group of patients (0.34–0.6 preoperative visual acuity). However, in all three groups of patients, AcrySof IQ toric SN6AT IOL had a statistically significant positive impact on the postoperative outcomes ($p < 0.05$); 1-month uncorrected postoperative visual acuity had a positive coefficient of B = 0.16, while the 1-month best corrected postoperative visual acuity had a positive coefficient of B = 0.14.

Another IOL model with a significant positive impact on postoperative visual acuity was found to be the FINEVISION HP (POD F GF) IOL (BVI, Waltham, MA, USA), similar to the AcrySof IQ toric SN6AT IOL. The highest positive impact was found in the second group of patients (B = 0.323). In terms of the total impact on the three groups, the FINEVISION HP (POD F GF) IOL was found to have a positive impact (B = 0.133) on uncorrected 1-month postoperative distance visual acuity, and an impact of B = 0.0914 in the 1-month best-corrected distance visual acuity, which was also statistically significant ($p < 0.05$).

The IOL used for most patients (43.36%), enVista MX-60 (Bausch & Lomb, Bridgewater, NJ, USA), exhibited an overall positive impact on the visual acuity in all patients. The positive impact on 1-month uncorrected distance visual acuity was B = 0.0411, whereas for 1-month best-corrected distance visual acuity, B = 0.0245. However, this was not considered statistically significant.

The regression analysis results also showed the positive impact of the 677MTY (Medicontur Medical Engineering Ltd., Zsámbék, Hungary) IOL on postoperative visual outcomes. In all groups of patients, the 677MTY IOL has a statistically significant positive impact at the level of 5% ($p < 0.05$), with B = 0.179 for 1-month uncorrected distance visual acuity and B = 0.139 for 1-month best-corrected distance visual acuity (Table 11).

4.3. Results of Kosovan Patients

In the Kosovan study population, 416 patients diagnosed with cataract received surgical treatment by phacoemulsification followed by intraocular lens implantation at the University Clinical Center of Kosovo. The average patient age was 70.4 years, indicating an elderly cohort consistent with typical cataract demographics. The mean axial length measured in this group was 23.23 mm, while the anterior chamber depth averaged 3.12 mm, as summarized in Table 12.

Table 12. *Age, axial length, and anterior chamber depth in Kosovan patients*

Variables	Kosovo	
	Mean	**Std Dev**
Age	70.4	9.23
AL	23.23	0.98
ACD	3.12	0.42

The correlation analysis for Kosovan patients, presented in Table 13, demonstrates a pattern similar to that observed in the Hungarian sample. Although both axial length and anterior chamber depth tended to decrease with advancing age, only the latter relationship reached statistical significance. The association between age and axial length was minimal (r = –0.04) and non-significant (P = 0.330). However, age was significantly and negatively correlated with anterior chamber depth (r = –0.18, P = 0.000), indicating that older individuals exhibited a shallower anterior chamber.

Table 13. *Correlation between the age, axial length, and anterior chamber depth in Kosovan patients*

		Age	**AL**	**ACD**
Age	Cor	1	-0.048	-0.188**
	Sig		0.330	0.000
	N	416	415	392
AL	Cor	-0.048	1	0.289**
	Sig	0.330		0.000
	N	415	415	392
ACD	Cor	-0.188**	0.289**	1
	Sig	0.000	0.000	

	N	392	392	392

*Note: **. Correlation is significant at the 0.01 level (1%)*

Table 14 presents the preoperative distance visual acuity and the 1-month postoperative distance visual acuity of the Kosovan subjects. The mean preoperative distance visual acuity in these patients was 15% or 0.15 in decimal units, whereas the mean uncorrected 1-month postoperative distance visual acuity increased to 44% or 0.4 in decimal units, and the best-corrected distance visual acuity increased to 49.6% or 0.5 in decimal units.

Table 14. *Preoperative and postoperative visual acuity in Kosovan patients*

Variable	Obs	Mean	Std. Dev.	Min	Max
Visual acuity pre-op	407	0.15	0.424	0	0.8
UCDVA 1-month postop.	397	0.44	0.216	0.1	1
BCDVA 1-month postop.	397	0.496	0.229	0.1	1

Lens thickness is a key parameter in intraocular lens power calculation and is also associated with both patient age and visual acuity. To evaluate its relationship with postoperative vision, a correlation analysis was performed between lens thickness and postoperative visual acuity (Table 15).

Table 15. *Lens thickness and 1-month postoperative best-corrected distance visual acuity*

Variables		UCDVA preop.	BCDVA 1m postop.	Lens Thickness	IOL model
UCDVA preop.	Cor	1	0.608**	0.076	-0.051
	Sig		0.000	0.126	0.305
	N	407	389	407	407
	Cor	0.608**	1	0.030	-0.067

BCDVA 1m postop.	Sig	0.000		0.556	0.184
	N	389	397	397	397
Lens Thickness	Cor	0.076	0.030	1	0.076
	Sig	0.126	0.556		0.124
	N	407	397	416	416
	Sig	0.633	0.409	0.409	0.348
	N	406	396	415	415
IOL model	Cor	-0.051	-0.067	0.076	1
	Sig	0.305	0.184	0.124	
	N	407	397	416	416

*Note**. Correlation is significant at the 0.01 level (1%).*

The results presented in Table 15 show a positive correlation between visual acuity and lens thickness in Kosovan patients, with a coefficient of r = 0.030.

The Kosovan patients were treated with one of the two monofocal IOL types, AcrySof SA60AT IOL (Alcon, Fort Worth, TX, USA) and Akreos ADAPT AO (Bausch & Lomb, Bridgewater, NJ, USA), available at the study center. Akreos ADAPT AO was used in 64.18% of the patients and AcrySof SA60AT was used in 35.82% of cases (Figure 4).

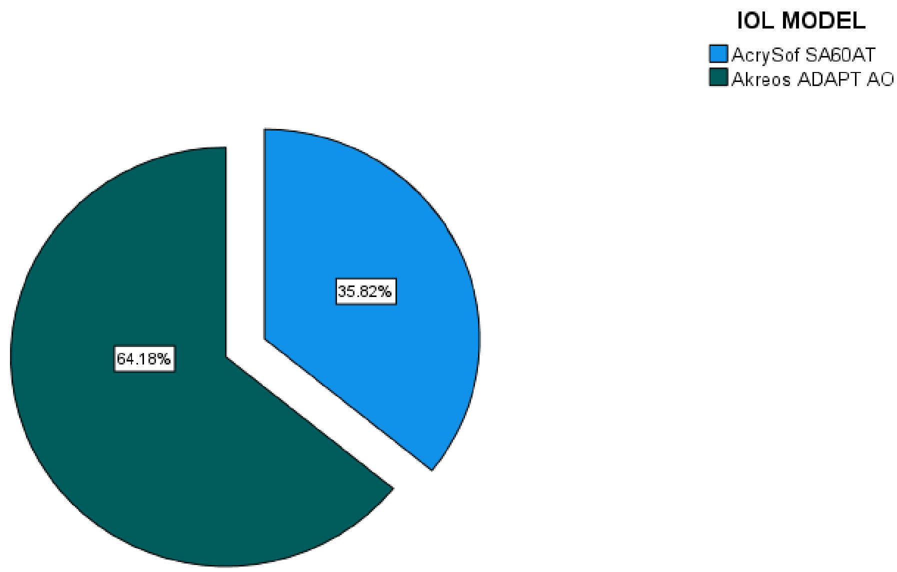

Figure 4. *IOL models in Kosovan patients*

The IOL model selection has an important role in the postoperative outcomes. Using the regression analysis, we have assessed the impact of the IOL model on the postoperative outcomes of the patients. Based on the preoperative visual acuity, we divided our patients into three main groups: Group 1 - 0–33% (hand movement—0.33 preoperative visual acuity); Group 2—34–66% (0.34–0.66 preoperative visual acuity); Group 3—67–100% (0.67–1.0 preoperative visual acuity. The same division was made as that for the Hungarian patients and visual acuity was measured 1 month after surgery in all three groups.

The AcrySof SA60AT IOL was used in 35.82% of the patients and was found to have an overall positive impact on postoperative distance visual acuity in all three groups. However, there was a higher positive impact on the postoperative distance visual acuity of patients in the second group, who had a preoperative UCDVA from 0.34 to 0.66 (B = 0.321), which was statistically significant.

The other IOL model, Akreos ADAPT AO, was used in 64.18% of cases, and it was found to have an overall positive impact on postoperative visual outcomes in all groups. Similar to AcrySof SA60AT, Akreos ADAPT AO also resulted in a higher positive impact (B = 0.408) on the patients, whose preoperative distance visual acuity was between 34 and 66%, which was statistically significant at the 5% level. Even though both IOL models had a statistically significant positive impact on postoperative distance visual acuity, Akreos ADAPT AO was considered to have a higher positive impact (B = 0.408) than AcrySof SA60AT. (Table 16)

Table 16. *Intra-Ocular Lens (IOL) model and postoperative distance visual acuity*

Lens Type	**UCDVA 1-Month Postop.**	**UCDVA 1-Month Postop.**	**UCDVA 1-Month Postop.**	**UCDVA 1-Month Postop.**
	0–33	**34–66**	**67–100**	**Total**
AcrySof SA60AT	0.0152	0.321 *	0.101	0.0242
	(1.78)	(1.81)	(0.53)	(1.14)
Akreos ADAPT AO	0.0262	0.408 **	0.11	0.0309
	(1.30)	(2.20)	(0.62)	(1.37)
Cons	0.415 ***	0.575 **	0.743 ***	0.459 ***
	−25.74	−4.74	−5.58	−25.57
N	344	7	16	397

*Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.*

4.4. Results of Brazilian Patients

630 Brazilian patients with cataract were included in our study; they were surgically treated with phacoemulsification and IOL implantation in the Ophthalmology Department of the Faculty of Medicine of Ribeirão Preto, São Paulo in Brazil.

30.78% of our study sample was composed of Brazilian patients. Table 17 shows the mean anterior chamber depth and axial length in Brazilian patients.

Table 17. *Axial length and anterior chamber depth in Brazilian patients*

Variables	Brazil	
	Mean	Std Dev
AL	23.3	0.954
ACD	3.152	0.417

Brazilian patients demonstrated a mean axial length of 23.3 mm, which is comparable to the values observed in Hungary and Kosovo. However, their mean anterior chamber depth was slightly greater, averaging 3.15 mm. Four different intraocular lens types were used in this group. The most frequently implanted model was the AcrySof IQ ReSTOR SN6AD1 multifocal lens (Alcon, Fort Worth, TX, USA), accounting for 31.43% of cases. The Alcon SN60WF single-piece lens was the second most commonly selected (28.57%), followed by the AcrySof IQ Vivity in 20.95% of surgeries. The extended-depth-of-focus Tecnis Symfony IOL (Johnson & Johnson, Jacksonville, FL, USA) was used least often, at 19.05% (Figure 5).

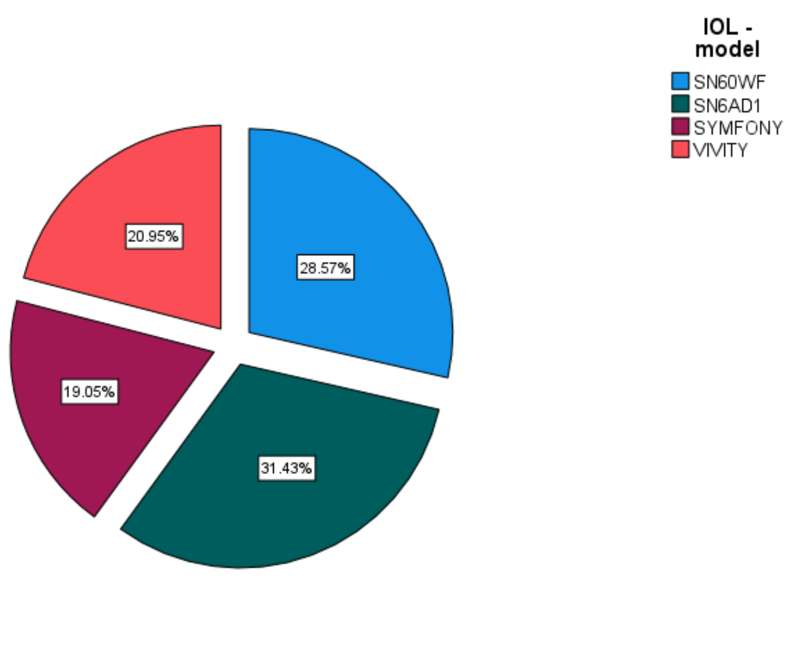

Figure 5. *IOL models in Brazilian patients*

Through the regression analysis, we have assessed the impact of each IOL model on the postoperative results. Based on the results presented in Table 18, the AcrySof IQ Vivity was the lens with the highest positive impact on the postoperative visual acuity, with the coefficient B=0.065, which is statistically significant at the level of 1% (p<0.01).

Tecnis Symfony has been shown to have a statistically significant positive impact at the level of 1% (p<0.01), in the postoperative visual acuity in the Brazilian patients. Also, the other IOLs, AcrySof IQ SN6AD1 and SN60WF had a positive impact on the postoperative results; however, it was not statistically significant (Table 18).

Table 18. *Intraocular lens (IOL) model and postoperative visual acuity*

BCDVA	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
SN6AD1	0.021	0.012	1.75	0.567	0.006	0.027	
SN60WF	0.001	0.007	0.00	0.999	-0.014	0.014	
SYMFONY	0.031	0.008	-3.86	0.000	-0.047	-0.015	***
VIVITY	0.065	0.008	-8.46	0.000	-0.081	-0.05	***
Constant	1.01	0.005	205.52	0.000	0.99	1.01	***
R-squared		0.630		Number of obs		624	
F-test		30.747		Prob > F		0.000	

*Note: *** p < 0.01, ** p < 0.05, * p < 0.1*

Table 19. *Correlation analysis between postoperative refractive correction and visual acuity*

Variables		BCDVA	Hypermetropic correction	Myopic correction	IOL model
BCDVA	Cor	1	0.121	0.038	-0.335**
	Sig		0.232	0.476	0.000
	N	624	99	356	624
	Cor	0.121	1	.b	-0.208*

Hypermetropic correction	Sig	0.232		.	0.039
	N	99	99	0	99
Myopic correction	Cor	0.038	.[b]	1	0.103
	Sig	0.476	.		0.050
	N	356	0	361	361
IOL - model	Cor	-0.335**	-0.208*	0.103	1
	Sig	0.000	0.039	0.050	
	N	624	99	361	630

*Note: *** p < 0.01, ** p < 0.05, * p < 0.*

In Table 19, we have employed the correlation analysis to assess the correlation between the postoperative refractive correction and visual acuity. Based on the presented coefficients, there is a positive correlation, r=0.12 in cases of hyperopic correction and r= 0.03 in cases of myopic correction.

Through regression analysis, we have analyzed the impact of postoperative refractive correction on the improvement of visual acuity. The data of postoperative refractive correction explains the difference in visual acuity 82.6% (R-squared=0.826). Based on the F-test 8.17 and P=0.000, the regression is statistically significant.

The regression coefficients indicate that hyperopic correction increased visual acuity (B = 0.052), reaching statistical significance at the 1% level (P = 0.001). Likewise, myopic correction also demonstrated a positive effect on visual acuity (B = 0.018), which was statistically significant at the 1% threshold (P = 0.005), as shown in Table 20.

Table 20. *Regression analysis between postoperative refractive correction and visual acuity*

BCDVA	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Hyperopic correction	0.052	0.016	3.24	0.001	-0.084	-0.021	***
Myopic correction	0.018	0.006	2.80	0.005	-0.031	-0.005	***
Constant	1.011	0.008	121.68	0.000	0.995	1.028	***
Mean dependent var	0.980	SD dependent var		0.074			
R-squared	0.826	Number of obs		609			
F-test	8.179	Prob > F		0.000			
Akaike crit. (AIC)	1453.596	Bayesian crit. (BIC)		-1440.361			

*Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0$.*

4.5. Comparison between countries – Hungary, Kosovo, and Brazil

This investigation involved 2,047 individuals who underwent cataract extraction by phacoemulsification followed by intraocular lens implantation. Of these, 1,001 patients were operated on at the Ophthalmology Department of Semmelweis University in Hungary, 630 patients were treated at the Faculty of Medicine of Ribeirão Preto in São Paulo, Brazil, and 416 patients received surgery at the University Clinical Center of Kosovo. These distributions are illustrated in Figure 6.

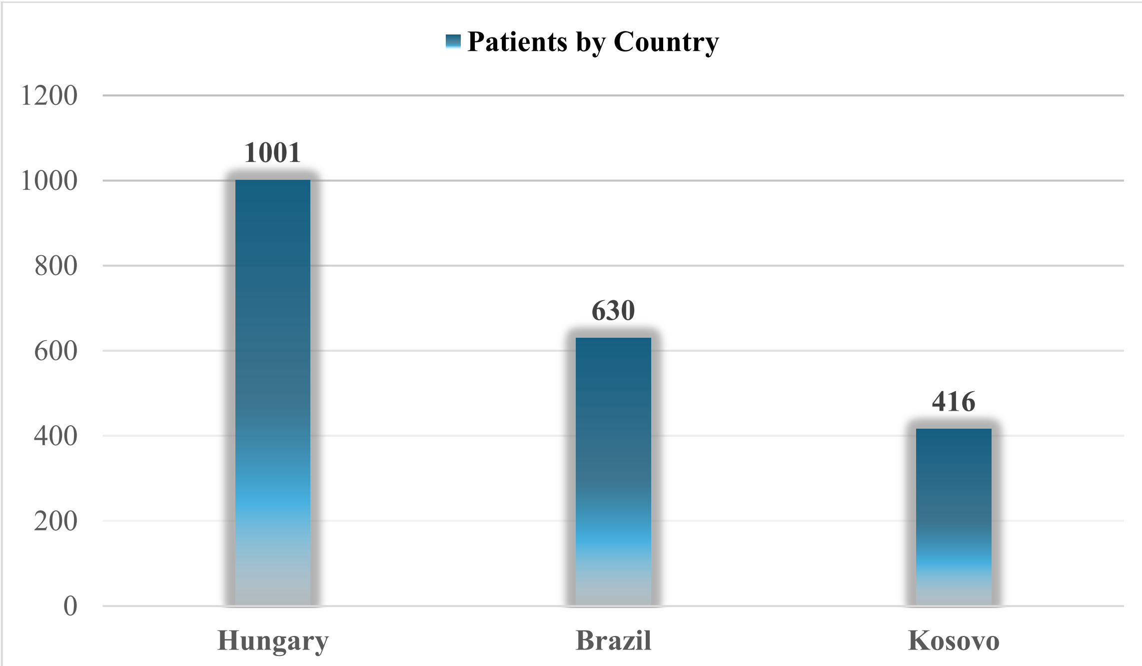

Figure 6. *Patients by country*

Comparison of the Axial Length and Anterior Chamber Depth between Hungary, Kosovo, and Brazil

Table 21. *Axial Length and Anterior Chamber Depth*

Variables	Kosovo		Hungary		Brazil	
	Mean	**Std Dev**	**Mean**	**Std Dev**	**Mean**	**Std Dev**
Age	70.4	9.23	68.97	12.35	-	-
AL	23.23	0.98	23.6	1.84	23.3	0.954
ACD	3.12	0.42	3.14	0.45	3.152	0.417

The comparative findings are shown in Table 21. The average axial length among Kosovan participants measured 23.23 ± 0.98 mm, closely matching that of Brazilian patients, whose mean value was 23.3 ± 0.954 mm. Hungarian patients, however, demonstrated a noticeably longer mean axial length of 23.60 ± 1.84 mm. For anterior chamber depth, the smallest mean measurement was observed in Kosovo (3.12 ± 0.42 mm), whereas Brazilian participants exhibited the deepest anterior chamber (3.15 ± 0.417 mm).

Statistical testing using one-way ANOVA confirmed significant biometric variation across the three national groups. A significant difference in axial length was found between Hungarian patients and those from both Kosovo and Brazil (p = 0.000), indicating longer eyes in the Hungarian cohort. Nonetheless, no statistically relevant difference was detected between the Kosovan and Brazilian groups. For anterior chamber depth, however, the analysis did not reveal any significant variation between the three study samples (p = 0.631), indicating comparable anterior chamber depth across all centers (Table 22, Figure 8).

The asterisks indicate extreme outliers, which are data points that are even further from the rest of the data set than the regular outliers. These are values that fall beyond 3 times the nearest quartile, which is present in both axial length and anterior chamber depth (Figures 7 and 8).

Table 22. *One-way ANOVA—Hungary, Kosovo, and Brazil*

		Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
AL	Between Groups	55.74	2	27.87	12.973	0.000
	Within Groups	4382.77	2040	2.14		
	Total	4438.51	2042			
ACD	Between Groups	0.175	2	0.088	0.460	0.631
	Within Groups	366.404	1924	0.190		
	Total	366.579	1926			

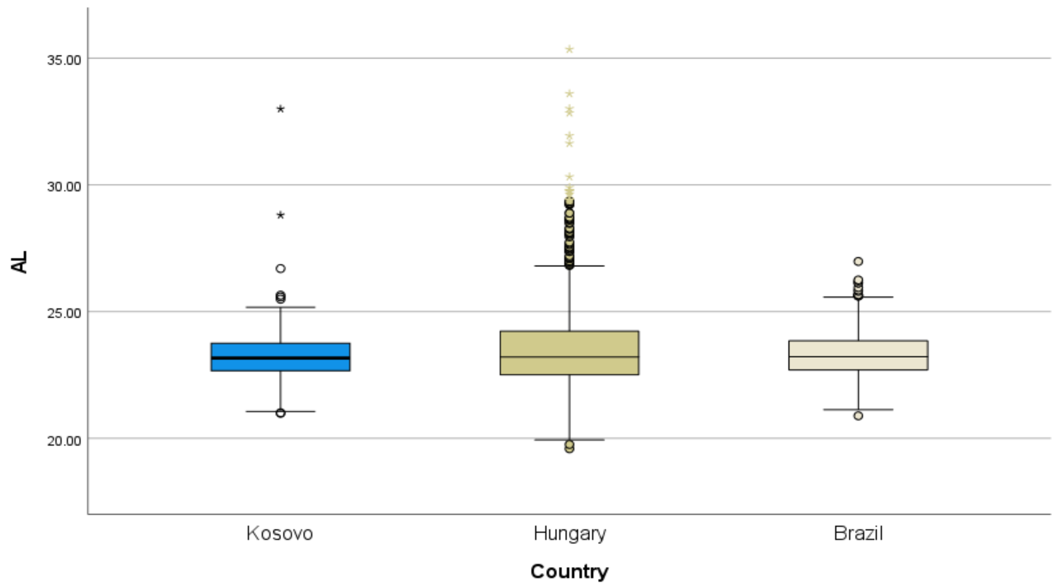

Figure 7. *Comparison of mean axial length between countries*

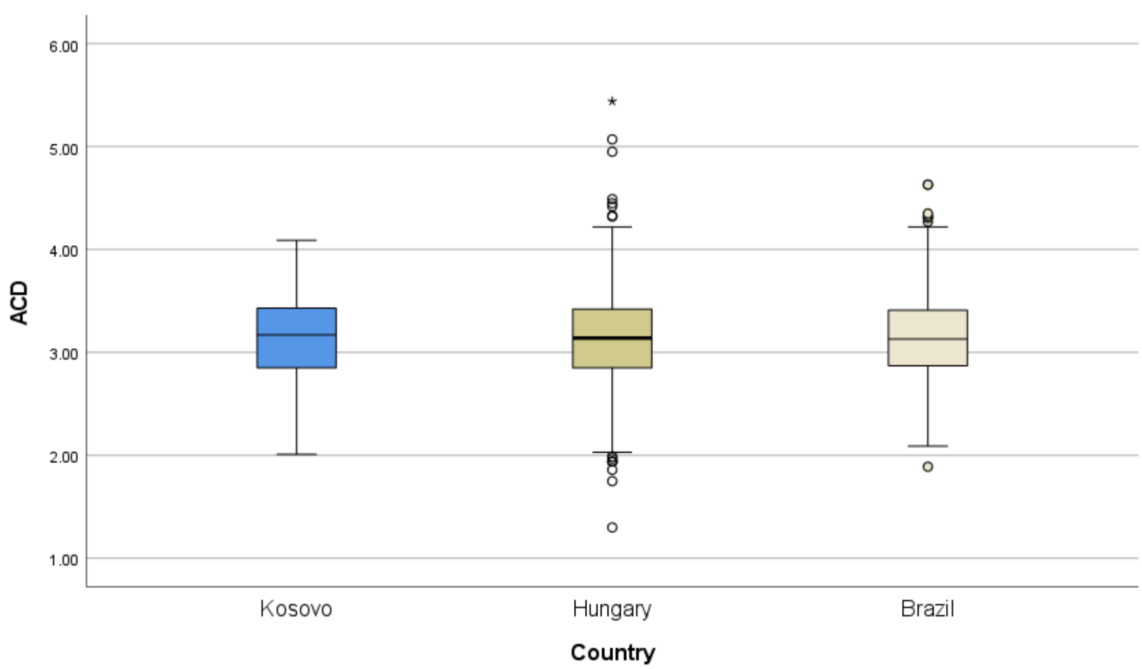

Figure 8. *Comparison of mean anterior chamber depth between countries*

The results of one-way ANOVA presented in Table 23 show the statistically significant differences in the lens thickness between Kosovo and Hungary. Mean lens thickness in Kosovan patients was 4.30 mm, whereas the mean lens thickness in Hungarian patients was

4.40 mm. According to ANOVA's results with F-statistic 10.13 and P=0.001, there is sufficient evidence to conclude that there are statistically significant differences in the mean lens thickness between countries (Table 23, Figure 9).

Table 23. *ANOVA for statistically significant differences in the lens thickness (LT)*

Lens Thickness	Posterior			95% Credible Interval			
	Mode	Mean	Variance	Lower Bound	Upper Bound	F	Sig.
Hungary	4.40	4.400	0.000	4.36	4.43	10.13	.001
Kosovo	4.30	4.302	0.001	4.25	4.35		

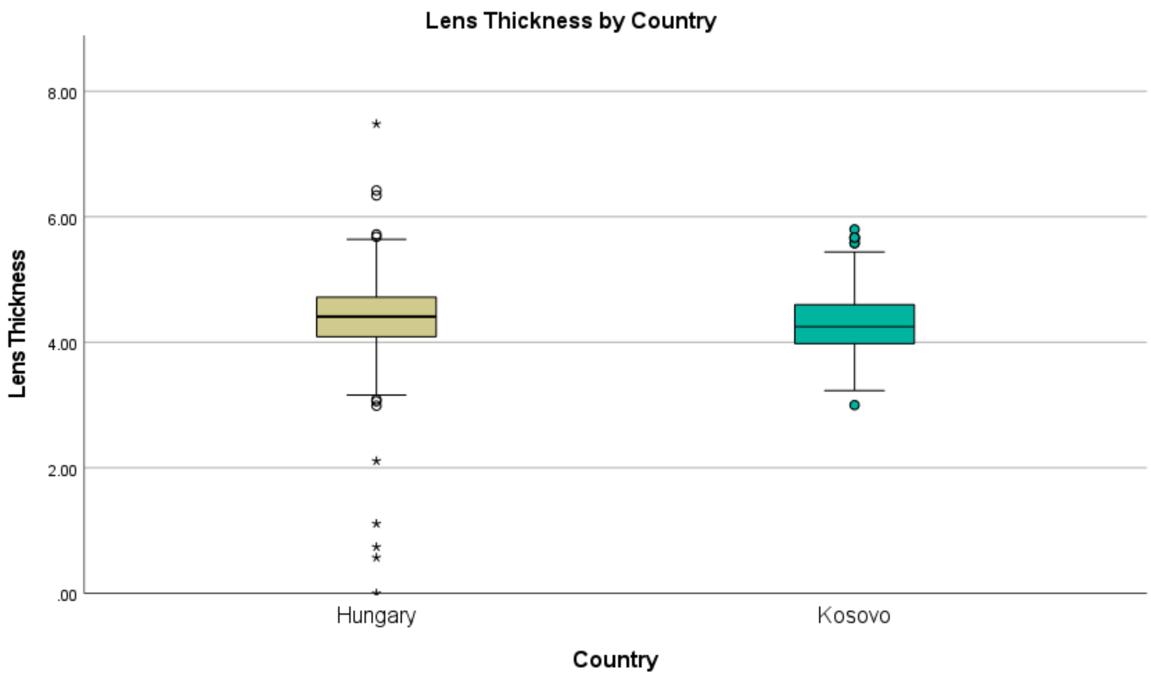

Figure 9. *Box plot for statistically significant differences in the lens thickness between countries*

Table 24. *Statistically significant differences in the postoperative outcomes based on the surgeon's experience*

UCDVA preop.	Posterior			95% Credible Interval		Sig. Diff.
	Mode	Mean	Variance	Lower Bound	Upper Bound	
11 Years Experience	0.150	0.150	0.000	0.121	0.180	P=0.000
24 Years Experience	0.247	0.247	0.000	0.227	0.266	
UCDVA 1-month postop.	**Posterior**			**95% Credible Interval**		**Sig. Diff.**
	Mode	**Mean**	**Variance**	**Lower Bound**	**Upper Bound**	
11 Years Experience	0.440	0.440	0.000	0.414	0.467	P=0.000
24 Years Experience	0.779	0.779	0.000	0.762	0.796	
BCDVA 1-month postop	**Posterior**			**95% Credible Interval**		**Sig. Diff.**
	Mode	**Mean**	**Variance**	**Lower Bound**	**Upper Bound**	
11 Years Experience	0.496	0.496	0.000	0.472	0.521	P=0.000
24 Years Experience	0.852	0.852	0.000	0.836	0.868	

One of the most important factors in the postoperative refractive outcomes is also the surgeon's experience. Table 24 presents the results of the impact of the surgeon's experience on the postoperative outcomes.

There was a statistically significant difference in the postoperative results based on the surgeon's experience. The preoperative UCDVA in the Kosovan patients, where the surgeon had 11 years of experience in phacoemulsification, was 0.15 or 15%, whereas the UCDVA in the Hungarian patients before the surgery was 0.25. Based on Table 24, there were statistically significant differences in the 1-month postoperative outcomes between the two groups, according to the particular surgeon.

The 1-month postoperative UCDVA in the patients treated by the surgeon with 11 years of experience was 0.4 (CI = 0.414–0.467) and the BCDVA = 0.5 or 50% (CI = 0.472–0.521). On the other hand, in the Hungarian patients, the 1-month postoperative outcomes showed a much higher visual acuity, both corrected and uncorrected; the 1-month postoperative UCDVA = 0.8 or 80% and the BCDVA = 0.85 or 85%. Based on the *p*-value, where $p = 0.000$, there was a statistically significant difference in the postoperative outcomes based on the surgeon's experience in phacoemulsification. Table 25 presents the statistically significant difference on the 1-month postoperative best corrected distance visual acuity. Statistically significant differences between the three groups of patients were found for the 1-month BCDVA. The BCDVA in the Hungarian patients was 85.2%, in the Kosovan patients, it was 49.6% whereas in the Brazilian patients, it was 98.1%.Based on the one-way ANOVA results with F-statistic of 859.57 and $p = 0.001$, we can conclude that there is a statistically significant difference in the 1-month postoperative distance visual acuity between the patients from all three countries.

Table 25. *One-way ANOVA on the 1-month postoperative distance visual acuity*

Country	BCDVA	Mode	Mean	df	F	Sig.
Hungary	Between Groups	0.852	0.852	2		
Kosovo	Within Groups	0.440	0.440	1966	859.57	0.000
Brazil	Total	0.981	0.981	1968		

Table 26. *Emmetropia in Hungarian and Kosovan patients*

Variable	Hungary		Kosovo	
UCDVA 1m post-op	Freq.	Percent	Freq.	Percent
1 (100%)	464	49.57	10	2.52
Total	936	100	397	100

Reaching emmetropia after cataract surgery is the most important goal. Table 26 shows the percentage of patients who have reached emmetropia, 1 month after cataract surgery. Based on these results, emmetropia was reached in 49.57% of the cases, whereas in the Kosovan patients it was reached in only 2.52% of the cases.

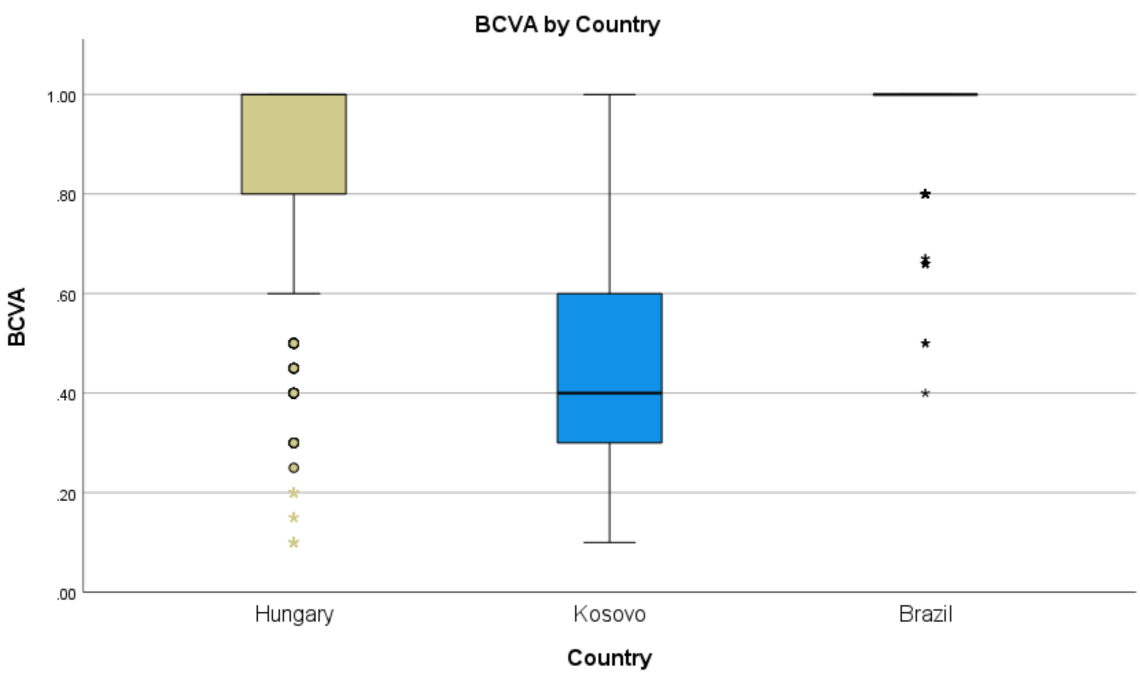

Figure 10. *Box plot for the BCDVA by country*

The box plot for the statistically significant differences in the 1-month postoperative best corrected distance visual acuity is presented in Figure 10. The above box plot shows that the differences in the postoperative visual acuity between the three countries are significant.

5. DISCUSSION

The present research examined and compared key biometric parameters relevant to intraocular lens power calculation in three patient cohorts originating from Hungary, Kosovo, and Brazil. All individuals included in the analysis were diagnosed with cataract and underwent phacoemulsification with IOL implantation.

Precise biometric measurements remain the primary determinant of accurate IOL power prediction. From the earliest IOL formulas to the most modern calculation methods, the literature consistently highlights that reliable preoperative biometric evaluation is essential for achieving optimal refractive outcomes. Axial length, anterior chamber depth, and corneal curvature are considered the most important determinants for accurate intraocular lens power calculations [57]. Advances in the IOL power calculation and the ongoing perfection of surgical approaches and techniques have contributed to much higher postoperative expectations from patients [58,59].

The study analyzed biometric measurements from 2,047 cataract patients originating from Hungary, Kosovo, and Brazil. The average axial length among Kosovan subjects measured 23.23 mm, which was almost identical to the Brazilian cohort (23.3 mm). In contrast, Hungarian patients exhibited a longer mean axial length of 23.60 ± 1.84 mm. Statistical testing confirmed a significant difference between the Hungarian group and the other two populations ($p = 0.000$), while no significant axial length difference was detected between the Kosovan and Brazilian patients. Hui Chen et al. in their study on the distribution of axial length, anterior chamber depth, and corneal curvature in South China, found that the AL in this Chinese cohort was greater than that observed in the Singaporean Chinese, but smaller than that observed in Malaysia and for Caucasians [60].

Biometric variables such as axial length, anterior chamber depth, and lens thickness are known to vary according to socio-demographic and environmental factors, including race, ethnicity, and lifestyle. These variations partly explain the differences in refractive error patterns observed across populations. Previous research has shown that ocular biometry is influenced by genetic background, age, sex, ethnicity, and whether an individual lives in an urban area [61,62]. Consistent with this evidence, our findings indicate that age affects both axial length and anterior chamber depth, with statistically significant negative correlations observed between age and these two parameters in our study population. The correlation between age and the biometric parameters of axial length and anterior chamber depth found in our study also aligns with the study of Fotedar et al., on the distribution of the axial length and ocular biometry, measured using partial coherence laser interferometry (IOL Master), in an older white population who also found that there was a mean reduction in the axial length with age [63], in addition to that also the longitudinal population study of Chinese adults, conducted by Mingguang He et al., the mean axial length was greater for younger persons compared to the older persons included in the study [64]. Anterior chamber depth is a critical parameter in both preoperative planning and postoperative refractive outcomes [65,66]. The anterior chamber depth differences between our groups of patients were not statistically significant.

Lens thickness plays a key role not only in the calculation and selection of intraocular lens power but also in determining postoperative visual outcomes. To evaluate how preoperative lens thickness influenced visual results one month after surgery, Pearson’s correlation analysis was applied. Similar to the findings of Shajari et al., who concluded that the lens thickness played an important role in the outcomes of femtosecond-assisted cataract surgery [67], based on the results of our study, we also found that there was a statistically significant negative correlation ($r = -0.096$) at the 1% ($p = 0.003$) level of significance between lens thickness and distance visual acuity after surgery; in our Hungarian patients, therefore, the greater the lens thickness before surgery, the lower the postoperative visual outcomes. On the other hand, the results differed in the Kosovan patients, in which group we obtained a positive correlation with a coefficient of $r = 0.030$; however, it was not statistically significant. The one-way ANOVA demonstrated that lens thickness differed significantly between the Hungarian and Kosovan patient groups.

In our analysis, Kosovan patients achieved a postoperative uncorrected distance visual acuity of 0.4 (44%), compared with a preoperative value of 0.15 (15%). Despite this improvement, their postoperative visual outcomes remained lower than those observed in the Hungarian and Brazilian cohorts. Multiple contributing factors may explain this discrepancy, including restricted access to advanced IOL types, the absence of multifocal and toric lenses, and financial limitations that delay timely cataract surgery. Additionally, the Heilongjiang Eye Study, conducted by Zhijian Li et al. [49], concluded that the visual outcomes after cataract surgery in northern China were poor, primarily due to economic barriers to the uptake of cataract surgery. The results of a study from the Swedish National Cataract Register [68] on the factors that might impact postoperative refraction showed that the mean absolute prediction error was related to the study year and that it decreased the more recently the surgery was performed, a result that could be attributed to improvements in the technique and equipment. Their findings also showed that preoperative visual acuity influenced the mean absolute prediction error. This observation is consistent with our results, in which postoperative uncorrected visual acuity was 44% among Kosovan patients, compared with 85.2% in the Hungarian group and 98.1% in the Brazilian group. These differences highlight the importance of comprehensive preoperative evaluation and precise IOL planning in achieving better postoperative visual outcomes [69–71].

One plausible explanation for the reduced postoperative visual acuity in the Kosovan group is the comparatively shorter period of clinical experience with the LenStar 900 biometer and IOL calculation process, as well as limited exposure to premium lens technologies. To further strengthen the originality of this study, we investigated whether the choice of IOL model affected postoperative outcomes when considering patients' preoperative visual acuity. Individuals were categorized into three subgroups based on their decimal preoperative distance vision. Out of the 14 different IOL designs implanted in Hungarian patients, three were associated with a statistically significant improvement in postoperative distance visual acuity. Our results showed that the AcrySof IQ toric SN6AT IOL (Alcon Laboratories, Inc.) had a statistically significant positive impact in all groups ($p < 0.05$), with the highest positive impact (B = 0.043) on the second group of patients, who had a 0.34–0.6 preoperative distance visual acuity. The AcrySof IQ toric SN6AT IOL has been widely researched, and many studies show that it has a positive effect in the correction of pre-existing astigmatism [72-74]. Scialdone A. et al. [75], concluded that patients who were implanted AcrySof IQ toric

SN6AT IOL were significantly closer to emmetropia postoperatively. A significant improvement in both postoperative UCDVA and BCDVA was also observed in patients implanted with the FINEVISION IOL. As with the AcrySof IQ toric SN6AT lens, the strongest benefit appeared in the subgroup with preoperative visual acuity between 0.34 and 0.6 (B = 0.323). When considering all three preoperative VA groups collectively, the FINEVISION HP (POD F GF) lens demonstrated a positive effect of B = 0.133 on 1-month postoperative distance visual acuity, and an additional effect of B = 0.0914, which reached statistical significance ($p < 0.05$). The FINEVISION HP (POD F GF) trifocal hydrophobic glistening-free lens also had positive outcomes [76-79] in other studies.

Across the entire study population, implantation of the enVista MX-60 IOL was associated with an improvement in postoperative visual function. At the 1-month follow-up, the lens produced a beneficial effect size of B = 0.0411 for uncorrected distance visual acuity and B = 0.0245 for best-corrected distance visual acuity. Even though this impact was not statistically significant in our study, in the study conducted by C. Ton Van et al. [80], the incidence of posterior capsular opacification in cases treated with enVista MX-60 IOL was only 2.2%, and no glistening was observed. These results confirm the safe profile of this IOL.

Among the Brazilian patients, the AcrySof IQ Vivity and the Tecnis Symfony lenses produced the greatest improvement in postoperative visual acuity, each showing a positive effect size of B = 0.065, which was statistically significant at the 1% level ($p < 0.01$).

Across all three study populations, the highest postoperative visual acuity was observed in patients whose preoperative visual acuity ranged from 0.34 to 0.66. Many different factors can explain our results. The study from the European Registry of Quality Outcomes for Cataract and Refractive Surgery suggests that ocular comorbidity, surgical complications, and complex surgery have an impact on the postoperative visual acuity [81]. Furthermore, a preoperative visual acuity of 0.34-0.66 is considered to be good preoperative visual acuity; therefore, it could also explain the results of our study. Our findings align with the results of other studies [82-84], Thurschwell [85]suggests that the possible reason might be that patients with better preoperative visual acuity may have a more intact optical system, faster neural adaptation, and a quicker adjustment to the new artificial lens after cataract surgery.

Due to the limited availability of IOL models, including the absence of premium lenses, the Kosovan cohort received only two types of implants: the SA60AT and ADAPT AO lenses. Numerous publications have demonstrated the superiority of multifocal IOLs over monofocal designs [86,87]. Although both monofocal lenses in our sample produced statistically significant improvements in postoperative visual acuity at the 5% level, the ADAPT AO lens showed a stronger effect (B = 0.408) than the SA60AT. Nevertheless, postoperative visual outcomes differed markedly between the two clinical centers. This disparity is consistent with previous research comparing monofocal lenses to premium IOLs, which generally report better visual performance with multifocal designs. Multifocal IOLs provide an overall spectacle independence in 81%–85% of patients, whereas the toric IOLs provide spectacle independence in 60%–85% of patients [88].

Longer surgical experience enables faster and safer surgery, thus reducing the postoperative complications and producing better postoperative results [89-91]. Our analysis showed that postoperative results varied significantly according to the surgeon's level of experience in performing phacoemulsification. This difference was confirmed by a highly significant p-value ($p = 0.000$), demonstrating that surgical expertise plays a measurable role in visual outcomes. J.M. Sparrow et al. [92] reported on the importance of the preoperative factors that are associated with intraoperative complications, and also the importance of having skillful and highly experienced surgeons to manage these cases. Additionally, the increased risk of intraoperative complications when the preoperative risk scores are higher is confirmed by the findings of the Auckland Cataract Study [93]. Furthermore, findings reported from different studies [94-96] emphasize the relationship between surgical complications, shorter surgeons' experience, and worse postoperative visual outcomes [96-98].

The outcomes of this study support existing evidence in the literature, indicating that surgeons with more extensive experience achieve statistically superior postoperative results compared with less experienced surgeons.

6. CONCLUSIONS

Cataract is one of the ophthalmic disorders with the highest prevalence among the elderly, and its surgical treatment using phacoemulsification and IOL implantation is the most commonly used treatment method. However, the ongoing advances in Ophthalmology have contributed to the increase in the postoperative expectations from patients.

Achieving optimal postoperative outcomes requires careful and accurate preoperative evaluation, particularly with respect to biometric measurements and intraocular lens power calculation.

The biometric parameters of the eye differ between different populations, ethnicities, and races. Our project aimed to analyze and compare the biometric data of three groups of patients from: Hungary, Kosovo, and Brazil, and to predict possible factors that play a role in the differences between these groups, which have different demographic and socio-economic features. Through the literature search, we have come across many studies conducted in many countries and populations; however, our study is the first one to compare these three populations. We have also assessed the impact of the IOL model on the postoperative results, based on the preoperative visual acuity of the patients. This factor, together with the specific study populations, highlights the novelty of our research.

The present research involved a multicenter design, incorporating biometric data from cataract patients treated with phacoemulsification and IOL implantation across three different clinical sites. Among the various metrics used to evaluate surgical effectiveness, postoperative visual acuity is considered the most critical determinant of cataract surgery success. To address this very important factor, we have also analyzed and compared the postoperative refractive outcomes between our groups of patients.

The analysis focused on the primary biometric indices relevant for IOL calculation, namely axial length, anterior chamber depth, corneal refractive power, and lens thickness. Comparative assessment revealed statistically significant variations in axial length and anterior chamber depth across the three study populations—Hungarian, Kosovan, and Brazilian patients.

When examining demographic influences, a statistically significant inverse association emerged between age and the examined biometric parameters, specifically axial length and anterior chamber depth. These results indicate that older individuals tend to exhibit shorter axial lengths and shallower anterior chambers.

The availability of premium IOLs is a key factor to obtain satisfactory postoperative outcomes, based on our results, we can conclude that premium IOLs produce better postoperative outcomes. Our findings are consistent with this conclusion, as we observed statistically significant differences in 1-month postoperative distance visual acuity among the three study populations. Hungarian and Brazilian patients achieved notably higher postoperative visual acuity than the Kosovan group. This disparity may be partly explained by the lack of access to premium intraocular lenses in Kosovo. Furthermore, the surgeons differed in their levels of experience, which also contributed to significant variations in refractive outcomes. Hungarian patients demonstrated superior postoperative distance vision, likely influenced by the greater surgical experience of the operating ophthalmologist.

Our results highlight the significant role that the choice of intraocular lens plays in determining refractive outcomes after cataract surgery. Postoperative visual performance was more than 35% higher in the Hungarian cohort and over 48% higher in the Brazilian group compared with the Kosovan patients.

Optimal postoperative refractive results following cataract surgery depend on highly accurate biometric measurements, access to premium intraocular lenses, greater surgical experience, and the individualized selection of the most suitable IOL for each patient.

7. SUMMARY

Cataract remains a preventable cause of blindness, and phacoemulsification combined with intraocular lens (IOL) implantation represents the standard treatment. With continual improvements in IOL power calculation methods and refinements in surgical techniques, cataract surgery has evolved into a procedure capable of delivering excellent postoperative visual quality, leading to progressively higher patient expectations.

The present study examined differences in ocular biometric characteristics and postoperative refractive performance among cataract patients from Hungary, Kosovo, and Brazil, while accounting for several key determinants of visual outcomes following surgery. A total of 2,047 patients undergoing phacoemulsification and IOL implantation were included, and their biometric profiles together with their 1-month postoperative visual acuity results were assessed. Statistically significant variations were observed in axial length and anterior chamber depth across the three populations. One-month postoperative distance visual acuity was markedly higher in Hungarian (85%) and Brazilian (98%) patients compared with the Kosovan cohort (49.7%).

Fourteen different IOL models were used in Hungary, three of which—AcrySof IQ toric SN6AT, FINEVISION HP (POD F GF), and 677MTY—showed a significant positive influence on visual acuity at 1 month ($p < 0.05$). In Kosovo, where only two monofocal models were available, both AcrySof SA60AT and Akreos ADAPT AO produced statistically significant improvements, with ADAPT AO demonstrating the stronger effect. For the Brazilian group, the AcrySof IQ Vivity lens provided the highest visual benefit ($B = 0.065$, $p < 0.01$), and Tecnis Symfony also yielded a significant impact at the 1% level.

Results highlight the decisive role of accurate biometric evaluation, precise IOL power calculation, and individualized lens selection in achieving superior postoperative vision. The originality of this study lies in its multinational composition and in its analysis of how different IOL models affect postoperative outcomes when stratified by preoperative visual acuity.

8. REFERENCES

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9. BIBLIOGRAPHY OF THE CANDIDATE'S PUBLICATIONS

9.1. Publications related to the thesis

I. **Shoshi, F**.; Shoshi, F.; Xhafa, A.; Nagy, Z.Z. Refractive Outcomes After Cataract Surgery—The Impact of Preoperative Visual Acuity, the Intraocular Lens Model, and the Surgeon's Experience: An Empirical Analysis of Hungarian and Kosovan Patients. *J. Clin. Med. 2024, 13, 7013.* https://doi.org/10.3390/jcm13237013
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II. **Shoshi F,** Messias A, Shoshi F, Pelicano VS, Shoshi A, Nagy ZZ. The Axial Length and Anterior Chamber Depth in Patients with Cataracts: A Study of Hungarian, Kosovan, and Brazilian Populations. *International Journal of Biomedicine. 2025;15(1):101-107.* https://www.ijbm.org/v15i1_16.htm
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9.2. Other related publications

I. Shoshi F, Spahiu K, **Shoshi F.** A Comparative Study on Surgically Induced Astigmatism after Phacoemulsification and Its Correlation with the Central Corneal Thickness. *International Journal of Biomedicine. 2023;13(4):277-280.* *https://www.ijbm.org/v13i4_13.htm*

IF. 0.2

9.3. Other publications

I. Hoxha G, **Shoshi F,** Hoxha FI, Xhafa A, Shoshi F. Timolol 0.5% versus Latanoprost 0.005% as A Single Hypotensive Drug in Glaucoma Patients: A 2-year Follow-up. *International Journal of Biomedicine. 2024;14(4):626-631.* *https://www.ijbm.org/v14i4_15.htm* **IF. 0.2**

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Refractive Outcomes After Cataract Surgery—The Impact of Preoperative Visual Acuity, the Intraocular Lens Model, and the Surgeon's Experience: An Empirical Analysis of Hungarian and Kosovan Patients

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Abstract: Background/Objectives: Phacoemulsification and intraocular lens (IOL) implantation comprise a standard procedure for cataract treatment. However, minimal refractive error remains a determinant of postoperative results. Our study aimed to evaluate the refractive outcomes and the impact of the surgeon's experience and the IOL model on Kosovan and Hungarian patients after cataract surgery. **Methods:** This study included the preoperative and postoperative data of 1417 patients scheduled to undergo cataract surgery with IOL implantation at two centers: the Ophthalmology Department of Semmelweis University, Budapest, Hungary, and the Ophthalmology Department of the University Clinical Center of Kosovo, Prishtina, Kosovo. STATA and SPSS were used for statistical analysis. **Results:** The data of 1001 Hungarian and 416 Kosovan patients were included in this study. There was a statistically significant difference between the groups in the 1-month postoperative best-corrected distance visual acuity (BCDVA) ($p = 0.001$); in the Hungarian patients, the 1-month BCDVA was 85.2%, while in the Kosovan patients, it was 49.6%. Of the 14 different IOLs implanted in the Hungarian patients, the AcrySof IQ toric SN6AT, FineVision HP (POD F GF), and 677MTY IOLs resulted in a statistically significant positive impact on the 1-month postoperative visual acuity ($p < 0.05$). The AcrySof SA60AT and Akreos ADAPT AO, implanted in the Kosovan patients, had a statistically significant positive impact on the 1-month postoperative visual acuity ($p < 0.05$). More extensive surgeon experience had a statistically significant positive impact on postoperative outcomes ($p < 0.00$). **Conclusions:** Multifocal and toric IOLs showed superiority in terms of postoperative outcomes in our study; therefore, we conclude that greater surgeon experience, the availability of premium IOLs, and appropriate IOL selection have a considerable impact on refractive outcomes after cataract surgery.

Keywords: cataract surgery; refractive outcomes; monofocal IOLs; multifocal IOLs; toric IOLs; surgeon's experience

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1. Introduction

Despite the increased prevalence of age-related cataracts due to the acceleration of the aging process [1], especially in low- and middle-income economies [2], they are considered a preventable cause of blindness. Treatment with phacoemulsification and intraocular lens (IOL) implantation is a standard approach, especially in developed countries. With advances in the IOL power calculation formulas and the ongoing perfection of surgical techniques, cataract surgery is considered a procedure that will ensure high-quality post-operative vision for patients [3,4]. The results from the 2004 Survey of Health, Ageing, and Retirement in Europe (SHARE) indicate that persons with visual impairment have a lower quality of life, reading and concentration problems, and difficulty completing other daily tasks, in addition to feeling irritable, fatigued, and sad [5]. The satisfactory outcomes of the surgery are based, not only on increased visual acuity, but also on a better quality of life [6] and independence from eyeglasses [7] or other refractive correction means. Minimal postoperative refractive error is important with all types of IOLs, but it is crucial when premium IOLs, such as multifocal or toric IOLs, are implanted [8], as they are considered the best solution for patients who want to become independent from eyeglasses after cataract surgery [9–12]. The postoperative refraction target is between 0.0 and 0.5 diopter (D). In general, it is expected that 90% of patients have a spherical equivalent (SE) refraction within ±1.00 D of the target refraction [13,14]. These postoperative outcomes are sometimes difficult to achieve when routine cataract surgery is performed; specifically, study results suggest that this postoperative refraction is achieved in 75–90% of cases after routine cataract surgery [6,15–17].

To achieve these goals, precise preoperative assessment, IOL selection and availability, intraoperative complications, surgeon experience, and postoperative follow-up have a major influence. Precise preoperative IOL planning depends on the axial length (AL), corneal power (K), and anterior chamber depth (ACD); a 1 mm error in the AL results in up to a 3 diopter (D) refractive error, and a 1 D error in the corneal power alters the IOL power for 1 D [18]. Despite the refinement of the IOL power calculation formulas, most large refractive errors greater than 2 D occur due to inaccurate preoperative measurements [13]. Artificial intelligence (AI) has played a major role in the diagnosis, management, and treatment of cataracts, especially in biometry and IOL power calculation formulas [19]. AI-generated IOL power calculation formulas have proven to be very promising in predicting postoperative refraction [20]. Studies have found that, of the AI formulas, the Kane formula, which focuses on improving the accuracy at the extremes of the various ocular dimensions, such as AL, K, and ACD, obtains the most accurate results, and its mean absolute error (MAE) was the lowest among the other AI-generated IOL power calculation formulas [21–25].

Despite the advances in the power calculation formulas, the IOLs, as artificial lenses, have no accommodation ability; therefore, most patients receiving a monofocal IOL require postoperative refractive correction to conduct their daily activities [26]. The results of the ASCRS 2016 Young Eye Surgeons survey indicated that there was an increase in the use of toric IOLs among young ophthalmologists because of their positive refractive outcomes [27]. Therefore, despite the ongoing research in this area, our research group studied these two populations for the first time and compared the postoperative outcomes between the patients treated by a surgeon with 24 years of experience and the patients treated by a surgeon with 11 years of experience in phacoemulsification. Moreover, the latter practiced in a center with no available premium IOLs.

The purpose of our study was to evaluate the refractive outcomes and the impact of the IOL model and surgeon experience on postoperative visual acuity in Kosovan and Hungarian patients after cataract surgery and IOL implantation.

2. Materials and Methods

This was a cross-sectional observational multicenter study that included the data of patients scheduled to undergo cataract surgery with IOL implantation at two centers: the Ophthalmology Department of Semmelweis University, Budapest, Hungary, and the Ophthalmology Department of the University Clinical Center of Kosovo, Prishtina, Kosovo. This was a single-surgeon study per center, where all the patients were surgically treated and followed up by the same surgeon in each center. Prof. Dr. Zoltan Zsolt Nagy treated the Hungarian patients, while Dr. Agim Xhafa treated the Kosovan patients. We compared the patients from 2 countries with different levels of development in terms of IOL model availability and phacoemulsification experience to evaluate the impact of these factors on the postoperative outcomes. Prof. Nagy is a surgeon with 24 years of experience, whereas Dr. Xhafa is a surgeon with 11 years of experience in phacoemulsification. All the preoperative measurements were performed using the Lenstar 900 (Haag-Streit, Köniz, Switzerland) biometer. To evaluate the postoperative refractive outcomes, we analyzed 14 different IOL models in the Hungarian patients and 2 IOL models in the Kosovan patients.

2.1. Patient Selection and Data Collection

In total, 1417 cataractous patients were included in the study: 1001 patients from Hungary and 416 patients from Kosovo. The data collection process included the following variables: the patient age, the operated eye (right or left), the lens thickness, the uncorrected preoperative distance visual acuity (UDVA), the best-corrected preoperative distance visual acuity (BCDVA), the 1-month postoperative uncorrected distance visual acuity, the 1-month postoperative best-corrected distance visual acuity (BCDVA), and the IOL model.

The data for each patient were compiled using the patient data management system in each center. All the variables were collected from the patients treated by one surgeon in each center, Dr. Nagy in Hungary with 24 years of experience, and Dr. Xhafa in Kosovo with 11 years. This study only included patients who were diagnosed with cataracts as their only ocular disorder. All the patients who were scheduled to undergo cataract surgery but had other ocular comorbidities, such as corneal disorders or previous corneal surgical procedures, were excluded. Those with glaucoma, amblyopia, or posterior segment disorders, such as diabetic retinopathy, age-related macular degeneration (AMD), macular degeneration, or optic neuropathy, were excluded from the study. Only the patients without any preoperative, intraoperative, or up to 1-month postoperative complications and with a standard deviation < 0.2 mm in the AL measurement for the IOL power calculation were considered. Because we aimed to evaluate the postoperative outcomes based on three factors—preoperative visual acuity, the IOL model, and the surgeon's experience—we excluded all the cases with other comorbidities that could act as confounding factors. To prevent any possible infection, intracameral cefuroxime 1.0 mg/0.1 mL was administered to all the patients following the cataract surgery. Thus, no cases of postoperative endophthalmitis were reported in our study. The data extraction and insertion in our database was completed by the same people in each center to avoid mistakes and mismatches in reporting.

The visual acuity was registered using the decimal system or percentage—hand movement—of 1.0 (0–100%).

This study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the Kosovo Chamber of Doctors (No. 49/2022; date 12 April 2022) and by the Regional Institutional Scientific and Research Ethics Committee at Semmelweis University (SE RKEB 82/2024; Date 14 May 2024).

2.2. Statistical Analysis

Quantitative methods were used to analyze the data. This study included patients from two countries—Hungary (n = 1001) and Kosovo (n = 416).

Descriptive statistics were used to summarize the central tendencies and variability. To analyze the correlation between the variables, we used Pearson's index of correlation, whereas, to measure the impact of the independent variables on the dependent variable, we used multiple linear regression analysis. For the assessment of the group differences, we used a one-way ANOVA. Three levels of statistical significance, 1% ($p < 0.01$), 5% ($p < 0.05$), and 10% ($p < 0.1$), were used to present the statistically significant differences; this enabled us to highlight not only the most robust results (at 1%) but also those that were moderately strong (at 5%), and suggestive trends (at 10%). This layered approach helped distinguish between varying degrees of evidence, making the results easier to interpret and offering a comprehensive view of the statistical significance across different thresholds.

3. Results

3.1. Descriptive Statistics

Table 1 presents the sample size by country. We included the data of 1417 cataractous patients, comprising 1001 (70.64%) Hungarian and 416 (29.36%) Kosovan patients.

Table 1. Sample size.

Country	Sample Size	
	n	%
Hungary	1001	70.64
Kosovo	416	29.36
Total	1417	100

Cataract surgery and IOL implantation in the right eye were performed in 731 patients and in the left eye in 684 patients (Table 2).

Table 2. Operated eye.

Surgery	Hungary		Kosovo		Total
	n	%	*n*	%	*n*
Right Eye	513	51.35	218	52.4	731
Left Eye	486	48.65	198	47.6	684
Total	999	100	416	100	1415

3.2. Results for the Hungarian Patients

Regression analysis was used to determine the impact of the refractive correction on the distance visual acuity of the patients before the surgery. Based on the results presented in Table 3, in general, refractive correction using eyeglasses or contact lenses explained the change in the distance visual acuity of 33.2% of the patients (R-squared = 0.332). This regression was statistically significant based on the following: F-statistics = 5.36 and $p = 0.001$.

Table 3. Regression analysis of the impact of refractive correction on visual acuity before surgery.

BCDVA Preop.	Coef	St.Err.	*t*-Value	*p*-Value	[95% Conf]	[Interval]	Sig
Hyperopic correction	0.01	0.005	3.03	0.006	−0.01	0.011	***
Myopic correction	0.01	0.002	0.57	0.571	−0.006	0.003	
Hyperopic astigmatism	0.02	0.02	0.12	0.903	−0.038	0.043	
Myopic astigmatism	0.12	0.012	2.45	0.017	−0.036	0.012	**
Constant	0.562	0.04	14.07	0	0.484	0.641	***
Mean dependent var		0.543		SD dependent var		0.291	
R-squared		0.332		Number of obs		820	
F-test		5.369		Prob > F		0.001	
Akaike crit. (AIC)		310.429		Bayesian crit. (BIC)		333.976	

*** $p < 0.01$, ** $p < 0.05$; BCDVA preop.—preoperative best-corrected distance acuity.

Based on the coefficient results, the correction in the hyperopic patients had a positive impact on visual acuity (B = 0.01), which was statistically significant ($p = 0.006$). There was also a positive impact on the visual acuity in terms of myopic correction (B = 0.01); however, this was not statistically significant. In the patients with astigmatism, we obtained statistically significant results in cases of myopic astigmatism, where the correction had a high positive impact on visual acuity (B = 0.12) ($p = 0.017$). The impact of the correction on visual acuity was also positive in the cases of hyperopic astigmatism (B = 0.02); however, it was not considered statistically significant.

The preoperative uncorrected distance visual acuity (UDVA preop.), preoperative best-corrected distance visual acuity (BCDVA preop.), 1-month postoperative uncorrected distance visual acuity (UDVA 1 month postop.), the best-corrected visual acuity, and the 1-month postoperative best-corrected distance visual acuity (BCDVA 1 month postop.) in Table 4 show that in the Hungarian patients, the preoperative UDVA was 24.7% or 0.25 in decimal units, while the preoperative BCDVA was 54.4% or 0.5 in decimal units. The visual acuity improved significantly after surgery, with a mean of 77.9% or 0.8 of the UDVA and a mean of 85.2% or 0.85 of the BCDVA. Compared to the uncorrected distance visual acuity and the best-corrected distance visual acuity before cataract surgery, our results indicated that the improvement in visual acuity after surgery was significant and that the refractive outcomes were positive.

Table 4. Preoperative visual acuity and 1-month postoperative visual acuity in Hungarian patients.

Variable	Obs	Mean	Std. Dev.	Min	Max
UDVA preop.	911	0.247	0.22	0	0.9
BCDVA preop.	828	0.544	0.291	0.1	1
UDVA 1 month postop.	936	0.779	0.286	0.1	1
BCDVA 1 month postop.	948	0.852	0.258	0.1	1

UDVA preop.—preoperative uncorrected distance visual acuity; BCDVA preop.—preoperative best-corrected distance acuity; UDVA 1 month postop.—1-month postoperative uncorrected distance visual acuity; BCDVA 1 month postop.—1-month postoperative best-corrected distance visual acuity.

To analyze the correlation between the variables, we used Pearson's correlation (Table 5). According to our findings, there was a negative correlation (r = −0.096), which is statistically significant at the 1% level (p = 0.003), between the lens thickness and the distance visual acuity after surgery; therefore, the greater the lens thickness before surgery, the lower the postoperative visual outcome.

Table 5. Lens thickness and 1-month postoperative best-corrected distance visual acuity.

Variables		UDVA Preop.	BCVA Preop.	BCVA 1 m Postop.	Lens Thickness	Lens Type
UDVA preop.	Cor	1	0477 **	0.334 **	0.019	0.084 *
	Sig		0.000	0.000	0.565	0.012
	N	911	763	881	911	911
BCDVA preop.	Cor	0.477 **	1	0.402 **	−0.038	0.162 **
	Sig	0.000		0.000	0.273	0.000
	N	763	828	816	828	828
BCDVA 1 month postop.	Cor	0.334 **	0.402 **	1	−0.096 **	0.033
	Sig	0.000	0.000		0.003	0.308
	N	881	816	948	948	948
Lens thickness	Cor	0.019	−0.038	−0.096 **	1	−0.048
	Sig	0.565	0.273	0.003		0.129
	N	911	828	948	1001	1001
IOL model	Cor	0.084 *	0.162 **	0.033	−0.048	1
	Sig	0.012	0.000	0.308	0.129	
	N	911	828	948	1001	1001

Note: ** The correlation is significant at the 0.01 level (1%). * The correlation is significant at the 0.05 level (5%). BCDVA preop.—preoperative best-corrected distance visual acuity.

To assess the impact of the 14 implanted IOL models (Figure 1) on the postoperative uncorrected visual acuity and best-corrected visual acuity, we used regression analysis. All the subjects were divided into three groups based on the preoperative distance visual acuity, as follows: Group 1—preoperative UDVA = 0–0.33 (0–33%); Group 2—preoperative UDVA = 0.34–0.66 (34–66%); Group 3–preoperative UDVA = 0.67–1.0 (67–100%). We then analyzed the impact of each IOL model on the visual acuity improvement 1 month after the surgery without correction (UDVA 1 month postop.) and 1 month after the surgery with correction (BCDVA 1 month postop.) for each of the three groups.

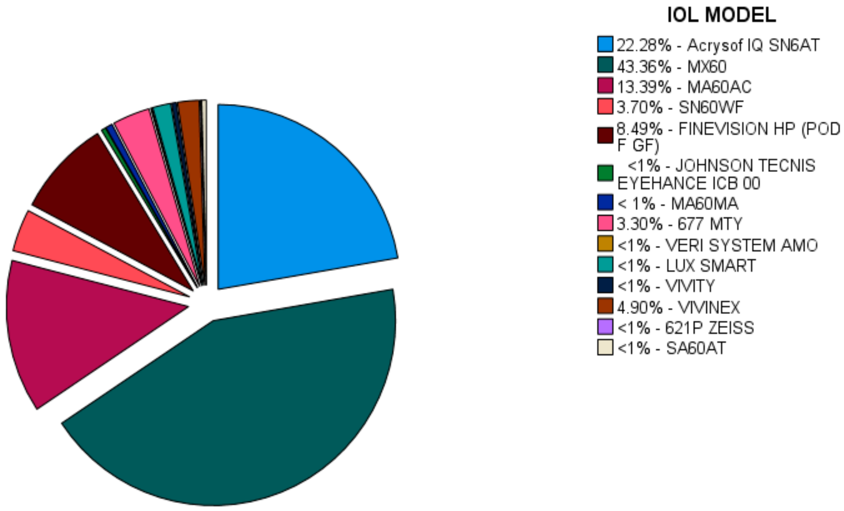

Figure 1. Intraocular lens (IOL) models in Hungarian patients.

To evaluate the impact of the IOL model on the postoperative visual outcomes, we divided our patients into three groups based on the preoperative visual acuity: Group 1—0–33% (hand movement—0.33 preoperative visual acuity); Group 2—34–66% (0.34–0.66 preoperative visual acuity); Group 3—67–100% (0.67–1.0 preoperative visual acuity). Our results showed that the AcrySof IQ toric SN6AT (Alcon, Fort Worth, TX, USA) IOL had a statistically significant positive impact on all the groups ($p < 0.05$), with the highest positive impact (B = 0.043) on the 1-month postoperative visual acuity of the second group of patients (0.34–0.6 preoperative visual acuity). However, in all three groups of patients, the AcrySof IQ toric SN6AT IOL had a statistically significant positive impact on the postoperative outcomes ($p < 0.05$); the 1-month uncorrected postoperative visual acuity had a positive coefficient of B = 0.16, while the 1-month best-corrected postoperative visual acuity had a positive coefficient of B = 0.14.

Another IOL model with a significant positive impact on the postoperative visual acuity was found to be the FineVision HP (POD F GF) IOL (BVI, Waltham, MA, USA), similar to the AcrySof IQ toric SN6AT IOL. The highest positive impact was found to be on the second group of patients (B = 0.323). In terms of the total impact on the three groups, the FineVision HP (POD F GF) IOL was found to have a positive impact (B = 0.133) on the uncorrected 1-month postoperative distance visual acuity and an impact of B = 0.0914 on the 1-month best-corrected distance visual acuity, which was also statistically significant ($p < 0.05$).

The IOL used for most of the patients (43.36%), enVista MX-60 (Bausch and Lomb, Bridgewater, NJ, USA), exhibited an overall positive impact on the visual acuity in all the patients. The positive impact on the 1-month uncorrected distance visual acuity was B = 0.0411, whereas the 1-month best-corrected distance visual acuity was B = 0.0245. However, this was not considered statistically significant.

The regression analysis results also indicated the positive impact of the 677MTY (Medicontur Medical Engineering Ltd., Zsámbék, Hungary) IOL on postoperative visual outcomes. In all the groups of patients, the 677MTY IOL had a statistically significant positive impact at the level of 5% ($p < 0.05$), with B = 0.179 for the 1-month uncorrected distance visual acuity and B = 0.139 for the 1-month best-corrected distance visual acuity (Table 6).

Table 6. Intraocular lens (IOL) model and postoperative visual acuity.

Lens Type	**UDVA 1 m postop.**	**BCDVA 1 m postop.**	**UDVA 1 m postop.**	**BCDVA 1 m postop.**	**UDVA 1 m postop.**	**BCDVA 1 m postop.**	**UDVA 1 m postop.**	**BCDVA 1 m postop.**
	0–33 * (Hand Movement—0.33)		**34–66 * (0.34–0.66)**		**67–100 * (0.67–1.0)**		**Total**	**Total**
SN6AT	0.034 **	0.032	0.043 **	0.03 **	0.008 ***	0.002 **	0.16 **	0.014 **
	(2.67)	(1.14)	(2.12)	(2.22)	(4.53)	(1.99)	(2.14)	(2.85)
MX60	0.0428	0.0168	0.136	0.0521	0.115	0.0594	0.0411	0.0245
	(1.38)	(0.58)	(1.38)	(0.51)	(1.97)	(1.03)	(1.81)	(1.19)
MA60AC	−0.177 ***	−0.0924 *	−0.177	−0.0255	−0.223 **	−0.08	−0.169 ***	−0.0852 **
	(−4.41)	(−2.44)	(−1.77)	(−0.25)	(−3.24)	(−1.20)	(−5.44)	(−3.04)
SN60WF	−0.0564	−0.0736	0.323	0.233	0.133	0.111	−0.073	−0.0658
	(−0.88)	(−1.24)	(1.62)	(1.1)	(1.4)	(1.18)	(−1.51)	(−1.51)
PODFGF PHYSIOL	0.164 **	0.117 *	0.323 *	0.233	0.175 *	0.121	0.133 ***	0.0914 **
	(3.24)	(2.44)	(2.33)	(1.6)	(2.49)	(1.71)	(3.91)	(2.93)
JOHNSON JOHNSON TECNIS EYEHANCE ICB 00	−0.0184	0.188	0.323	0.233	0.204	0.14	0.145	0.146
	(−0.06)	(0.67)	(1.62)	(1.1)	(1.26)	(0.86)	(1.1)	(1.21)
MA60MA	−0.335 **	−0.345 **					−0.397 ***	−0.388 ***
	(−2.74)	(−2.97)					(−3.69)	(−3.94)
677MTY	0.219 **	0.182 *	0.256	0.217	0.16	0.129	0.179 ***	0.139 **
	(2.83)	(2.47)	(1.97)	(1.59)	(1.85)	(1.5)	(3.62)	(3.09)
VERI SYSTEM AMO	−0.0184							
	(−0.06)							
LUX SMART	0.0482	−0.0454	0.223	0.233	0.144	0.12	0.184 *	0.139 *
	(0.28)	(−0.28)	(1.12)	(1.1)	(1.33)	(1.11)	(2.56)	(2.11)
VIVITY	0.182	0.088					0.12	0.0457
	(1.22)	(0.62)					(0.91)	(0.38)
VIVINEX	−0.0851	−0.0787	−0.527	−0.167	−0.646 **	−0.26	−0.0442	−0.0385
	(−0.84)	(−0.82)	(−1.93)	(−0.78)	(−2.88)	(−1.60)	(−0.69)	(−0.68)
621P ZEISS		−0.312					−0.28	−0.354 *
		(−1.92)					(−1.85)	(−2.56)
SA60AT	−0.218						−0.18	−0.254
	(−1.28)						(−0.69)	(−1.07)
Cons	0.718 ***	0.812 ***	0.677 ***	0.767 ***	0.796 ***	0.860 ***	0.780 ***	0.854 ***
	(28.27)	(34.14)	(9.28)	(10.5)	(17.4)	(19.42)	(42.55)	(51.8)
N	612	619	62	67	118	122	883	895

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. UDVA 1 m postop.—1-month postoperative uncorrected distance visual acuity, BCDVA 1 m postop.—1-month postoperative best-corrected visual acuity, Visual acuity in percentage (%).

3.3. Results for Kosovan Patients

Table 7 presents the preoperative distance visual acuity and the 1-month postoperative distance visual acuity of the Kosovan subjects. The mean preoperative distance visual acuity in these patients was 15% or 0.15 in decimal units, whereas the mean uncorrected

1-month postoperative distance visual acuity increased to 44% or 0.4 in decimal units and the best-corrected distance visual acuity increased to 49.6% or 0.5 in decimal units.

Table 7. Preoperative and postoperative distance visual acuity.

Variable	Obs	Mean	Std. Dev.	Min	Max
Visual acuity preop.	407	0.15	0.424	0	8
UDVA 1 month postop.	397	0.44	0.216	0.1	1
BCDVA 1 month postop.	397	0.496	0.229	0.1	1

UDVA 1 month postop.—1-month postoperative uncorrected distance visual acuity, BCDVA 1 month postop.—1-month postoperative best-corrected distance visual acuity.

In contrast to that observed for the Hungarian patients, there was a positive correlation (r = 0.030) between the lens thickness (LT) and the postoperative visual acuity in the Kosovan patients (Table 8); however, this was not statistically significant.

Table 8. Lens thickness and postoperative distance visual acuity.

Variables		UDVA Preop.	UDVA 1-Month Postop.	Lens Thickness	Lens Type
Visual acuity preop.	Cor	1	0.608 **	0.076	−0.051
	Sig		0.000	0.126	0.305
	N	407	389	407	407
Visual acuity 1 month postop.	Cor	0.608 **	1	0.030	−0.067
	Sig	0.000		0.556	0.184
	N	389	397	397	397
LT	Cor	0.076	0.030	1	0.076
	Sig	0.126	0.556		0.124
	N	407	397	416	416
Lens type	Cor	−0.051	−0.067	0.076	1
	Sig	0.305	0.184	0.124	
	N	407	397	416	416

Note: ** The correlation is significant at the 0.01 level (1%). UDVA preop.—Preoperative uncorrected distance visual acuity; UDVA 1 month postop.—1-month postoperative uncorrected distance visual acuity.

The Kosovan patients were treated with one of the two monofocal IOL types, AcrySof SA60AT IOL (Alcon, Fort Worth, TX, USA) and Akreos ADAPT AO (Bausch and Lomb, Bridgewater, NJ, USA), available at the study center. Akreos ADAPT AO was used in 64.18% of the patients and AcrySof SA60AT was used in 35.82% of the cases (Figure 2).

To evaluate the impact of the IOL model on the postoperative visual acuity, we performed a regression analysis. All the patients were divided into three groups based on the preoperative visual acuity. The same division was made as that for the Hungarian patients: Group 1—preoperative UDVA = 0–0.33 (0–33%); Group 2—preoperative UDVA = 0.34–0.66 (34–66%); Group 3—preoperative UDVA = 0.67–1.0 (67–100%). Visual acuity was measured 1 month after surgery in all three groups.

The AcrySof SA60AT IOL was used in 35.82% of the patients and was found to have an overall positive impact on the postoperative distance visual acuity in all three groups. However, there was a higher positive impact on the postoperative distance visual acuity of the patients in the second group, who had a preoperative UDVA from 0.34 to 0.66 (B = 0.321), which was statistically significant.

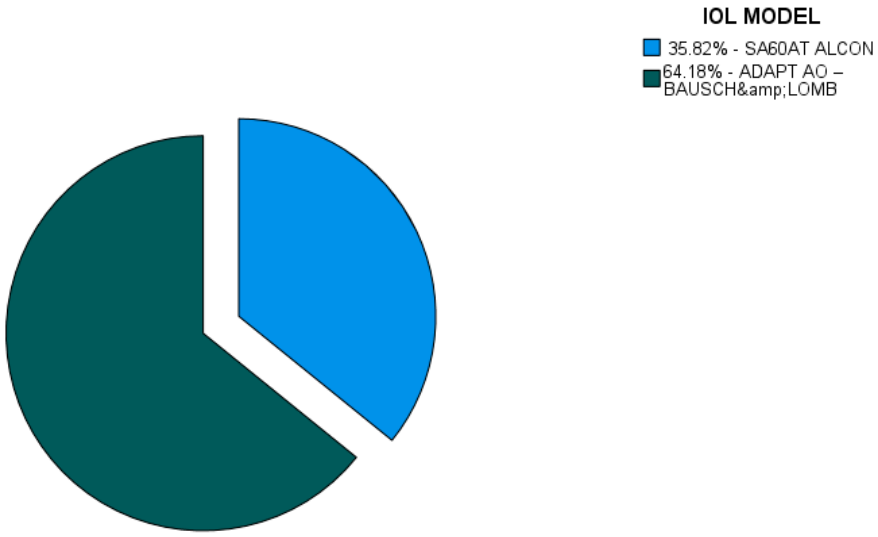

Figure 2. Intraocular lens (IOL) model in Kosovan patients.

The other IOL model, Akreos ADAPT AO, was used in 64.18% of the cases, and it was found to have an overall positive impact on the postoperative visual outcomes in all the groups. Similarly to AcrySof SA60AT, Akreos ADAPT AO also resulted in a higher positive impact (B = 0.408) on the patients, whose preoperative distance visual acuity was between 34% and 66%, which was statistically significant at the 5% level. Even though both the IOL models had a statistically significant positive impact on the postoperative distance visual acuity, Akreos ADAPT AO was considered to have a higher positive impact (B = 0.408) than AcrySof SA60AT (Table 9).

Table 9. Intraocular lens (IOL) model and postoperative distance visual acuity.

Lens Type	UDVA 1 Month Postop.	UDVA 1 Month Postop.	UDVA 1 Month Postop.	UDVA 1 Month Postop.
	0–33 ** (Hand Movement-0.33)	34–66 ** (0.34–0.66)	67–100 ** (0.67–1.0)	Total
AcrySof SA60AT	0.0152	0.321 *	0.101	0.0242
	(1.78)	(1.81)	(0.53)	(1.14)
Akreos ADAPT AO	0.0262	0.408 **	0.11	0.0309
	(1.30)	(2.20)	(0.62)	(1.37)
Cons	0.415 ***	0.575 **	0.743 ***	0.459 ***
	−25.74	−4.74	−5.58	−25.57
N	344	7	16	397

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. UDVA 1 month postop.—1-month postoperative uncorrected visual acuity, Visual acuity in percentage (%).

3.4. Comparison Between Centers

Table 10 shows the results of the statistically significant differences in the LT between the Kosovan and the Hungarian patients using a one-way ANOVA. The mean LT in the Hungarian patients was 4.40 mm, and that in the Kosovan patients was 4.30 mm. The one-way ANOVA revealed statistically significant differences in the mean LT between the Hungarian and Kosovan patients (F-statistics = 10.13 and $p = 0.001$).

Table 10. Statistically significant differences in lens thickness.

Lens Thickness	Posterior			95% Credible Interval		F	Sig.
	Mode	Mean	Variance	Lower Bound	Upper Bound		
Hungary	4.40	4.400	0.000	4.36	4.43	10.13	0.001
Kosovo	4.30	4.302	0.001	4.25	4.35		

Table 11 presents the preoperative UDVA, 1-month postoperative UDVA, and 1-month postoperative BCDVA for all the patients in the two centers. Based on the complete data available from the Hungarian patients, the preoperative UDVA was 24.7% or 0.25, and in the Kosovan patients, the preoperative UDVA was 15% or 0.15. The UDVA improved to 77.92% or 0.8 and the BCDVA improved to 85.21% or 0.85 one month after the cataract surgery and IOL implantation in the Hungarian patients. Improvements in the postoperative visual acuity were also observed in the Kosovan patients: the 1-month postoperative UDVA improved to 43.97% or 0.4, and the 1-month postoperative BCDVA improved to 49.57% or 0.5.

Table 11. Preoperative and postoperative visual acuity—Kosovo and Hungary.

Country	Variable	Obs	Mean	Std. Dev.	Min	Max
Hungary	UDVA	911	0.247	0.22	0	0.9
Kosovo	preop.	407	0.15	0.424	0	8
Hungary	UDVA 1-month	936	0.7792	0.28673	0.10	1.00
Kosovo	postop.	397	0.4397	0.21586	0.10	1.00
Hungary	BCDVA 1-month	948	0.8521	0.25827	0.10	1.00
Kosovo	postop.	397	0.4957	0.22920	0.10	1.00

UDVA preop.—Preoperative uncorrected distance visual acuity, UDVA 1 month postop.—1-month postoperative uncorrected distance visual acuity, BCDVA 1 month postop.—1-month postoperative best-corrected distance visual acuity.

Statistically significant differences between the two groups of patients were found for the 1-month BCDVA. The BCDVA in the Hungarian patients was 85.2%, whereas it was 49.6% in the Kosovan patients.

Based on the one-way ANOVA results with F-statistics of 568.26 and $p = 0.001$, we can conclude that there is a statistically significant difference in the 1-month postoperative distance visual acuity between the patients from both of the countries (Table 12, Figure 3).

Table 12. One-way ANOVA for statistically significant differences.

Country	BCVA	Mode	Mean	df	F	Sig.
Hungary	Between Groups	0.852	0.852	2	568.26	0.001
Kosovo	Within Groups	0.496	0.496	1343		

Table 13 presents the results of the impact of the surgeon's experience on the postoperative outcomes. There was a statistically significant difference in the postoperative results based on the surgeon's experience. The preoperative UDVA in the Kosovan patients where the surgeon had 11 years of experience in phacoemulsification was 0.15 or 15%, whereas the UDVA in the Hungarian patients before the surgery was 0.25. Based on Table 13, there were statistically significant differences in the 1-month postoperative outcomes between the two groups, according to the particular surgeon. The 1-month postoperative UDVA in the patients treated by the surgeon with 11 years of experience was 0.4 (CI = 0.414–0.467) and the BCDVA = 0.5 or 50% (CI = 0.472–0.521). On the other hand, in the Hungarian patients, the 1-month postoperative outcomes showed a much higher visual acuity, both corrected and uncorrected; the 1-month postoperative UDVA = 0.8 or 80% and the BCDVA = 0.85 or 85%. Based on the p-value, where $p = 0.000$, there was a statistically significant difference in the postoperative outcomes based on the surgeon's experience in phacoemulsification.

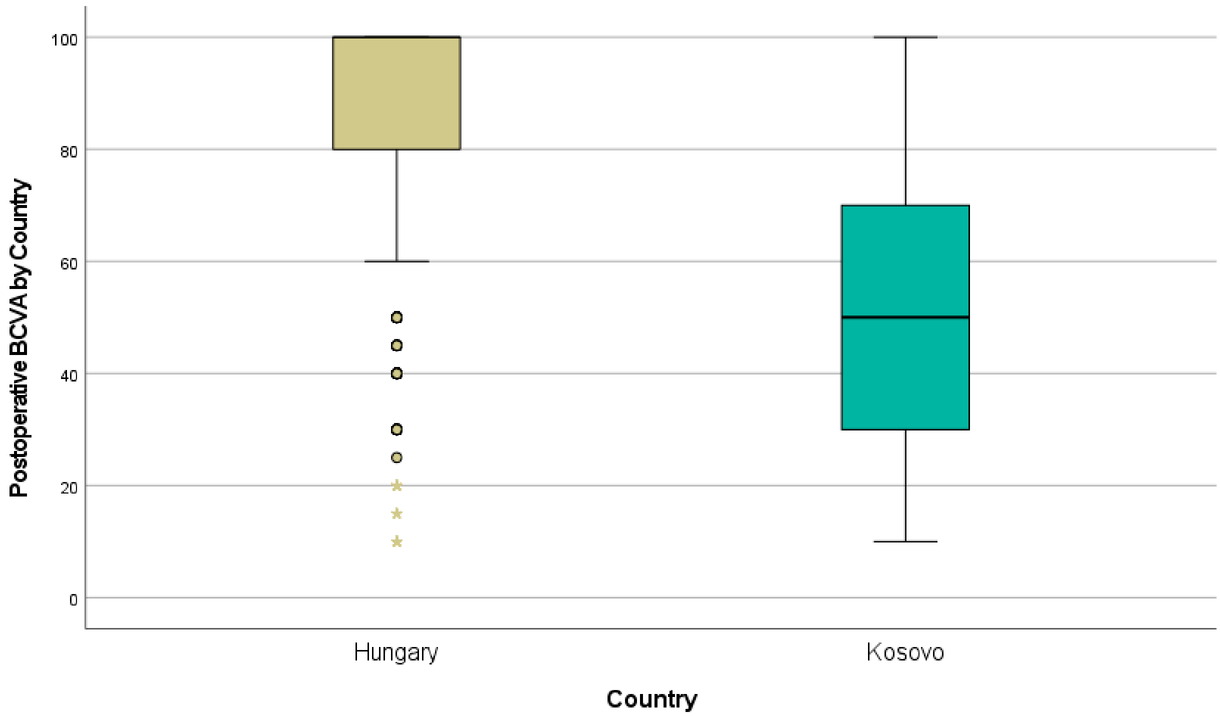

Figure 3. Box plot for statistically significant differences in visual acuity. ⋆ Extreme outliers, which are data points even farther from the rest of the dataset compared to regular outliers. These are values that fall beyond 3 times from the nearest quartile. ∘ Outliers in the dataset for Hungary. These values deviate notably from the majority of data points because they are much lower compared rest of the data.

Table 13. Statistically significant differences in the postoperative outcomes based on the surgeon's experience.

UDVA Preop.	**Posterior**			**95% Credible Interval**		**Significant Differences**
	Mode	**Mean**	**Variance**	**Lower Bound**	**Upper Bound**	
11 Years Experience	0.150	0.150	0.000	0.121	0.180	$p = 0.000$
24 Years Experience	0.247	0.247	0.000	0.227	0.266	
UDVA 1 month postop.	**Posterior**			**95% Credible Interval**		**Significant Differences**
	Mode	**Mean**	**Variance**	**Lower Bound**	**Upper Bound**	
11 Years Experience	0.440	0.440	0.000	0.414	0.467	$p = 0.000$
24 Years Experience	0.779	0.779	0.000	0.762	0.796	
BCDVA 1 month postop.	**Posterior**			**95% Credible Interval**		**Significant Differences**
	Mode	**Mean**	**Variance**	**Lower Bound**	**Upper Bound**	
11 Years Experience	0.496	0.496	0.000	0.472	0.521	$p = 0.000$
24 Years Experience	0.852	0.852	0.000	0.836	0.868	

UDVA preop.—Preoperative uncorrected distance visual acuity, UDVA 1 month postop.—1-month postoperative uncorrected distance visual acuity, BCDVA 1 month postop.—1-month postoperative best-corrected distance visual acuity.

4. Discussion

The outcomes after cataract surgery are determined by many factors, most of which should be assessed preoperatively. To minimize the MAE owing to the lack of access to the AI-based IOL power calculation formulas for the IOL planning, we included only the IOL calculation data where the SD in the axial length measurement was <0.2 mm. The refractive outcomes after cataract surgery depend on the accuracy of preoperative biometric data, such as AL, K, and ACD; therefore, inaccuracy in their measurement can contribute to 36%, 22%, and 42% of errors, respectively [28]. Another important factor is the accuracy of the IOL power calculation formula; the study of Ferrara et al. found that AI-based formulas and the formulas based on the theory of vergence proved to be more accurate in the IOL power calculation in corneas with low mean keratometry [29].

In our study, we found that the uncorrected postoperative distance visual acuity in the Kosovan patients was only 0.4 or 44% compared to the preoperative visual acuity, which was 0.15 or 15%. Another important aspect of the refractive outcomes was the analysis we conducted of the impact of the IOL model on the postoperative visual acuity of the patients, grouping our patients into three different groups based on their preoperative distance (decimal) visual acuity.

Owing to the unavailability of certain IOL models and premium IOLs, the Kosovan patients were treated with only two types of IOLs: the SA60AT IOL and the ADAPT AO. The superiority of multifocal IOLs has been demonstrated based on the results of many studies [30,31]. Even though both monofocal IOLs had a statistically significant positive impact on the postoperative visual acuity at the 5% level in our Kosovan patients, with ADAPT AO having a higher positive impact (B = 0.408) than SA60AT, the postoperative visual acuity was significantly different between the two groups of patients treated at the two different centers.

Of the 14 IOL models implanted in the Hungarian patients, three had a significant impact on the postoperative distance visual acuity. Our results showed that the AcrySof IQ toric SN6AT IOL (Alcon Laboratories, Inc.) had a statistically significant positive impact on all the groups ($p < 0.05$), with the highest positive impact (B = 0.043) on the second group of patients, who had a 0.34–0.6 preoperative distance visual acuity. The AcrySof IQ toric SN6AT IOL has been widely researched, and many studies found that it has a positive effect on the correction of pre-existing astigmatism [32–34]. Scialdone A. et al. [35], in their comparative study of two aspheric toric IOLs, concluded that the patients who were implanted with the AcrySof IQ toric SN6AT IOL were significantly closer to emmetropia postoperatively. Significant positive impact on the postoperative UDVA and BCDVA were also obtained in the cases where FineVision IOL was used. Similarly to the AcrySof IQ toric SN6AT IOL, the highest positive impact was found in the group of patients with 0.34–0.6 preoperative visual acuity (B = 0.323). In terms of the total impact on the three groups, the FineVision HP (POD F GF) IOL resulted in the positive impact of B = 0.133 on the 1-month postoperative distance visual acuity and an impact of B = 0.0914, which was also statistically significant ($p < 0.05$). The FineVision HP (POD F GF) trifocal hydrophobic glistening-free lens also had positive outcomes [36–39] in other studies.

The enVista MX-60 IOL showed an overall positive impact on the visual acuity in all the patients; the positive impact on the 1-month postoperative distance visual acuity was B = 0.0411, whereas the 1-month postoperative best-corrected distance visual acuity was B = 0.0245. Even though this impact was not statistically significant in our study, in the study conducted by C. Ton Van et al. [40], the incidence of posterior capsular opacification in the cases treated with the enVista MX-60 IOL was only 2.2%, and no glistening was observed. These results confirm the safe profile of this IOL.

The 1-month postoperative distance visual acuity was 0.85 or 85.21% in the Hungarian patients, which was much higher and statistically significant compared to the Kosovan patients. This difference in postoperative outcomes can be attributed to several factors, such as the limited availability of IOL models, the lack of multifocal and toric IOLs, and the economic barriers to timely cataract surgery. Similarly, Zhijian Li et al., in their Heilongjiang Eye Study [41], concluded that the visual outcomes after cataract surgery in northern China were poor and mainly due to economic barriers to cataract surgery uptake. The results of a study from the Swedish National Cataract Register [42] on the factors that might impact postoperative refraction showed that the mean absolute prediction error was related to the study year and that it decreased the more recently the surgery was performed, a result that could be attributed to improvements in the technique and equipment. However, another factor that had an impact on the mean absolute prediction error, according to the results of their study, was preoperative visual acuity. These results correspond to our results on the postoperative visual acuity of Kosovan subjects (44%) compared to Hungarian subjects (85.2%). The lower visual acuity in Kosovan patients can also be explained by the shorter experience with the optical biometer LenStar900 and IOL planning, the lack of experience in the application of premium IOLs, and the overall shorter experience of the surgeon. J. M. Sparrow et al. [43] reported on the importance of both the preoperative factors associated with intraoperative complications and also the importance of having skillful and highly experienced surgeons to manage these cases. In addition, the Auckland Cataract Study [44] confirmed that the risk of intraoperative complications increases when the preoperative risk scores are higher. Furthermore, the findings reported from different studies [45–47] emphasize the relationship between surgical complications and worse postoperative visual outcomes. Similarly to the findings in the literature, our results emphasize the importance of the surgeon's experience in postoperative outcomes. There was a statistically significant difference in the postoperative outcomes between the Hungarian patients treated by a surgeon with 24 years of experience and the Kosovan patients treated by a surgeon with 11 years of experience. The findings of our study align with the findings reported by Haripriya et al. [48] where the complications in the cases with highly experienced surgeons were lower than those in the cases treated by less experienced surgeons.

5. Conclusions

Our findings indicate the importance of the IOL model and the surgeon's experience in the refractive outcomes following cataract surgery. The postoperative outcomes were more than 35% higher in the Hungarian patients than in the Kosovan ones. Our results suggest that better postoperative outcomes are related to the greater experience of the surgeon; in our study, the Hungarian patients treated by a surgeon with 24 years of experience had much more positive postoperative outcomes compared to the Kosovan patients who were treated by a surgeon with fewer years of experience. In conclusion, the availability of premium IOLs, the surgeon's experience, and the selection of an appropriate IOL based on the individual patients' needs play a crucial role in better refractive outcomes after cataract surgery.

6. Limitations of the Study

To our best knowledge, this study is the first to compare the patients from Kosovo and Hungary. However, several limitations should be taken into consideration in the interpretation of our findings:

Unequal access to premium IOLs: Kosovan patients had no access to premium IOLs (multifocal and toric) and were therefore treated with only one of the two available monofocal IOLs. On the other hand, the Hungarian patients had access to a wider range of IOL models—14 models in total. This disparity in IOL type could significantly influence the refractive outcomes and patient satisfaction. Therefore, the refractive outcomes were statistically significant between the two groups;

Variation in surgeon experience: The Hungarian surgeon had 24 years of experience, whereas the Kosovan surgeon had 11 years, resulting in statistically significant differences between the two groups;

IOL power calculation formulas: This study utilized non-AI-based IOL power calculation formulas. Therefore, the use of AI-based IOL power calculation formulas in future research is expected to improve the accuracy of IOL power determination and postoperative refractive outcomes.

Author Contributions: Conceptualization, investigation, methodology, data curation and statistical analysis, and manuscript preparation: F.S. (Flaka Shoshi); data collection and curation, visualization, and review: F.S. (Fitore Shoshi); literature review and data collection: A.X.; supervision, project administration, conceptualization, methodology, formal analysis, review, and editing: Z.Z.N. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: This study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the Kosovo Chamber of Doctors (No. 49/2022; date: 12 April 2022) and by the Regional Institutional Scientific and Research Ethics Committee at Semmelweis University (SE RKEB 82/2024; date: 14 May 2024).

Informed Consent Statement: Informed consent was obtained from all the subjects.

Data Availability Statement: All research data and results are available upon request to the corresponding author, Flaka Shoshi; e-mail: flaka.shoshi@phd.semmelweis.hu.

Conflicts of Interest: The authors declare no conflicts of interest.

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ORIGINAL ARTICLE

Ophthalmology

The Axial Length and Anterior Chamber Depth in Patients with Cataracts: A Study of Hungarian, Kosovan, and Brazilian Populations

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Abstract

Background: Two crucial parameters to consider when calculating the intra-ocular lens are the axial length (AL) and anterior chamber depth (ACD). This study aims to compare the AL and ACD between Hungarian, Kosovan, and Brazilian patients with cataracts and to predict the possible factors that play a role in these differences.

Methods and Results: This comparative cross-sectional observational study included pre-operative biometric parameters, AL and ACD, measured with LenStar900 in patients from Hungary, Kosovo, and Brazil who were scheduled to undergo cataract surgery. We performed biometric measurements of 2043 eyes of patients with cataracts. There was a statistically significant weak negative correlation between age and both biometric parameters (AL and ACD) in Hungarian subjects (P=0.000), while in Kosovar subjects, a statistically significant weak negative correlation was observed only between age and ACD. Unfortunately, this type of analysis was not conducted among Brazilian subjects.

A one-way ANOVA with Tukey HSD test showed a statistically significant difference in AL between the Hungarian and Kosovan patients (P=0.0000) and Hungarian and Brazilian patients (P=0.0002); however, no statistically significant difference was found in AL between the Kosovan and Brazilian patients (P=0.7284). There was no statistically significant difference in ACD values between all three groups (P=0.5064).

Conclusion: There are statistically significant differences in the AL biometric parameter between the three groups of patients, which could be attributed to demographic and social factors specific to each group. Furthermore, this is the first study to include patients from these three countries.(**International Journal of Biomedicine. 2025;15(1):101-107.**)

Keywords: Intra-ocular lens • axial length • anterior chamber depth • biometry • cataracts • LenStar 900

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Introduction

The eye is an optical system that, explained in a simplified way, consists of the cornea, crystalline lens, and vitreous body; therefore, any change in the components of this optical system causes an alteration in the eye's refractive power.[1] Among other contributing factors, demographic features such as age and age-related diseases, such as cataracts, play a major role in the alteration of the biometric factors of the eye, and other socioeconomic factors should also be considered.

Cataracts are accountable for visual impairment and blindness worldwide.[2-4] Blindness rates due to cataracts vary by country; however, 90% of the total disability-adjusted life years in developing countries is attributed to cataracts.[5]

Despite the ongoing advances in science, cataracts remain the leading cause of vision loss in middle- and low-income countries, causing 50% of blindness cases and 5% in developed countries.[6] Cataract is the ocular pathology with the highest prevalence in people over 65 and is considered a leading cause of preventable blindness worldwide;[7] cataract extraction with intra-ocular lens (IOL) implantation is perhaps the most effective surgical procedure. Currently, considering the advances in cataract treatment, patients expect more than just removing the opacified crystalline lens. Therefore, for better post-operative refractive outcomes, it is crucial to analyze and assess the parameters of the anterior segment of the eye thoroughly and precisely. One of the most important biometric parameters of the eye is the axial length (AL), which represents the length of the eyeball from front to back and changes with age. A newborn's eye has an AL of 16 mm, and it increases to up to 24–25 mm;[8,9] a normal AL is in the range of 22 mm–25 mm.[10]

Although AL is a crucial measurement when investigating eye growth and development, advances in ocular biometry have added valuable supplementary measures that provide a more comprehensive point of view. Research into ocular biometry has shed light on the relationship between AL and other biometry parameters in myopic eyes.[11,12]

Different refractive error variations in older adults aged 50 years or above are mostly influenced by variations in AL and crystalline lens refractive power, followed by variations in corneal refractive power and, to a minor degree, by variations in lens thickness and anterior chamber depth (ACD).[13,14] Calculating an intraocular lens (IOL) with an appropriate power lowers the degree of post-operative refractive error; thus, IOL planning requires high-precision measurements of biometric parameters. As ophthalmology advances, the need for precise ocular parameters increases. One crucial biometric parameter of the eye is the AL, which is commonly needed for intra-ocular lens power calculation before cataract and refractive surgery.[15,16] An accurate evaluation of ACD (ACD—the measurement from the anterior surface of the cornea to the anterior surface of the crystalline lens) is also critical when planning procedures utilizing either a phakic or pseudophakic intra-ocular lens (IOL).[17] The anterior chamber (ACD) is an important parameter in intra-ocular lens (IOL) power formulas to predict the appropriate IOL power. It is also critically important for the Haigis formula, which only uses AL and ACD to predict the effective lens position (ELP).[18-20] Furthermore, the pre-operative ACD is considered a crucial component in the IOL calculation process since an increase in the AL causes the ACD to increase accordingly.[21]

In search of higher precision and better post-operative refractive outcomes, cataract surgeons choose to work with modern biometric devices. Certain modern biometric devices have become the preferred choice among cataract surgeons because they can produce high-precision measurements and due to the possibility of capturing multiple biometric dimensions of the eye. The Lenstar LS 900 (Haag–Streit AG, Köeniz, Switzerland) is used by many surgeons since it is an optical low-coherence refractometry instrument that captures the AL, white-to-white (WTW) distance, central corneal thickness (CCT), aqueous depth (AD; the distance between the corneal endothelium and anterior lens capsule), ACD (the distance between the corneal epithelium and anterior lens capsule), crystalline lens thickness, and keratometric values (K) in a single measurement.[22,23]

However, even with modern biometry and continuous improvements in surgical techniques, intra-ocular lenses (IOLs), and IOL power formulas, the refractive outcomes in approximately 5% of eyes remain more than 1.0 diopter (D) from the intended target.[24,25] Furthermore, the surge in refractive surgery in recent years has led to the discovery of many patients with a shallow ACD at a younger age.[26] Studies have shown that the biometric parameters of the eye, such as AL and ACD, can be influenced by many demographic and socioeconomic factors such as race, ethnicity, and lifestyle. Therefore, the differences in biometric parameters among different populations could probably explain the differences in refractive errors in each population.

This study aims to compare the AL and ACD between Hungarian, Kosovan, and Brazilian patients with cataracts and to predict the possible factors that play a role in these differences.

Materials and Methods

This comparative cross-sectional observational study included consecutive patients with cataracts from three countries (Hungary, Kosovo, and Brazil) who were scheduled to undergo cataract surgery between 2020 and 2023. Patients' biometric data were collected using the biometry reports of patients appointed for cataract surgery in the Department of Ophthalmology of Semmelweis University in Budapest, Hungary; the Department of Ophthalmology of the University Clinical Center of Kosovo in Prishtina, Republic of Kosovo; and the Department of Ophthalmology of the Faculty of Medicine of Ribeirão Preto, Sao Paulo, Brazil.

Data Collection

Data were collected from the Patient Data Management System in each clinic and consisted of the biometry measurements performed using a Haag-Streit LenStar 900 (Haag-Streit, Köniz, Switzerland) biometer. These measurements were performed by a skilled and well-trained resident before cataract surgery to calculate the intra-ocular lens (IOL), while the standard deviation (SD) was automatically computed in the device. Patients with a standard deviation (SD) higher than SD > 0.2 mm for the AL and SD > 0.13 mm for the ACD were not included in this study. We selected all patients whose data were measured by the same resident and who were scheduled to be operated on by the same surgeon. This study included all patients diagnosed with cataracts in one or both eyes who were scheduled to undergo cataract surgery in 2020–2023. Only measurements of patients with a healthy corneal surface were included in this study, while patients with corneal disorders were excluded. However, patients with other comorbidities, such as pseudo-exfoliation syndrome (PEX), proliferative diabetic retinopathy, non-proliferative diabetic retinopathy, and exudative and non-exudative age-related macular degeneration (AMD), which did not influence the corneal surface nor the accuracy of the measurement of the biometric factors (AL and ACD, respectively), were included in this study. We complied with the inclusion and exclusion criteria by analyzing all patients' pre-operative medical reports registered in the Patient Data Management System, and we only included patients who were not diagnosed with any type of corneal disorder. The definitive diagnosis was given by the operating surgeon.

The biometry parameters were taken from the biometry reports that fulfilled the inclusion criteria and that were registered in the optical biometer patient database. Each biometry report represented five consecutive biometric measurements performed for all patients, and the SD of <0.2 mm for AL and SD of <0.13 mm for ACD were strictly applied. All biometric data were measured using the same equipment, the Haag-Streit LenStar 900 biometer, in all three centers.

All the data of eligible patients were collected and inserted in a separate database for analysis by the same person appointed in each center who was a part of this study group. We collected the biometry measurements of patients assigned to undergo cataract surgery with the standard procedure of phacoemulsification by the same surgeon with 10 years of experience or more in cataract surgery using this method in each center. Phacoemulsification, as a standard type of procedure for cataract surgery, was performed under local anesthesia, which was either subconjunctival or retrobulbar based on the surgeon's choice.

Statistical Analysis

STATA 18 and SPSS 27.0 were used for the statistical analysis and graphic presentation of the collected data results. Baseline characteristics were summarized as mean and standard deviation (SD). Multiple comparisons were performed with one-way ANOVA and a Post Hoc Tukey HSD test. Pearson's correlation coefficient (r) was used to determine the strength of the relationship between the two continuous variables. All values of $P<0.05$ were considered significant.

Results

In this study, we analyzed the biometric data obtained using a LenStar 900 optical biometer, and we used biometry reports from measurements performed before cataract surgery, which were inserted in the LenStar 900 database and Patient Data Management System. We extracted and analyzed the biometric data of 2043 eyes of patients with cataracts who were scheduled to undergo phacoemulsification cataract surgery in one or both eyes in one of three different centers in three countries: Hungary, Kosovo, and Brazil.

We included the data on AL and ACD of 998 eyes of patients from Hungary, 630 eyes of patients from Brazil, and 415 eyes of patients from Kosovo. We compared the AL and ACD of patients scheduled for cataract surgery in three different countries' centers.

Using Pearson's correlation coefficient, we also assessed the correlation between the patients' age and AL and ACD.

Table 1 shows the general results of the descriptive statistics; the mean age of subjects in Kosovo was 70.4±9.23, while the mean age of subjects in Hungary was 68.9±12.35.

The mean AL in Kosovan patients was 23.23±0.98 mm, and a similar AL was found in Brazilian patients (23.3±0.954 mm); however, AL in Hungarian patients (23.60±1.84 mm) differs compared to that of patients from Kosovo and Brazil. The mean ACD was the lowest in the Kosovan patients (3.12±0.42 mm) and the highest in the Brazilian patients (3.15±0.417 mm).

Table 1.
Descriptive statistics.

Variables	Kosovars		Hungarians		Brazilians	
	Mean	SD	Mean	SD	Mean	SD
Age, yrs	70.4	9.23	68.97	12.35	-	-
AL, mm	23.23	0.98	23.6	1.84	23.3	0.954
ACD, mm	3.12	0.42	3.14	0.45	3.152	0.417

Table 2 presents the results of the correlation analysis between the age of Hungarian patients, AL and ACD. There was a statistically significant (P=0.000) negative weak correlation between age and both evaluated parameters, AL (r=-0.116) and ACD (r=-0.250), indicating that AL and ACD decreased with patient age.

Table 2.
The results of the correlation analysis between the age, AL, and ACD of Hungarian patients.

		Age	AL	ACD
Age	r	1	−0.116	−0.250
	P-value		0.000	0.000
	n	993	990	900
AL	r	−0.116	1	0.351
	P-value	0.000		0.000
	n	990	998	908
ACD	r	−0.250	0.351	1
	P-value	0.000	0.000	
	n	900	908	908

According to the results in Table 3, there was also a negative weak correlation between age and AL (r=-0.048) and ACD (r=-0.188) in Kosovan subjects. The correlation between age and ACD was statistically significant (P=0.000); however, there was no statistically significant correlation between age and AL (P=0.330). Unfortunately, this type of analysis was not conducted among Brazilian subjects.

Table 3.
The results of the correlation analysis between the age, AL, and ACD of Kosovan patients.

		Age	AL	ACD
Age	r	1	−0.048	−0.188
	P-value		0.330	0.000
	n	416	415	392
AL	r	−0.048	1	0.289
	P-value	0.330		0.000
	n	415	415	392
ACD	r	−0.188	0.289	1
	P-value	0.000	0.000	
	n	392	392	392

A one-way ANOVA with Tukey HSD test showed a statistically significant difference in AL between the Hungarian and Kosovan patients (P=0.0000) and Hungarian and Brazilian patients (P=0.0002); however, no statistically significant difference was found in AL between the Kosovan and Brazilian patients (P=0.7284) (Table 4, Figure 1). There was no statistically significant difference in ACD values between all three groups (P=0.5064) (Table 4, Figure 2).

Table 4.
One-way ANOVA and Tukey HSD for pairwise comparisons.

Parameter	Hungarian patients (n=998)	Brazilian patients (n=630)	Kosovan patients (n=415)	One-way ANOVA and Tukey HSD
	[1]	[2]	[3]	F=13.1629, P=0.0000
AL, mm	23.6±1.84	23.3±0.954	23.23±0.98	P_{1-2}=0.0002, P_{1-3}=0.0000 P_{2-3}=0.7284
ACD, mm	3.14±0.45	3.152±0.417	3.12±0.42	F=0.6807, P=0.5064

In Figures 1 and 2, the asterisks indicate extreme outliers, values greater than three times the interquartile range from the upper or lower quartiles.

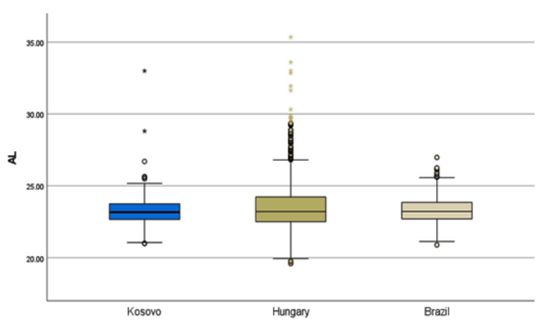

Fig. 1. *Comparison of the mean axial length between study groups.*

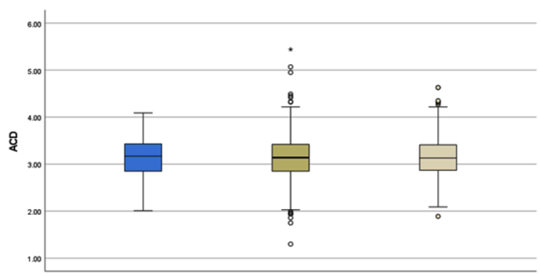

Fig. 2. *Comparison of the mean anterior chamber depth between study groups.*

Discussion

This study compared the axial length (AL) and anterior chamber depth (ACD) between Hungarian, Kosovan, and Brazilian populations; the pre-operative biometric data of patients with cataracts who were scheduled to undergo phacoemulsification cataract surgery were analyzed. Socioeconomic and demographic factors, such as race, ethnicity, and lifestyle, impact biometric parameters such as AL, ACD, and lens thickness; these factors can also explain differences in refractive errors between populations.

Guo Yin et al.[13] in the Beijing Eye Study found that the axial length was significantly associated with the systemic parameters of a higher age (P<0.001), higher body height (P=0.003), higher level of education (P<0.001), and an urban region of habitation (P<0.001). These findings align with our results because we also found a statistically significant negative correlation (P=0.000) between age and biometric parameters (AL and ACL) in Hungarian patients. We found that there was also a statistically significant negative correlation between age and the anterior chamber depth in the Kosovan patients (P=0.000).

The correlation between age and the axial length and anterior chamber depth found in our study also aligns with another survey of the distribution of the axial length and ocular biometry, measured using partial coherence laser interferometry (IOL Master) in an older white population conducted by Fotedar et al.,[27] who also found that there was a mean reduction in the axial length with age.

Our findings are also supported by Mingguang He et al.,[28] as in their longitudinal population study of Chinese adults, the mean axial length was greater for younger persons than the older persons included in the study.

Lowe's findings[29] show that lens growth and lens thickening are associated with shallowing of approximately 0.35–0.50 mm in the anterior chamber with increasing age, particularly over 50.[30]

The results of the study conducted by Arad et al.[31] on the biometric factors in Caucasian patients with cataracts show that the AL, ACD, lens thickness (LT), keratometry, and white-to-white distance (W-W) are negatively correlated with age but positively correlated with each other.

However, in his research on the age-related paraxial schematic emmetropic eye, D. Atchison[32] argued that with increasing age, in the schematic eye, there are some changes such as a decreased anterior chamber depth, increased lens thickness, decreased vitreous length, increased axial length, decreased anterior lens radius of curvature, and increased lens equivalent refractive index. Differently from the age-related schematic eye, our results present a negative correlation between age and AL and ACD, which shows that not only the ACD but also the AL decreases with age. The results of our research show a statistically significant correlation between age and the AL in the Hungarian population.

Regarding the effect of socioeconomic differences on the biometric parameters in populations, the results of the Beijing Eye Study[13] correspond to our results showing a statistically significant difference in AL between the Hungarian patients and Kosovan and Brazilian patients based on socioeconomic differences in these populations, especially those between Hungary and other two countries, Kosovo and Brazil.

Lam et al.[33] reported that ACD was significantly shorter in Hispanic patients compared to non-Hispanic patients. A study comparing the anterior segment biometry between Chinese and Caucasian patients showed that ACD was smaller in Chinese patients; however, there were no significant differences in AL between the two groups.[34] A study on a Caucasian population showed that there are statistically significant differences in the ACD and lens thickness (LT), which are correlated with patients' ages such that elderly patients had a lower ACD and higher LT;[35] this is similar to the results of our study.

In a study titled "Racial and Ethnic Differences in the Roles of Myopia and Ocular Biometrics as Risk Factors for Primary Open-Angle Glaucoma," based on the data used from the Los Angeles Latino Eye Study (LALES) and the Chinese American Eye Study (CHES), Zhou et al.[36] found out that although the POAG risk conferred by myopic refractive error (RE) and a longer AL is similar between Latino and Chinese Americans, the difference in POAG prevalence between the two groups is narrowed by higher myopia prevalence among Chinese Americans.

Many population studies have reported the association between biometric factors, particularly the axial length, and sociodemographic and economic factors, mainly those conducted in Asia. In their cross-sectional survey study analyzing education, socioeconomic status, and ocular dimensions in Chinese adults, Wong et al.[37] concluded a statistically significant correlation between socioeconomic factors and AL. They concluded that subjects with a high level of education, higher incomes, and work-related occupations had a longer axial length (0.60 mm; 95% confidence interval (CI)).

The study by Nangia et al.[38] supports the findings of our study and those of previous studies because they concluded that the mean axial length in a rural population in India was shorter than that in other populations; thus, a higher axial length is related to higher socioeconomic standards.

Our study found a statistically significant difference in the axial length between the Hungarian subjects and the subjects from Kosovo and Brazil. However, no statistical significance was found between the axial length of subjects from Kosovo and Brazil.

According to many studies, an increase in axial length and higher myopia in an urban population, especially younger ones, is attributed to the fast-developing economy and more stringent educational systems.[39,40] The results of the EPIC—Norfolk Eye Study show that the AL was strongly related to education level,[41] whereas, similar to our findings apart from the correlation between the ACD and age, there was no other significant finding regarding the ACD.

Many studies that were conducted to determine the differences in the biometric parameters of the anterior segment of the eye between different groups and populations support the results of our research, showing that genetic, social, and environmental factors play key roles in the differences in these parameters.

Conclusion

In our comparative study of patients with cataracts from Hungary, Kosovo, and Brazil, we found statistically significant differences in the axial length between the Hungarian patients and the other two groups of patients; however, there was no statistically significant difference in the anterior chamber depth between the countries. In terms of demographics, the results of our study show a statistically significant negative correlation between age and the biometric parameters studied, namely the axial length and the anterior chamber depth. Our study shows a decrease in the axial length and anterior chamber depth with increasing age. With many studies already conducted in several countries in Asia in addition to England and the United States of America, including Caucasian, non-Caucasian, Hispanic, and non-Hispanic subjects, we consider the novelty of our research to be the findings obtained by analyzing the biometric data of subjects from the three countries that we included in this study. Furthermore, this is the first study comparing the biometric data of adult Hungarian, Kosovan, and Brazilian patients with cataracts before surgery.

Institutional Review Board Statement

This study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the Kosovo Chamber of Doctors (No. 49/2022; 12 April 2022), the Regional Institutional Scientific and Research Ethics Committee at Semmelweis University (SE RKEB 82/2024; 14 May 2024), and the National Commission of Research Ethics at the University of Sao Paulo—Ribeirão Preto, Brazil (CAAE:79011223.2.0000.5440; 26 August 2024).

Competing Interests

The authors declare that they have no competing interests.

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