https://doi.org/10.5272/jimab.2019254.2733

Journal of IMAB
ISSN: 1312-773X
https://www.journal-imab-bg.org

Journal of IMAB - *Annual Proceeding (Scientific Papers).* 2019 Oct-Dec;25(4)

Original article

EVALUATION OF THE KERATOMETRIC, BIOMETRIC DATA AND THE BIOMETRIC DEPENDENCIES AS RISK FACTORS OF REFRACTIVE ERROR IN IOL POWER CALCULATION

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ABSTRACT

Purpose: The aim of the study is to evaluate the keratometric and biometric data and the biometric dependencies as risk factors of absolute refractive error (AE) in IOL power calculation of monofocal lenses in cataract patients using immersion ultrasound biometry (US-BM) and third generation formulas - SRK-T, Holl-1, Hoff-Q.

Methods: We present a retrospective, case-control study. Two hundred and fifteen eyes of 158 patients with cataract are included that underwent uncomplicated phacoemulsification with implantation of monofocal IOL. Automated keratometry (Potec - 700), immersion ultrasound biometry (US-BM) and third generation formulas-SRK-T, Holladay-1, Hoffer-Q were used. Correlation analysis was performed between ocular keratometry and biometry values and the absolute error.

Results: The predicted postoperative refraction (SE) in 137 eyes (63.7%) was successfully achieved with AE ± 0.50D. On the second visit after phacoemulsification (1-st month), 133 eyes (61.9%) had uncorrected distant visual acuity UCDVA ≥0.8. In our study was found that the keratometry procedure (KER) and surgically-induced astigmatism (SIA) were not sources of refractive error. Groups with larger relative shares of AE> ± 0.50D are with cylinder value prior to phacoemulsification (befCylD) > -0.75D, longer axial lenght (AL > 26.00 mm), shallower anterior chamber (ACD < 2.6 mm), smaller anterior segment (ACD + LT) <6.6 mm), smaller ratio of the anterior segment to the axial length (ACD+ LT / AL < 0.30). A methodology for estimating the expected AE has been proposed.

Conclusion: The expected AE can be predicted via two preoperative factors: befCylD and the ratio of the anterior segment to the axial length (ACD + LT)/AL.

Keywords: IOL power calculation, Refractive Error, Cataract, Immersion ultrasound biometry,

INTRODUCTION:

Cataract surgery is the most common surgical procedure. Advances in modern technology and surgical technique have significantly improved postoperative results. The success of IOL implantation after cataract surgery depends on achieving the desired postoperative refraction and patients' satisfaction which is of significance for a successful outcome. Essential for this purpose are precise measurements of keratometric and biometric data of the eye and selection of the optimal IOL calculation formula, [1]. According to the studies 1 mm deviation of the corneal diameter, AL and ACD leads to 5.7 D, 2.7 D and 1.5 D of refractive error respectively. The contribution to error from ACD, AL and K (D) is 42%, 36%, 22% respectively, [2].

Recent studies are focused on refining the IOL calculation formulas and to improve their accuracy. According to Norrby S, the biggest source of error -35.5% is the inaccuracy of prediction of postoperative ELP position, [3]. ELP is the only parameter that can't be measured. Third-generation formulas (Hoffer Q, Holladay 1, SRK-T) use AL and corneal power to predict the ELP. Fourth-generation formulas use additional parameters to refine the IOL position – ACD, lens thickness, preoperative refraction, WTW, [4]. In spite of that, we still get refractive surprises in some patients. Gale et al. found that 87% of patients achieved an outcome within ± 1.0D of target with appropriate formula selection, optical biometry, optimized A-constant [5]. After half a century of clinical studies the ideal refractive formula is yet to be found. Optical biometry (OPT-BM) and refractive fourth generation formulas are not widely available. That's why automated keratometry and ultrasound biometry are regularly used. The aim of the study is to improve the individual ophthalmic practice in the treatment of patients with cataract. To this end, a method of measurement of an absolute error (AE) in IOL power calculation of monofocal lenses, using immersion ultrasound biometry and third generation formulas - SRK-T, Holladay 1, Hoffer Q, is proposed.

MATERIALS AND METHODS:

The study included 215 eyes of 158 patients with cataract. Uncomplicated phacoemulsification and implantation of monofocal IOL was performed by single surgeon Inclusion criteria - patients with phacoemulsification and in the bag monofocal IOL implantation. Exclusion criteria - patients with phacoemulsification and multifocal IOL, corneal diseases, previous refractive surgery, other intraocular surgery, complicated cataract surgery. The selection of cases is hospital-based, using the registers of the Multi-profile University Hospital for Active Treatment "PLOVDIV". All manipulations have been performed in accordance with the principles of the Helsinki Declaration and patients have given informed consent. The study is a retrospective, case-control type. The frequency has been determined and the interrelationships between monofocal IOL implantation and the occurrence of AE have been analyzed. Patients were selected based on whether they had an AE above ± 0.50D (cases) or below ± 0.50D (controls). Odds Ratio (OR) was used to measure the impact strength of the studied factor- keratometric, biometric, optic and IOL power calculation formulas. Complete ophthalmic examination was performed which included: visual acuity (VA) before and after surgery, biomicroscopy, tonometry, ophthalmoscopy, automated kerato-refractometry before and after surgery (Potec PRK 5000), immersion ultrasound biometry (Ocuscan RxP, Alcon) and IOL power calculation with SRK-T, Holladay 1, Hoffer Q formulas. Follow-up examinations were performed on the 7-th and 30-th day after the surgical procedure. The data was processed and analyzed using IBM SPSS Statistics Version 19.00 for Windows. Statistical methods for quantitative and qualitative estimation of factor influence and statistical hypothesis checks were used.

RESULTS AND DISCUSSION:

Assessment of the efficiency of the surgical procedure: Efficiency is determined by achieving the predicted postoperative refraction (SE) and the achieved postoperative uncorrected visual acuity. The goal of perfect refractive surgery is emmetropia. This is the spherical equivalent -0.5D to +0.5D and astigmatism <1.0D. The Royal College of Ophthalmologyst has adopted a standart of 85% of patients within ± 1.00D of target and 55% within ± 0.50D of target, [6].

In our study in 63.7% of cases, 137 eyes, the predicted SE was successfully achieved with a minimum permissible AE up to ± 0.50D, and in 87.4% of cases, 188 eyes with AE up to ± 1.00D, (Table 1).Within one month after the phacoemulsification 61.9% of cases, 133 eyes had the best uncorrected distance visual acuity UCDVA ≥0.8, (Table 2). Our results are near to the reported relative share by using US-BM – 69.5% with AE up to ± 0.50D, and in 93.7% with AE up to ± 1.00D, [7].

Table 1. Distribution of the value of an absolute error, AE SE

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	no err: AE < ± 0.50D	137	63,7	63,7	63,7
	yes err: AE: ± 0.50 ± 1.00D	51	23,7	23,7	87,4
	yes err: AE > ± 1.00D	27	12,6	12,6	100,0
	Total	215	100,0	100,0	

Table 2. Distribution of frequency and relative share of the eyes with UCDVA

Vis		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	,1	1	,5	,5	,5
	,2	5	2,3	2,3	2,8
	,3	5	2,3	2,3	5,1
	,4	9	4,2	4,2	9,3
	,5	18	8,4	8,4	17,7
	,6	19	8,8	8,8	26,5
	,7	25	11,6	11,6	38,1
	,8	54	25,1	25,1	63,3
	,9	47	21,9	21,9	85,1
	1,0	32	14,9	14,9	100,0
	Total	215	100,0	100,0	

Assessment of keratometric data: AE associated with the optical power of the cornea is due to an erroneous evaluation and rounding up of the recalculation of the radius of the corneal curvature in optical power. The estimation of corneal curvature is most often performed at only 4 points with a paracentral range of 3.0 ÷ 3.2. mm, [2]. The error of 0.5D in corneal power leads to an error of 0.5D in postoperative refraction, [8].

In our study the procedure of keratometry before and after surgery is performed approximately the same way and correctly. In 87.4% ,188 eyes, the surgical incision technique did not induce astigmatism (SIA) up to ± 0.50D, (Table 3), and was not a source of residual refractive error in our study. Only in 12.6% ,27 eyes, SIA was up to ± 0.50D, the value of which is close to that found in literature, 10.00%, [2, 9].

Table 3. Distribution of SIA

	SIA	Frequency	Percent	Valid Percent	Cumulative Percent
Valid	CylD: -0.25 +0.25	149	69,3	69,3	69,3
	CylD: = 0.50	39	18,1	18,1	87,4
	CylD: > 0.50	27	12,6	12,6	100,0
	Total	215	100,0	100,0	

It was found that from all measured preoperative keratometric parameters, only the preoperative cylinder value (befCylD) is a risk factor associated with the onset of AE. In the group with AE > ± 0.50D, the weighted average value of the cylinder power is greater. The relative risk (OR) and the relative share of cases with AE> ± 0.50D increase with befCylD > (-) 1.00D. Fig. 1, Table 4.

According to the studies one third of cataract patient are with preexisting corneal astigmatism > ± 1.0D, [10, 11, 12]. Our results indicate that 46.7% of the patients have befCylD > ± 1.0D. Resent study (2018) reported results according to the impact of the orientation of corneal astigmatism on the postoperative target refraction, where was found no significant difference in the magnitude of preoperative corneal astigmatism and postoperative SE prediction error between the anterior corneal astigmatism orientation groups in eyes with AL ≤ 22.0 mm and AL ≥ 25.0 mm, [13].

Fig.1. Relative share of cases with AE ± 0.50D SE and befCyl D

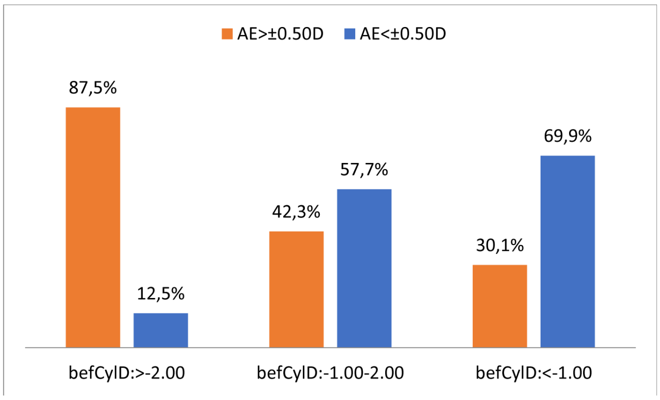


Table 4. OR for AE according to befCylD

befCylD	OR for AE
-0.75	2.0
-1.00	2.3
-2.00	13.4

Assessment of biometric data: AE is associated to the method of measuring the axial length (AL). Non-contact optical biometry (OPT-BM) has become a gold standart because of its accuracy and reproducibility, [1, 14]. With optical biometry AL is the most accurately measured and longest. With the immersion US-BM AL is measured shorter, with contact US-BM - the shortest, [15, 16]. According to AAO every error in measuring AL by 0.1 mm corresponds to 0.27 D of AE. The immersion US-BM is more effective than OPT-BM in the absence of a central fixation of the eyeball, dense posterior capsular and mature cataract, haemophthalm, nystagmus and macular degeneration, [8, 17]. In approximately 10% of eyes optical biometry is unable to measure the AL, [1]. The relative share of AE cases above ± 1.00D is the smallest in emmetropic eyes, greater in hypermetropic eyes, and largest in myopic eyes. In high and ultra-high degree of myopia, the use of US-BM is associated with AE > ± 1.00D, [18, 19].

Immersion ultrasound biometry was used in this study. The groups with larger relative shares of eyes with AE> ± 0.50 have longer axial lenght (AL > 26.00 mm), (Fig. 2), shallower anterior chamber (ACD < 2.6 mm), (Fig. 3), thicker or normal lens (LT ≥ 4.0 mm), (Fig. 4), smaller anterior segment (ACD+LT) < 6.6 mm, (Fig. 5), smaller ratio of anterior segment to the axial length (ACD+LT)/AL < 0.30.

Fig. 2. Relative share of cases with AE ± 0.50D SE and ALmm

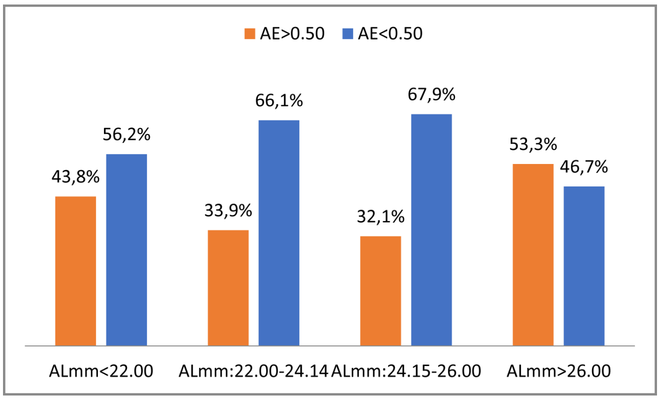


Fig. 3. Relative share of cases with AE ± 0.50D SE and ACDmm

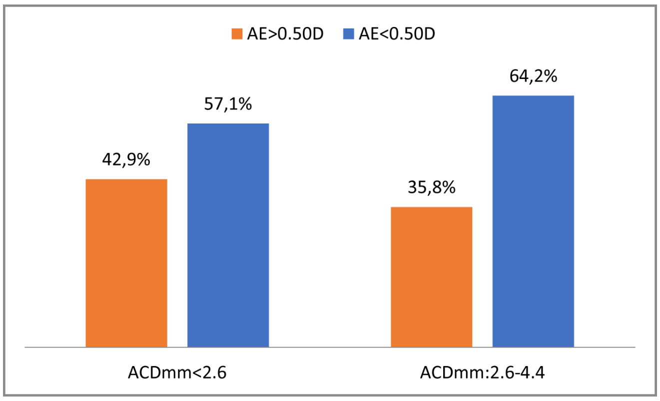


Fig. 4. Relative share of cases with AE ± 0.50D SE and LTmm

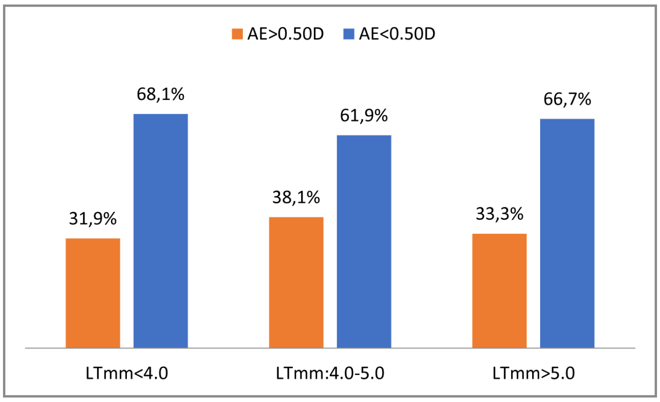
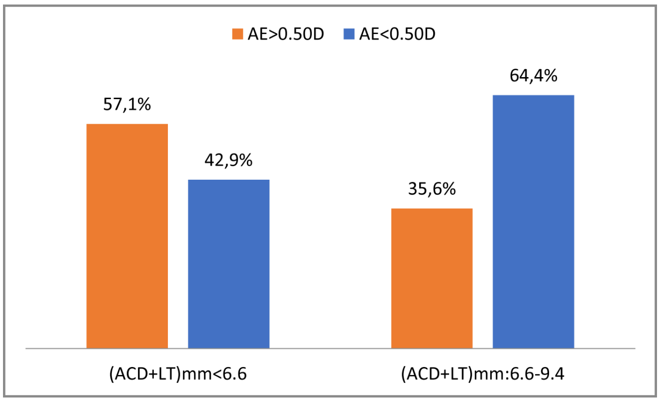
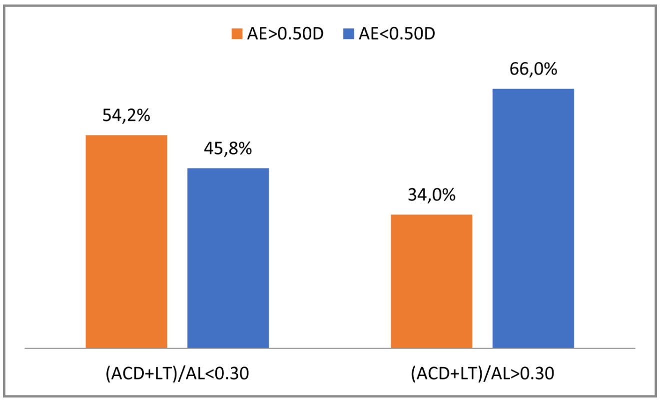


Fig. 5. Relative share of cases with AE ± 0.50D SE and (ACD+LT)mm



Proportionality of the anterior segment to the axial length is directly related to the total refraction of the eye and combines the effect of the three main biometric parameters - AL, ACD, LT. It is a statistically significant risk factor for the occurrence of AE up to ± 0.50 D. According to our results in eyes with (ACD + LT)/AL <0.30 there is 2.3 times higher OR for occurrence of AE up to ± 0.50D, Fig. 6.

Fig. 6. Relative share of cases with AE ± 0.50D SE and the ratio (ACD+LT)/AL

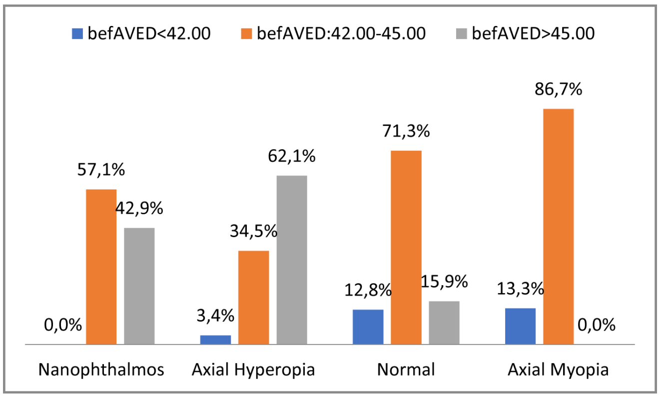


Anterior eye segment as a risk factor is directly related to the depth of the pseudophakic anterior chamber (ACDpost). The results of the meta-analysis for the assessment of the factor influence attribute greatest significance to the depth of the pseudophakic ACD relative to the other biometric parameters - AL and K: ACDpost - 42.00%; axial length, AL - 36.00%; keratometric measurement, K - 22.00%; pupil diameter, [2, 3]. Other study reports that preoperative ACD is the only significant factor in the expected difference between all 3rd generation formulas and the Haigis formula, [20]. Because 3rd generation formulas use A constant to estimate the ELP, AL and ACDpostop are the most significant factor for AE.

Assessment of the biometric dependencies: An inversely proportional relationship is established between the optical power of the cornea, K (D) and the horizontal diameter of the cornea (WtW) and the axial length (AL), [21, 22] On its part, WtW is in a directly proportional relationship with the diameter of the pupil; the sum of (ACD + LT) and AL. The disproportionality of the corneal diameter is directly related to the refractive error. A disproportional corneal diameter may occur at any AL value, but most common are cases with AL <22.4mm. An inversely proportional dependence was found between the phakic and the pseudophakic AL mm with the pseudophakic AL being shorter, [23].

This study establish the relationship between AL, ACD, and LT. The less refractive eyes, Nanophthalmos (ACD+LT <6.6mm, AL <22.00mm) and Axial Hyperopia (ACD+LT = 6.6-9.4mm, AL <22.00), have a compensatory stronger corneal power, more commonly with a total power of K > 45.00D. The stronger refractive eyes, Axial Myopia (ACD+LT ≥6.6-9.4mm, AL >26.00) have a compensatory weaker corneal power, more commonly with a total refractive power of K < 42.00D, Fig. 7

Fig. 7. Distribution according to type of eyes and corneal power, befAVED



We found that in eyes of type Nanophthalmos and Axial Myopia, the relative share of eyes with AE up to ± 0.50D is greatest, Fig. 8. These are the two types of eyes with a ratio (ACD+LT)/AL < 0.30 (30%.). Nanophthalmos, Axial Hyperopia, Axial Myopia are related to 2.2 times greater OR for the occurrence of AE above ±0.50D. There are not reported data about the ratio (ACD+LT)/AL. According to our results we propose a methodology for estimating the expected AE, Table 5. A-constant can be reduced by 0.15 to (-)0.25D of the expected AE.

Fig. 8. Distribution according to type of eyes and AE ± 0.50D SE

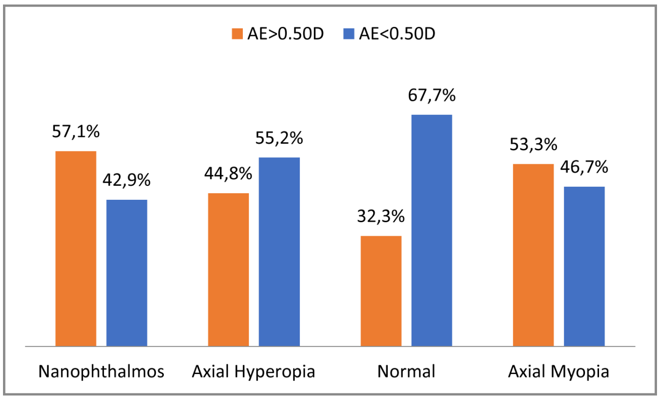


Table 5. Expected according to befCylD and the ratio (ACD+LT)/AL.

befCyl D KER	(ACD+LT)/AL ≤ 0.25 AE (D)	(ACD+LT)/AL ≥ 0.26 AE (D)
= -0.75	-0.50	-0.25
-1.00 ÷ -1.50	-0.75	-0.50
-1.75 ÷ -2.25	-1.00	-0.75

CONCLUSIONS:

We found that from the keratometric and biometric sources of refractive error only two parameters are statistically significant - the cylinder value before the surgical procedure, befCylD, and the proportionality of anterior segment to the axial lenght, (ACD + LT)/AL. At befCylD > -0.75D, the relative risk and relative share for AE over ± 0.50D are doubled. The ratio of (ACD + LT)/AL <30% has two times higher OR for AE > ± 0.50D. The less refractive eyes with shorter AL have a compensatory steeper cornea, more often with a refractive power AVE K (D) > 45.00D. The more refractive eyes with longer AL have a compensatory flater cornea, more often with a refractive power AVE (D) < 42.00D. All three types of eyes are connected to a higher OR for > ± 0.50 D. According to these results we propose a methodology for estimating and correcting the expected AE.

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Please cite this article as: Popova G, Voynov L. Evaluation of the keratometric, biometric data and the biometric dependencies as risk factors of refractive error in IOL power calculation. *J of IMAB.* 2019 Oct-Dec;25(4):2733-2738.
DOI: https://doi.org/10.5272/jimab.2019254.2733

Received: 31/01/2019; Published online: 14/10/2019

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