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REFRACTIVE SURPRISE IN FOUR CATARACT CASES WITH EXTREME AXIAL LENGTHS

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Abstract: *We present four operated cataract cases with extreme axial lengths where the biometric formulas used for intraocular lens dioptre calculation have made surprising or unusual predictions. The four operated cases were part of a study on 1192 eyes that compared the accuracy of five biometric formulas. Case 2 and 3 had an unexpected increase in both keratometric and refractive cylinder, compared to the preoperative cylinder. Case 1 with short axial length showed unexpectedly poor results for Hoffer Q formula and Case 4 showed good results for all five formulas, even Hoffer Q that is not recommended for long axial lengths. Refraction prediction errors altered by test-to-test variations in keratometry or surgically induced astigmatism, as well as other erroneous measured variables, could influence the results of studies analysing accuracy of biometric formulas, if the number of cases is great enough, and should not be ignored.*

INTRODUCTION

Prediction of postoperative refractive result after cataract or refractive lens exchange surgery has become more accurate with the progress of medical technology. Optic coherence biometers allow the measurement of several case specific variables that are used in biometric formulas for calculation of the optimal intraocular implant dioptre. Therefore, correct measurement of these variables is crucial for avoiding refractive surprises. If any of the measured variables (axial length - AL, anterior chamber depth - ACD, lens thickness or keratometry) are erroneous, it could have an influence on the refractive prediction, depending on the biometric formula used. These errors can reflect poorly on the biometric formulas when evaluating their accuracy in clinical studies.

CASE REPORTS

The four operated cases were part of a study on 1192 eyes that compared the accuracy of five biometric formulas (Barrett Universal I, Haigis, Hoffer Q, Holladay 1, and SRK/T). They were selected and are presented as special cases with unusual postoperative refractive results, that did not resemble the majority of the other evaluated cases included in the study, nor the results presented in other published studies.

The data collection was approved by "Prof. Dr. Agrippa Ionescu" Emergency Hospital's Ethical Committee (Bucharest) after the patients have been informed about the benefits and risks of the surgical procedure and signed an informed consent.

The postoperative follow-up was done at one week and one month. The cases were part of a greater study analysing the accuracy of five different biometric formulas. Inclusion criteria for the study were: age 40 or over, endothelial cell count more than 1500 cells/mm^2, no corneal opacities, no retinal diseases, no previous ocular surgery or ocular trauma, normal central and peripheral retina.

The preoperative ocular examination included: best corrected distance visual acuity, manifest refraction, keratometry, tonometry and corneal pachymetry measured with the auto-refracto/kerato/tono/pachymeter Tonoref III (Nidek Co, Ltd, Japan), corneal endothelial cell count evaluated with the SP 3000P Specular Microscope (Topcon, Japan), optical coherence biometry measured with the Aladdin HW3.0 (Topcon, Japan), anterior segment slit-lamp biomicroscopy, mydriatic fundoscopy and optical coherence tomography performed with the Cirrus HD-OCT 4000 (Carl Zeiss Meditec AG, Germany).

Spherical equivalent formula predictions were performed with the Topcon Aladdin biometer using 5 incorporated biometric formulas: Barrett Universal II, Haigis, Hoffer Q, Holladay 1 and SRK/T. The formulas had the following constants, provided by the lens manufacturers:

- For the SN60WF intraocular lens (IOL) SRK/T A-constant of 119.0, Hoffer Q pACD of 5.640, Holladay 1 surgeon factor of 1.840, Haigis'a-constants of -0.769 for a0, 0.234 for a1 and 0.217 for a2 and Barrett lens factor of 1.884.
- For the ZCB00 IOL: SRK/T A-constant of 119.3, Hoffer Q pACD of 5.800, Holladay 1 surgeon factor of 2.020, Haigis'a-constants of -1.302 for a0, 0.210 for a1 and 0.251 for a2 and Barrett lens factor of 2.041.
- For the TFNT0 IOL: SRK/T A-constant of 119.100, Hoffer Q pACD of 5.630, Holladay 1 surgeon factor of 1.830, Haigis'a-constants of 1.390 for a0, 0.400 for a1 and 0.100 for a2 and Barrett lens factor of 1.936.

All four cases were operated on by the same surgeon (HTS) using the same surgical protocol, under local peribulbar anesthesia with 2.5 mL lidocaine 4% and 2.5 mL marcaine 0.5%. The phacoemulsification was performed using the INFINITI® Vision System phacoemulsifier (Alcon, U.S.). After surgery, all cases were prescribed the same treatment with

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topical antibiotic, corticosteroid, parasympatholytic mydriatic and lubricant. The first follow-up visit was in the first day postoperatively when the eye bandage was removed and slit lamp examination and mydriatic fundoscopy was performed. The second and the third follow-up visit, at one week and one month after surgery, consisted in uncorrected distance visual acuity, best corrected distance visual acuity, manifest refraction, keratometry, tonometry, corneal pachymetry, anterior segment slit lamp biomicroscopy and mydriatic fundoscopy. All the measurements were performed by the same technician on the same devices, including final postoperative manifest refraction, which was done on the same auto-kerato-refractometer one month after the surgery and was converted into its spherical equivalent. The refractive prediction error (RPE) was calculated for each case by subtracting the value of refractive prediction (RP) made by each biometric formula from the value of the postoperative spherical equivalent (SE) at one month postoperatively.

From all the eyes included in the main study, 4 cases (table no. 1) had surprising refractive postoperative results, that showed unusual predictions made by the used biometric formulas. Two cases had short and two had long axial lengths. All cases underwent standard cataract surgery with no postoperative complications.

Case 1 was a 74-year-old female with cataract in the right eye, AL of 20.68 mm, ACD of 2.95 mm and keratometric cylinder of -1.10 D at 171* (table no. 1 and figure no. 1). Considering the prediction made by the Hoffer Q formula (-0.03 D), it was opted for a 33.5 dioptre monofocal implant (ZCB00) for a target of emmetropia. At one month postoperatively, the manifers refraction was -01.00 sfD -0.75 cylD at 140*, SE was -01.25 D and keratometric values were K1 42.25, K2 43.25, -1.00 cylD at 167* (figure no. 1). The patient had an uncorrected distance visual acuity (UDVA) of 20/25 and a best corrected visual acuity (BCVA) of 20/20 with -0.75 sfD. In this case, SRK/T formula obtained the RPE closest to 0 (-0.15 D) (table no. 2). Hoffer Q formula (-1.22 D) had the greatest error among the 5 formulas. Barrett Universal II, also had a greater prediction error (-1.14 D) (table no. 2).

For Case 2, a 50-year-old female, the biometric measurements of the left eye showed the following parameters: AL of 21.6 mm, ACD of 3.21 mm and keratometric cylinder of -0.33 D at 176* (table no. 1 and figure no. 1). Considering the prediction made by the Hoffer Q formula (-0.03 D), it was opted for a 32.0 dioptre multifocal implant (TFNT0). At one month postoperatively, the manifers refraction was -00.00 sfD -1.25 cylD at 90*, SE was -00.75 D and keratometric values were K1 40.50, K2 41.25, -0.75 cylD at 105* (figure no. 1). For this case, Holladay 1 formula had the prediction error closest to 0 (-0.10 D) (table no. 2). The difference between the most positive prediction error (+0.40 D) for SRK/T and the most negative prediction errors, for the fourth-generation formulas Haigis (-1.24 D) and Barrett Universal II (-0.82D) was of 1.62 D and 1.22 D. In this situation however, the obtained RPEs might not have been influenced by the biometric formulas, but by the increase in both keratometric (-00.75 cylD 105*) and refractive cylinder (-01.25 cylD 90*), that was not expected, considering that the preoperative cylinder was -0.33 D.

Case 3 was a 63-year-old female with cataract in the left eye. The biometric measurements showed the following parameters: AL of 30.0 mm, ACD of 3.51 mm and keratometric cylinder of -0.42 D at 176* (table no. 1 and figure no. 2). Considering the prediction made by the SRK/T formula (-2.07 D), it was opted for a 7.5 dioptre monofocal implant (SN60WF) for a target of -2 D. At one month postoperatively, the manifers refraction was -01.25 sfD -1.25 cylD at 95*, SE was -02.00 D and keratometric values were K1 42.00, K2 42.75, -0.75 cylD at 100* (figure no. 2). BCVA was 20/20 with -02.00 sfD. The SRK/T formula had the smallest RPE (+0.07 D) (table no. 3). All formulas had the RPE in the interval of ±0.50 D except Holladay 1 (+0.61 D). Hoffer Q also showed good results (RPE= +0.42 D) despite it being recommended mainly for short axial lengths. Hover, as in previous case, in this case there was a difference between the preoperative keratometric cylinder (-0.42 D 76*) and the postoperative keratometric (-0.75 D 95*), and refractive cylinder (-1.25 D 100*).

Table no. 1. Measurements obtained by the low coherence optical biometer for each case

Case	AL (mm)	ACD (mm)	K1	K2	Cylinder	Lens type	Lens diopter	Eye
1	20.68	2.95	42.75	43.85	-1.10 D 171*	ZCB00	33.5	OD
2	21.6	3.21	40.84	41.17	-0.75 D 105*	TFNT0	32.0	OS
3	30.0	3.51	42.18	42.60	-0.42 D 107*	SN60WF	7.5	OS
4	28.9	3.69	43.09	44.20	-1.12 D 32*	SN60WF	9.0	OD

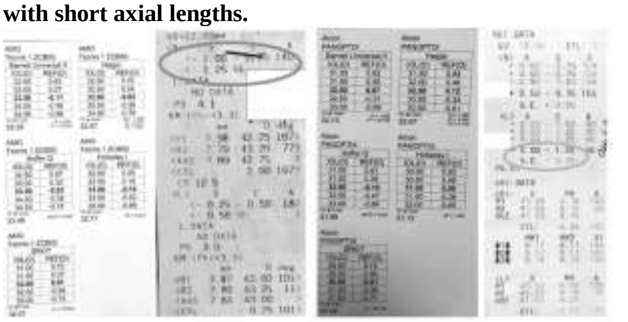
Table no. 2. Refractive predictions for each formula – cases with short axial lengths

Formula	Case 1 (AL: 20.68 mm, 33.5 D ZCB00)		Case 2 (AL: 21.60 mm, 32.0 D TFNT0)	
	RP (D)	RPE (RP -ES)	RP (D)	RPE (RP - ES)
BU II	-0.11	-1.14	+0.07	-0.82
Haigis	-0.39	-0.86	+0.49	-1.24
Hoffer Q	-0.03	-1.22	-0.10	-0.65
Holladay 1	-0.52	-0.73	-0.65	-0.10
SRK/T	-1.10	-0.15	-1.15	+0.40

Table no. 3. Refractive predictions for each formula – cases with long axial lengths

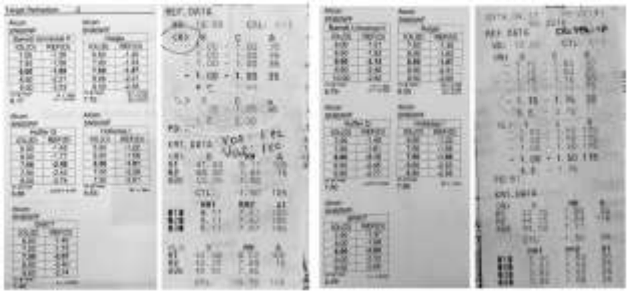
Formula	Case 3 (AL: 30.0 mm, 7.5 D SN60WF)		Case 4 (AL: 28.9 mm, 9.0 D SN60WF)	
	RP (D)	RPE (RP -ES)	RP (D)	RPE (RP - ES)
BU II	-1.58	-0.42	-2.15	-0.60
Haigis	-1.87	-0.13	-2.31	-0.44
Hoffer Q	-2.42	+0.42	-2.77	+0.02
Holladay 1	-2.61	+0.61	-2.92	+0.17
SRK/T	-2.07	+0.07	-2.33	-0.42

Figure no. 1. Biometry refractive prediction report and postoperative refraction for Case 1 (left) and Case 2 (right) with short axial lengths.



Case 1 Case 2

Figure no. 2. Biometry refractive prediction report and postoperative refraction for Case 3 (left) and Case 4 (right) with long axial lengths



Case 3 Case 4

Case 4 was a 44-year-old female with cataract in the right eye. The biometric measurements showed the following parameters: AL of 28.9 mm, ACD of 3.69 mm and keratometric cylinder of -01.12 D at 32* (table no. 1 and figure no. 2). Considering the prediction made by the SRK/T formula (-2.33 D), it was opted for a 9.0 dioptre monofocal implant (SN60WF) for a target of -2.00 D. It was the patient's choice to opt for a monofocal and not a toric implant. At one month postoperatively, the manifers refraction was -02.00 sfD -1.75 cylD at 30*, SE was -02.75 D and keratometric values were K1 42.75, K2 44.25, -1.50 cylD at 25* (figure no. 2). BCVA was 20/20 with -02.50 D sfD x -00.50 cylD at 30*. Contrary to expectations, in this case Hoffer Q showed the best results (RPE = +0.02 D) (table no. 3). All formulas except Barrett Universal II ((RPE= -0.60 D) had the RPE in the ±0.50 D interval.

DISCUSSIONS

The four operated cases were part of a study on 1192 eyes that compared the accuracy of five biometric formulas. These cases showed unexpected refractive results compared to the other cases included in the main study.

In the first case with short axial length (20.68 mm) and monofocal IOL, the SRK/T formula obtained the RPE closest to emmetropia. Hoffer Q formula, considered to be the most appropriate third generation biometric formula for short axial lengths (1-7), had the greatest error among the 5 formulas. Barrett Universal II, named the "universal" formula for its accuracy for all axial lengths (8-16) also had a greater prediction error. This inaccuracy of commonly used IOL power formulas to predict postoperative refractive error in short eyes has been documented by several studies (16-18) and could explain these results.

For the second case, a left eye with short axial length (21.6 mm) and multifocal IOL, Holladay 1 formula had the prediction error closest to emmetropia. There was an important difference between the most positive (+0.40 D) and the most negative (-1.24 D) RPE, showing great variability between formulas. However, there was an unexpected increase in both keratometric and refractive cylinder, compared to the preoperative cylinder. The obtained RPEs might have been influenced by these keratometric changes. It was either an erroneous initial keratometric measurement, or surgically induced astigmatism.

For the third case, a left eye with long axial length (30.0 mm) and monofocal implant, the SRK/T formula had the smallest RPE and all formulas except Holladay 1 had the RPE in the interval of ±0.50 D, even Hoffer Q, despite it being recommended mainly for short axial lengths. There was, however, as in the previous case, a difference between the preoperative and postoperative keratometric values. These changes influenced the obtained SE and altered the RPEs for the compared formulas.

The fourth case, a right eye with long axial length (28.9 mm) and monofocal IOL, showed good results for all formulas, and, surprisingly, Hoffer Q had RPE closest to 0.

Surgically induced astigmatism could be one reason for the increase in keratometric cylinder for some of the presented cases. It has been shown (19) that temporal incisions have smaller corneal and astigmatic changes in the early postoperative period, compared to nasal incisions. However, at 8 weeks postoperatively the two are comparable.(19) Other studies did not find significant differences between incision sites even at one or three months postoperatively.(20) Temporal incisions also induce a lower degree of SIA than superior ones.(21)

Another reason for variation in surgically induced astigmatism estimation could be due to test-to-test variations in keratometry. A study comparing four devices with incorporated keratometers (22) showed clinically significant astigmatism measurement variation. Even if the preoperative evaluation included at least three repeated measurements, depending on tear film and lid position, erroneous keratometric measurements could occur.

Refraction prediction errors altered by test-to-test variations in keratometry, surgically induced astigmatism, as well as other erroneous measured variables, could influence the results of studies analysing accuracy of biometric formulas, if the number of cases is great enough. These cases should be analysed individually.

Financial Disclosures

None of the other authors has any financial or proprietary interests to disclose.

Statement of Ethics

This study was conducted ethically in accordance with the World Medical Association Declaration of Helsinki. It was approved by "Prof. Dr. Agrippa Ionescu" Emergency Hospital's Ethical Committee (approval no., 61/18.12.2017; Bucharest, Romania)

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