

# Immersion Biometry for Intraocular Lens Power Calculation with Fourth-Generation Formulas

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**Background:** Fourth-generation formulas for intraocular lens power calculations, including the Barrett Universal II formula, the Olsen formula or the Holladay 2 formula, were thoroughly validated with optical biometry measurements. They precisely predict the effective lens position not only in normal eyes but also in eyes with unusual anatomy. However, in the setting of dense nuclear or posterior subcapsular cataracts, optical biometers fail to obtain accurate measurements and third-generation formulas, i.e. the Hoffer Q or the SRK/T, combined with ultrasound measurements are a method of choice. Considering that optical biometry was fine-tuned to immersion ultrasound, we hypothesize that fourth-generation formulas will yield precise intraocular lens power calculations with immersion ultrasound measurements.

**Methods:** We retrospectively analyzed 50 eyes of 50 patients who underwent uneventful cataract surgery. All patients had intraocular lens power calculated based on immersion ultrasound measurements. Refractive error predictions were compared between third-generation formulas and fourth-generation formulas.

**Results:** There were no statistically significant differences in the median absolute error between formulas. In the study, 86%, 88%, 86%, 84%, 88% and 80% of eyes were within 1 D of target refraction for the SRK/T, the Barrett II, the Hoffer Q, the Holladay 1, the Holladay 2 and the Olsen formula respectively.

**Conclusion:** Fourth-generation formulas combined with immersion ultrasound produced similar results to third-generation formulas. However, the percentage of eyes within 1 D of target refraction remains inferior to previously reported results for optical biometry measurements.

**Keywords:** intraocular lens, intraocular lens power, Barrett Universal formula, cataract

## Introduction

Precise calculation of the intraocular lens (IOL) power is a cornerstone of modern cataract surgery.<sup>1</sup> Therefore, various approaches, including thin and thick lens theory, artificial intelligence or ray tracing, have been undertaken to develop accurate formulas.<sup>1</sup> Recent studies prove that fourth-generation formulas, including the Barrett Universal II formula, the Olsen formula or the Holladay 2 formula, provide the most precise results over a wide range of axial lengths (ALs).<sup>2</sup> They were shown to significantly outperform third-generation formulas, e.g. the SRK/T or the Hoffer Q, which are reliable only for normal to long eyes and normal to short eyes respectively.<sup>2</sup>

Third-generation formulas predict the effective lens position (ELP) as a function of keratometry (K) and AL.<sup>3,4</sup> In contrast, fourth-generation formulas incorporate

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a more refined approach to ELP calculations – based on white to white (WTW), lens thickness (LT) and anterior chamber depth (ACD) measurements.<sup>2</sup>

However, as fourth-generation formulas were mainly validated with optical biometry data, their applicability is perceived as limited. As some popular biometers fail to obtain AL measurements in the setting of dense cataract or inability to fixate, third-generation formulas in conjunction with ultrasound remain a method of choice.<sup>5</sup>

It is of note that except for extremely long eyes, optical biometry was proved to produce similar measurements to immersion ultrasound.<sup>6</sup> Therefore, we hypothesize that fourth-generation formulas, combined with an immersion technique, would produce reliable refractive predictions.

Here, we wanted to compare refractive predictions of the Barrett Universal II formula, the Olsen formula and the Holladay 2 formula with the SRK/T formula, the Hoffer Q formula and the Holladay 1 formula, based on measurements of AL with immersion ultrasound.

## Methods

The study adhered to the guidelines of the Declaration of Helsinki. Considering the retrospective character of the study, it did not require approval by the Local Bioethical Committee at the Centre for Postgraduate Medical Education in Warsaw. Patient data were collected anonymously and remained confidential during the study.

## Patient Inclusion Criteria

This retrospective study includes analysis of 50 consecutive patients who underwent phacoemulsification and IOL implantation at the Department of Ophthalmology at the Centre for Postgraduate Medical Education in Warsaw, between 2017 and 2018. All eyes included in the study were measured with immersion ultrasound biometry and implanted with SN60AT IOL (Alcon, USA). Patients with diabetic retinopathy, macular degeneration, advanced glaucoma or any other systemic and ocular disorder which could affect the ELP and best corrected visual acuity (BCVA) to the level below 0.5 (measured with Snellen charts) were excluded.

## Preoperative Evaluation

BCVA was assessed according to Snellen charts. Slit lamp examination of the anterior and posterior segments was performed prior to surgery. Immersion biometry was performed with Ocuscan (Alcon, USA), whereas keratometry readings with the autorefractor keratometer GR-3100K

(Grand Seiko, Japan). IOL power was calculated with formulas preinstalled on IOL Master 700 (Zeiss, Germany) and Lenstar 900 (Haag-Streit, Switzerland) at the Department of Ophthalmology, Medical University of Warsaw. Formulas were utilized with the optical A constant (118.7) recommended by the manufacturer.

## Surgical Technique

One 2.2-mm temporal main incision and one 1.2-mm side incision followed by routine phacoemulsification were utilized for all surgeries. All surgeries were performed by 5 experienced surgeons.

## Postoperative Evaluation

Patients were evaluated at least one day, one week and one month after the surgery. Routine assessment of visual acuity and examination of the anterior and posterior segments were performed on each visit. Lens tilt or dislocation, inflammation, macular oedema and any other significant complication would have been recorded and would exclude the patient from the study.

## Data Analysis

We followed the guidelines on comparisons between IOL power formulas published by Hoffer et al.<sup>7</sup> In brief, mean numerical errors of every formula were optimized with the “Goal Seek” function in Excel (Microsoft, USA), so that the mean predicted refraction error for each formula was 0. Subsequently, we calculated the median absolute prediction error for each formula.

## Statistical Analysis

Power of the study was set at 80%, whereas a significance level at 5% and a sample size of 10 per group was calculated to detect a mean difference in predicted refractive error at the level of  $0.5 \pm 0.5$  D, an amount we consider to be clinically significant. Comparisons between the groups were accomplished with analysis of variance, i.e. Friedman test followed by Wilcoxon signed-rank post hoc test. Contingency tables were analysed with the chi-square test. All calculations were performed with Excel (Microsoft, USA) or Graphpad Prism 7 (Graphpad Software, USA).

## Results

Baseline characteristics of the group are presented in Table 1. There was no statistically significant difference in median absolute error between the Barrett Universal II

**Table 1** Baseline Characteristics of the Studied Group

Parameter	No./Value $\pm$ SD (Range)
No. of patients	50
No. of eyes	50
Flat meridian	43.21 $\pm$ 1.65 D (39.75, 46.75)
Steep meridian	44.16 $\pm$ 1.65 D (41.5, 47)
Axial length	23.72 $\pm$ 1.66 D (22.07, 28.03)
Anterior chamber depth	3.14 $\pm$ 0.45 mm (2.28, 4.43)
Lens thickness	4.62 $\pm$ 0.63 mm (2.97, 5.84)

**Notes:** All results are expressed as a number or mean  $\pm$  standard deviation (SD). Range is given in brackets.

formula, the Olsen formula, the Holladay 1 formula, the Holladay 2 formula, the SRK/T formula and the Hoffer Q formula (Table 2).

## Discussion

Here, we found that fourth-generation formulas paired with immersion ultrasound measurements provide reliable IOL power calculations. However, this approach leads to a lower percentage of eyes within 1 D than previously reported results for a combination of fourth- and third-generation formulas and optical biometry.<sup>2</sup>

It has been recently shown that fourth-generation formulas, including the Barrett Universal II formula, the Olsen formula and the Holladay 2 formula, which utilize optical measurements, significantly outperform third-generation formulas in a non-selected group of patients.<sup>8</sup> It is of note that the superiority of fourth-generation formulas lies primarily in their refined approach to estimation of ELP.<sup>9</sup> Here, we found that fourth-generation formulas combined with immersion biometry are not significantly more accurate than third-generation formulas.<sup>2</sup> Furthermore, we found that our results are significantly worse than previously reported calculations based on fourth- and third-generation formulas and optical biometry. Notably, this remains in line with previous studies.

This might be related to operator-dependent accuracy of measurements or less precise fixation techniques with immersion ultrasound.<sup>10</sup>

Therefore, it is of no surprise that all major guidelines on cataract surgery recommend optical biometry as a method of choice for AL measurements.<sup>11</sup> Optical biometry is operator independent and has been shown to yield repeatable and precise measurements over a range of ALs, except for extremely long eyes.<sup>12–14</sup> However, in the setting of dense cataracts or inability to fixate, optical measurements are inaccurate and need to be replaced by ultrasound biometry. Although the immersion A-scan was a benchmark for development of optical biometers,<sup>15</sup> our study proves that these measurements should not be regarded as interchangeable.<sup>12</sup> Firstly, a regression model which converts slightly longer optical AL (from corneal epithelium to retinal pigment epithelium) into ultrasound AL (from corneal epithelium to internal limiting membrane) does not always produce accurate results and A-constant fine-tuning or other modifications, e.g. Wang–Koch formula for long eyes, are required.<sup>13</sup> Secondly, it has been recently shown that there might be significant discrepancies in ACD and LT measurements between different modalities.<sup>10,16,17</sup> Finally, these differences may be further increased between operator-dependent, i.e., immersion ultrasound, and operator-independent techniques, i.e., optical biometry.

Our study is limited by a relatively narrow range of ALs. Therefore, it is difficult to apply the results of our study to extremely short or long eyes. Furthermore, as we included only uncomplicated cataract surgeries, no predictions can be made for eyes with unusual K or skewed anterior to posterior segment ratio. Additionally, we did not input WTW measurements into the Barrett Universal II formula or the Holladay 2 formula.

In conclusion, fourth- and third-generation formulas combined with immersion ultrasound measurements produced

**Table 2** Refractive Predictions

Formula	MNE	Mean	SD	Median AE	Percentage of Eyes Within the Range			
					$\pm$ 0.25	$\pm$ 0.5	$\pm$ 0.75	$\pm$ 1.0
SRK/T	-0.43	0	0.66	0.47	24	54	76	86
Hoffer Q	-0.45	0	0.63	0.43	30	54	76	86
Holladay 1	-0.49	0	0.63	0.41	30	52	64	84
Holladay 2	-0.52	0	0.69	0.42	30	54	68	88
Olsen	-0.3	0	0.77	0.41	24	50	72	80
Barrett	-0.57	0	0.70	0.45	24	50	74	88

**Abbreviations:** MNE, mean numerical error; median AE, median absolute error; SD, standard deviation.

similar IOL power predictions in our group of patients. However, larger studies are needed to confirm our findings.

## Disclosure

The authors declare no conflicts of interest in this work.

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