· Clinical Research ·

Impact of ultrasound and optical biometry on refractive outcomes of cataract surgery after penetrating keratoplasty in keratoconus

Katarzyna Krysik[1], Anita Lyssek-Boron[1], Dominika Janiszewska-Bil[1,2], Edward Wylegala[2,3,4], Dariusz Dobrowolski[1,2,3]

[1]Department of Ophthalmology with Pediatric Unit, St. Barbara Hospital, Trauma Centre, Sosnowiec 41-200, Poland
[2]Department of Ophthalmology, District Railway Hospital, Katowice 40-760, Poland
[3]Chair and Clinical Department of Ophthalmology, School of Medicine with the Division of Dentistry in Zabrze, Medical University of Silesia in Katowice, Katowice 40-760, Poland
[4]Hebei Provincial Eye Hospital, Xingtai 054001, Hebei Province, China
Correspondence to: Dariusz Dobrowolski. Chair and Clinical Department of Ophthalmology, School of Medicine with the Division of Dentistry in Zabrze, Medical University of Silesia, District Railway Hospital, Panewnicka 65 str., Katowice 40760, Poland. dardobmd@wp.pl
Received: 2018-02-26 Accepted: 2018-09-13

Abstract
● AIM: To analyse the impact of ultrasound and optical intraocular lens (IOL) calculation methods on refractive outcomes of cataract phacoemulsification performed after penetrating keratoplasty (PK) in keratoconus.

● METHODS: Phacoemulsification cataract surgery was performed on 42 eyes of 34 patients with keratoconus who had previously undergone PK. The IOL power was determined by using both standard and corneal topography-derived keratometry using the SRK/T formula. We used two independent methods-ultrasound biometry (UB) and interferometry [optical biometry (OB)] for IOL calculation. The analysed data from medical records included demographics, medical history, best corrected visual acuity (BCVA) on Snellen charts, technique of IOL calculation and calculation formula and its impact on final refractive result.

● RESULTS: BCVA ranged from 0.01 to 0.4 (mean 0.09±0.19) before surgery and ranged from 0.2 to 0.7 (mean 0.38±0.14) at 1mo and from 0.2 to 1.0 (mean 0.56±0.16) (*P*<0.05) at 3mo, postoperatively. The refractive aim differed significantly from the refractive outcome in both the UB and OB groups (*P*<0.05). There was no statistically significant difference in the accuracy of the two biometry methods.

● CONCLUSION: The refractive aim in keratoconus eyes post-PK is not achieved with either ultrasound or OB.

● KEYWORDS: ultrasound biometry; optical biometry; cataract surgery; penetrating keratoplasty; keratoconus
DOI:10.18240/ijo.2019.06.11

Citation: Krysik K, Lyssek-Boron A, Janiszewska-Bil D, Wylegala E, Dobrowolski D. Impact of ultrasound and optical biometry on refractive outcomes of cataract surgery after penetrating keratoplasty in keratoconus. *Int J Ophthalmol* 2019;12(6):949-953

INTRODUCTION

Keratoconus is an ectatic non-inflammatory corneal disorder characterized by central or paracentral thinning and protrusion of the cornea, resulting in irregular astigmatism[1]. This condition is usually bilateral and diagnosed in the second or third decade of life[2]. Because of its progressive character, correction of the variable refractive error and irreversible scarring of the corneal tissue often demand lamellar or penetrating keratoplasty (PK) as refractive treatment. PK for advanced keratoconus remains the surgery of choice, but the type of keratoplasty depends on the corneal structure, the individual patient's needs and the surgeon's experience[3]. In eyes without stromal scars, the lamellar approach is a method of choice.

Knowledge of cornea stromal ultrastructure and its biomechanics can help explain and predict post-cataract wound healing. The anterior and peripheral stroma in keratoconus are more rigid than the posterior ones, and the interlamellar strength profile of the collagen lamellae is significantly weaker inferiorly and centrally. Recurrent keratoconus is related to the incomplete excision of the cone. Healing of the wounds in the peripheral cornea, where surgical cuts are performed during cataract surgery, may be difficult and unpredictable[4].

Cataract surgery in keratoconic eyes, especially after keratoplasty, is frequently challenging. Posterior chamber intraocular lens (PC IOL) power calculation is less predictable than in eyes without prior corneal surgery[5]. The choice of an accurate calculation formula is more difficult and demanding, especially when considering a low postoperative refractive error and rising patient expectations. With the improvement in surgical techniques and biometry devices, cataract surgery is now considered a form of refractive surgery. Accurate preoperative intraocular lens (IOL) power calculation is crucial in achieving satisfactory results[6]. IOL power calculation formulae are good for predicting the postoperative refractive status in eyes with normal axial length and with no prior ocular surgery[7]. The sequential procedure seems to be more accurate when calculating the IOL power compared to the triple procedure (cataract removal, IOL implantation and PK). The triple procedure allows for faster visual rehabilitation but may pose a higher risk of postoperative intraocular infection[8-9].

The accuracy of biometric measurements is higher for optical methods than for ultrasonic methods. In ultrasound biometry (UB), there are more operator-dependent factors that are not present with optical methods[10]. The development of optical devices indicates that UB will be used only given specific indications. Unfortunately, most authors of the available papers analysing post-keratoplasty procedures have focused on the refractive result and visual acuity rather than comparing the planned and obtained results.

UB remains the preferred method for IOL calculation in dense cataracts. In regular corneas, standard keratometry and computed corneal topography accurately measure central corneal power. In post-keratoplasty corneas, the average central corneal power is more secure and stable than in topography-derived keratometry. This may improve the accuracy of the IOL calculation. In our study, keratometry was achieved using swept-source optical coherence tomography (Casia SS-1000, Tomey, Nagoya, Japan). For axial length measurement in the first group, we used an A-scan ultrasonic biometer (Quantel Medical, Bozeman, MT USA) with an applanation technique under topical anaesthesia (group A: UB).

Optical biometry (OB) is the most commonly used method for IOL calculation; it uses keratometry measurements and thus obviates the need for a second instrument. The advantages of OB over applanation are the lack of risk of trauma or infection, increased patient comfort and improved accuracy and repeatability of measurements[11]. In the second group, we used an AL-Scan Optical Biometer (Nidek Co., Ltd., Japan) for the IOL calculation (group B: OB). The goal for IOL power selection was a postoperative refraction of ±1.00 D.

The present study's aim was to evaluate refractive outcomes in keratoconic patients who underwent cataract surgery after PK and to analyse the impact of different devices (ultrasonography and interferometry) for IOL calculation within this group.

SUBJECTS AND METHODS

Ethical Approval This retrospective research study was carried out in the Ophthalmology Department of Saint Barbara Hospital, Trauma Centre in Sosnowiec, Poland. It presents the surgical treatment of 42 eyes in 34 patients with keratoconus who primarily underwent PK with consecutive phacoemulsification. The data analysed from medical records included demographics, medical history, corrected distance visual acuity, technique of IOL calculation and calculation formula. All parts of the data analysis were conducted under the tenets of the Declaration of Helsinki, and all patients signed an individual informed consent form before every surgical procedure. All surgeries, as routine treatments, did not require bioethical committee approval.

All qualified patients underwent a complete ophthalmic examination, including best corrected distance visual acuity test (BCVA), an intraocular pressure (IOP) measurement by Goldmann applanation tonometry, a slit-lamp biomicroscopy and a fundus examination (if possible). Exclusion criteria were other corneal ectasias, other ocular surgery, previous trauma and high astigmatism (>8.0 D) that could affect the final refractive treatment. The keratoplasties were performed between 2009 and 2015, and the phacoemulsifications were performed between 2011 and 2017. The mean interval between the keratoplasty and the phacoemulsification was 32mo. All corneal sutures were removed at least one year before cataract surgery. Eight patients underwent PK and phacoemulsification in both eyes.

Keratoplasties were performed under general anaesthesia. The donor corneas originated from domestic tissue banks. For trephination, we used the Hanna vacuum trephine system (Moria Inc., Antony, France) and a femtosecond laser (VisuMax, Carl Zeiss, USA) or Barron radial vacuum trephines (Katena Products Inc. Denville, NJ, USA). The phacoemulsification procedure with PC IOL implantation (Acrysof IQ, Alcon, USA) was performed under topical anaesthesia (Alcaine, Alcon, Fort Worth, TX, USA) with the Infiniti or Centurion Vision Systems (Alcon, Fort Worth, TX, USA). IOL power was determined by using both standard and corneal topography-derived keratometry using the SRK/T formula[12]. We used two independent methods, UB and OB, for IOL calculation. In 16 eyes with dense cataracts, IOL power was based on UB, while for 26 eyes OB was the basis for choosing the IOL power. Target refraction, including refractive error of the contralateral eye, was evaluated to reach refractive errors between 0 and -1.0 D.

Statistical Analysis Statistical analysis was performed using Statistica v.3.1 (StatSoft, Tulsa, OK, USA). The Wilcoxon rank-sum test was used to compare numerical variables between the two groups. The results are presented as a

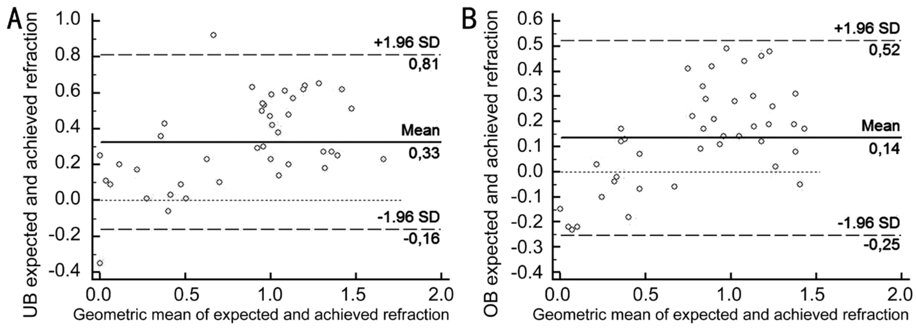

Figure 1 Results of the Bland-Altman test, presenting the mean difference between achieved and expected refractions and mean refractions in the UB measurement group (A) and the OB measurement group (B).

Table 1 Expected and achieved refractions

Refraction	Method 1, UB	Method 2, OB	*P* value
Expected refraction			0.47
Mean±SD	-0.69±0.40 D	-0.72±0.40 D	
Range in diopters (spherical equivalent)	-1.55 to -0.1	-1.43 to -0.20	
Achieved refraction			0.16
Mean±SD	-1.02±0.54 D	-0.86±0.53 D	
Range in diopters (spherical equivalent)	-1.78 to -0.25	-1.54 to -0.3	
P value	0.016	0.045	-

UB: Ultrasound biometry; OB: Optical biometry.

mean±standard deviation (SD). In a Bland-Altman plot, the difference between the measurements with different methods is plotted against their mean. The 95% limits of agreement (mean difference ±1.96SD) give the distance between the measurements of the methods with 95% confidence. The Bland-Altman plot also shows the proportional bias in the measurements, which is the relationship of the difference between the measurements and the true value. A *P* value of less than 0.05 was considered statistically significant.

RESULTS

The BCVA before cataract surgery ranged from 0.01 to 0.4 (mean 0.09±0.19) on Snellen charts. The BCVA ranged from 0.2 to 0.7 (mean 0.38±0.14) at 1mo after surgery and from 0.2 to 1.0 (mean 0.56±0.16; $P<0.05$) at 3mo postoperatively.

All 42 eyes underwent both methods of IOL calculation. Table 1 presents the expected and achieved refractions 3mo after phacoemulsification and PC IOL implantation (final refraction). Method 1 presents refraction dependent on UB, while Method 2 presents refraction dependent on OB. IOL power was calculated to reach final refractive errors between 0 and -1.0 D.

The expected and achieved refractions were not statistically significantly different in either Methods 1 or 2 ($P>0.05$), and there was no statistically significant difference when comparing the two different methods of IOL measurement. The distribution of final refractive errors in both groups is summarized in Table 2. A majority of patients in both groups did not meet the target refraction (below ±1.0 D): 64% with UB and 55% with OB.

Table 2 Distribution of final achieved spherical equivalent 3mo after surgery *n* (%)

Final refraction (spherical equivalent)	Method 1, UB	Method 2, OB
≤0.25 D	5 (12)	4 (10)
0.25 to ≤0.50 D	4 (10)	9 (21)
0.50 to ≤0.75 D	6 (14)	1 (2)
0.75 to ≤1.00 D	0	5 (12)
>1.00 D	27 (64)	23 (55)

UB: Ultrasound biometry; OB: Optical biometry.

The Bland-Altman test shows the difference between expected and achieved refractions using IOL measurement methods. The dotted lines represent the mean thickness differences between the two methods, and the interline zones represent the area of 95% limits of agreement (Figure 1). There were no statistically significant differences between expected and achieved refractions using IOL measurement methods ($P>0.05$).

The differences between expected and achieved refractions 3mo post-cataract surgery with myopic shift and the comparison of expected and achieved refractions are presented in Figures 2 and 3, respectively.

DISCUSSION

To achieve expected refraction after cataract surgery, precise IOL power calculation is crucial. Patients, especially younger ones, have higher expectations of and demands regarding the final optical result. As a group, our keratoconus patients are younger than typical cataract patients. One of the most important sources of refractive surprise in UB is the pressure on the cornea during measurement. Even when a single doctor

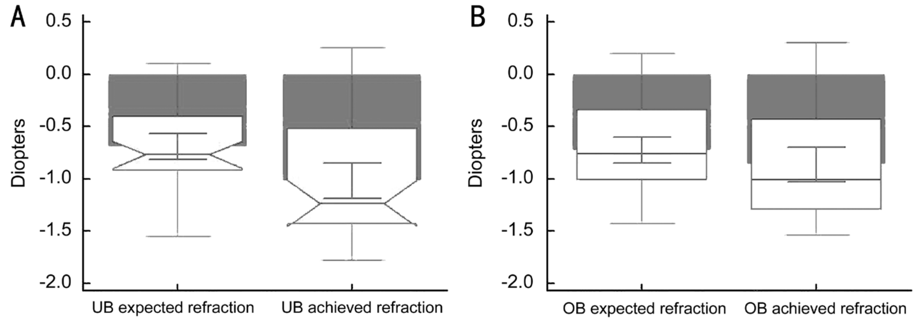

Figure 2 The difference between expected and achieved refractions in both measurement methods with myopic shift in UB measurement group (A) and OB measurement group (B); *P*<0.05.

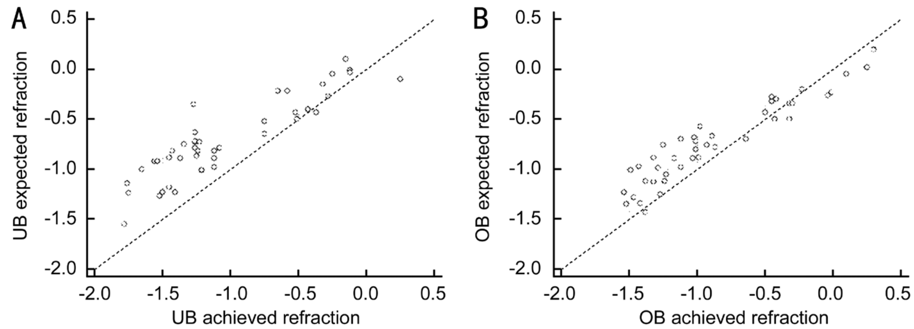

Figure 3 Comparison of expected and achieved refractions in UB measurement group (A) and OB measurement group (B). The significance level for both groups was *P*<0.0001.

takes all the measurements, its result is myopic shift, which is compatible with the findings of Karabela *et al*[13] and which contrasts with the results reported by Fontes *et al*[14].

Despite the common usage of UB, OB is now considered the gold standard in IOL calculation. Our results showed that it is difficult to judge which method is preferable in keratoconus patients who have undergone PK. Comparisons do not reveal significant differences between the approaches. Keratoplasty in keratoconus patients interferes not only with keratometry but also with axial length. In eyes that have undergone any kind of refractive surgery, preoperative data could be included in the IOL calculation formulae. In post-PK keratoconus patients, previous data are not applicable to IOL power evaluation[15]. The changes in axial length are high, as well as decrease of K-value. Additionally, after PK, refractive error is not stable, and many patients require changes in spectacle or contact lens correction[16]. Many patients expect additional correction such as soft contact lenses or RGP lenses to obtain better visual acuity and comfort.

In the present study, expected refraction did not accord with the final result; several reasons may account for this discrepancy. One is the presence of fluctuations of refractive error in a keratoconic cornea[17]. Such changes depend on the structure of a graft-host interface and on changes in the remaining peripheral stroma. A second reason may involve the clear corneal cut, and there is no data about the potential influence of this cut on the final refraction in keratoconus. We know that arcuate cuts in the peripheral cornea can be beneficial when correcting high astigmatism, but in keratoconus we cannot precisely predict the final influence of the cut. In such cases, we should consider a scleral tunnel for surgery or microincision techniques to decrease the cut's impact on postoperative refraction[18]. In specific and demanding situations, as in eyes with prior corneal surgery, especially post-PK, the standard IOL calculation remains insufficient[19]. New mathematical algorithms are necessary that take into account the specificity of corneal shape, the anterior chamber depth and the clear corneal cut location in keratoconus.

In the most challenging cases of high astigmatism, in patients with ectatic corneal disorders like pellucid marginal degeneration or keratoconus, cataract surgery with toric lens implantation is helpful in reducing refractive error[20-22]. This method is also applied to eyes with prior corneal refractive surgery with residual or induced astigmatism. In our group, 10 patients had astigmatism over 5 D; however, during the analysis of topographic values and previous medical history, we decided to apply a monofocal lens. These patients were offered, before cataract onset, spectacle astigmatism correction lower then keratometric values, with satisfactory results.

Cataract surgery after keratoplasty in keratoconus presents a significant challenge. While the surgeon must include all available data, including corneal shape and anterior chamber configuration, the surgeon's professional experience remains crucial to choosing the correct IOL power[23].

ACKNOWLEDGEMENTS

Conflicts of Interest: Krysik K, None; **Lyssek-Boron A,** None; **Janiszewska-Bil D,** None; **Wylegala E,** None; **Dobrowolski D,** None.

REFERENCES

1 Davidson AE, Hayes S, Hardcastle AJ, Tuft SJ. The pathogenesis of keratoconus. *Eye (Lond)* 2014;28(2):189-195.

2 Gokhale NS. Epidemiology of keratoconus. *Indian J Ophthalmol* 2013;61(8):382-383.

3 Brierly SC, Izquierdo L Jr, Mannis MJ. Penetrating keratoplasty for keratoconus. *Cornea* 2000;19(3):329-332.

4 Mader TH, Yuan R, Lynn MJ, Stulting RD, Wilson LA, Waring GO 3rd. Changes in keratometric astigmatism after suture removal more than one year after penetrating keratoplasty. *Ophthalmology* 1993;100(1):119-126; discussion 127.

5 Jurkunas U, Azar DT. Potential complications of ocular surgery in patients with coexistent keratoconus and Fuchs' endothelial dystrophy. *Ophthalmology* 2006;113(12):2187-2197.

6 Dietrich T, Viestenz A, Langenbucher A, Naumann GO, Seitz B. Accuracy of IOL power prediction in cataract surgery after penetrating keratoplasty: retrospective study of 72 eyes. *Klin Monbl Augenheilkd* 2011;228(8):698-703.

7 Gruenauer-Kloevekorn C, Kloevekorn-Norgall K, Duncker GI, Habermann A. Refractive error after triple and non-simultaneous procedures: is the application of a standard constant keratometry value in IOL power calculation advisable? *Acta Ophthalmol Scand* 2006;84(5):679-683.

8 Vicha I, Vlková E, Hlinomazová Z, Loukotová V, Horácková M, Němec J, Goutaib M. Calculation of diopter value of the IOL in simultaneous cataract surgery and perforating keratoplasty. *Cesk Slov Oftalmol* 2007;63(1):36-41.

9 Seitz B, Langenbucher A, Viestenz A, Dietrich T, Küchle M, Naumann GO. Cataract and keratoplasty: simultaneous or sequential surgery? *Klin Monbl Augenheilkd* 2003;220(5):326-329.

10 Turhan SA, Toker E. Predictive accuracy of intraocular lens power calculation: comparison of optical low-coherence reflectometry and immersion ultrasound biometry. *Eye Contact Lens* 2015;41(4):245-251.

11 Kaswin G, Rousseau A, Mgarrech M, Barreau E, Labetoulle M. Biometry and intraocular lens power calculation results with a new optical biometry device: comparison with the gold standard. *J Cataract Refract Surg* 2014;40(4):593-600.

12 Packer M, Fine IH, Hoffman RS. Refractive lens surgery. *Ophthalmol Clin North Am* 2006;19(1):77-88,vi.

13 Karabela Y, Eliacik M, Kocabora MS, Erdur SK, Baybora H. Predicting the refractive outcome and accuracy of IOL power calculation after phacoemulsification using the SRK/T formula with ultrasound biometry in medium axial lengths. *Clin Ophthalmol* 2017; 11:1143-1149.

14 Fontes BM, Fontes BM, Castro E. Intraocular lens power calculation by measuring axial length with partial optical coherence and ultrasonic biometry. *Arq Bras Oftalmol* 2011;74(3):166-170.

15 Langenbucher A, Haigis W, Seitz B. Difficult lens power calculations. *Curr Opin Ophthalmol* 2004;15(1):1-9.

16 Severinsky B, Behrman S, Frucht-Pery J, Solomon A. Scleral contact lenses for visual rehabilitation after penetrating keratoplasty: long term outcomes. *Cont Lens Anterior Eye* 2014;37(3):196-202.

17 Watson MP, Anand S, Bhogal M, Gore D, Moriyama A, Pullum K, Hau S, Tuft SJ. Cataract surgery outcome in eyes with keratoconus. *Br J Ophthalmol* 2014;98(3):361-364.

18 Thebpatiphat N, Hammersmith KM, Rapuano CJ, Ayres BD, Cohen EJ. Cataract surgery in keratoconus. *Eye Contact Lens* 2007;33(5):244-246.

19 Adrean SD, Reilly C, Mannis MJ. Intraocular lens calculation in a patient with previous penetrating keratoplasty and LASIK. *Cornea* 2005;24(5):629-631.

20 Thomas BC, Auffarth GU, Reiter J, Holzer MP, Rabsilber TM. Implantation of three-piece silicone toric additive IOLs in challenging clinical cases with high astigmatism. *J Refract Surg* 2013;29(3):187-193.

21 Balestrazzi A, Baiocchi S, Balestrazzi A, Cartocci G, Tosi GM, Martone G, Michieletto P. Mini-incision cataract surgery and toric lens implantation for the reduction of high myopic astigmatism in patients with pellucid marginal degeneration. *Eye (Lond)* 2015;29(5):637-642.

22 Wade M, Steinert RF, Garg S, Farid M, Gaster R. Results of toric intraocular lenses for post-penetrating keratoplasty astigmatism. *Ophthalmology* 2014;121(3):771-777.

23 de Sanctis U. Optics of Transplanted Grafts: IOL Calculation in Grafted Patients. de Sanctis U. eds. *Corneal Transplantation*. Cham: Springer International Publishing, 2015:163-172.