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ORIGINAL RESEARCH

Impact of Best Corrected Final Visual Acuity on the Performance of Intraocular Lens Power Calculations

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Purpose: To evaluate the impact of the best-corrected final visual acuity (BCFVA) on the accuracy of intraocular lens (IOL) power calculations.

Design, Setting and Methods: This is a retrospective observational study in a private practice setting, Lynwood, California, USA. We analyzed 1107 eyes undergoing standard monofocal cataract surgery, with IOL power calculated using the Barrett Universal II formula. We evaluated the Mean Prediction Error (MPE) and its standard deviation (SD), the Mean Absolute Error (MAE) and its SD and the percentage of eyes within ±0.50D and ±1.00D in relation to BCFVA.

Results: We analyzed 4 groups with BCFVA noted in LogMAR of ≤0.00, 0.02–0.10, 0.12–0.20 and 0.22–0.30. MPE was −0.030 ±0.321, −0.018±0.353, 0.015±0.369 and 0.070±0.421 D, respectively. MAE was 0.263±0.186, 0.282±0.213, 0.301±0.214 and 0.354 ±0.236 D, respectively. The percentage of eyes within ±0.50D was 85.9%, 82.6%, 81.5% and 75.5%, respectively. A subgroup analysis of the 1005 eyes with BCFVA of 0.20 LogMAR or better resulted in an MPE of −0.007±0.354 D, a MAE of 0.285±0.209 D and a percentage of eyes within ±0.50D of 82.8%. The difference between this subgroup and the group of eyes with a BCFVA 0.22–0.30 was statistically significant (p<0.001).

Conclusion: Better IOL power predictions were noted by limiting the study to eyes with BCFVA of 0.20 LogMAR or better.

Plain Language Summary: During cataract surgery, the clouded natural lens of the eye is removed and replaced with an intraocular lens, or IOL. Prior to surgery, calculations are required to determine the power of the IOL to be inserted in the eye at the time of surgery. Many studies evaluate the accuracy of such calculations by comparing the final refraction to the predicted one. Most of these patients are seniors and some of them present with concomitant retinal problems that limit the final visual acuity. Studies usually evaluate eyes that have achieved a vision of 0.30 LogMAR (20/40) or better. Our results showed that limiting the analysis to only those eyes that have achieved 0.20 LogMAR (20/32) or better will result in a more accurate evaluation of these predictions by eliminating those cases with poorer final vision that are prone to a higher variability in the post-operative refraction.

Keywords: intraocular lens power calculations, Barrett Universal II formula, post-operative visual acuity

Introduction

The use of an intraocular lens (IOL) to replace the natural lens of the eye has been a major advancement in cataract surgery. The pre-operative work-up requires an optical biometry to mainly measure the axial length, corneal diameter and power, anterior chamber depth and lens thickness. These values are then entered into one of the available IOL power formulas to calculate the required IOL power that will yield the best post-operative result. The accuracy of these predictions is a major indicator of surgical success and is best evaluated by comparing the post-operative refraction to the predicted one.

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The criteria for analyzing intraocular lens power (IOL) calculations accuracy have been well established. Editorials by Hoffer et al[1,2] and by Wang et al[3] recommend the analysis of eyes with a BCFVA of 0.30 LogMAR (20/40) or better. Most published studies[4–7] review the results of monofocal IOLs and limit the studies to eyes with BCFVA of 20/40 or better (LogMAR≤0.30) as recommended. One large study[8] also excluded cases with keratometric astigmatism over 4.00 D.

In 2008, Norrby[9] evaluated the sources of error in intraocular lens power calculations and reported a 26.98% relative error contribution from the postoperative refraction. We are herein postulating that eyes with a BCFVA exceeding 0.20 LogMAR exhibit greater inaccuracies during refractive measurements; most of these patients are seniors and some of them present with concomitant retinal problems that limit the final visual acuity.

The purpose of this study is to evaluate the impact of the BCFVA on the accuracy of intraocular lens (IOL) power calculations.

Patients And Methods

This study conformed to the ethics code based on the tenets of the Declaration of Helsinki. It is a comparative non-interventional study comprising a retrospective chart review of patients with a history of cataract surgery at one center. The study was approved by the Milkie-Shammas Surgery Center Institutional Review Board (Lynwood, CA). A waiver of informed consent was granted to allow use of de-identified patient data.

We analyzed 1107 eyes of 1107 patients that had undergone cataract surgery between September 2021 and September 2023. If both eyes of a patient were eligible to be included in the study, only the first operated eye was included. All eyes were measured with the Argos SS-OCT biometer, and all calculations were performed using the integrated Barrett Universal II formula.[10] Cataract surgery was uneventful in all cases with the implantation of an AcrySof SN60WF aspheric monofocal lens (Alcon, Fort Worth, TX) and had a BCFVA of 0.30 LogMAR (20/40) or better.

Postoperative (PO) refractive evaluation was performed 4–6 weeks after surgery, or 4 to 6 weeks after the second surgery if both eyes needed surgery. The operated eye was first checked objectively using an Auto Refractometer/keratometer (model ARK-1 from Nidek, Japan) followed by a subjective refraction performed by an ophthalmologist or an optometrist. The corrected post-operative distance visual acuity was measured using a high contrast ETDRS (Early Treatment Diabetic Retinopathy Study) chart at a distance of 6 meters under photopic lighting and recorded in LogMAR. The refraction results were documented with sphere, cylinder and axis readings, and the spherical equivalent value was noted.

The integrated Barrett II formula used a lens factor of 1.99 and resulted in a MPE of −0.05 for the entire series. MPE was zeroed using lens constant optimization from 1.99 to 2.02 prior to any statistical analysis. In each eye, the refractive prediction error (PE) is calculated by subtracting the predicted spherical equivalent refraction value from the spherical equivalent PO refraction value. The mean prediction error (MPE) and its standard deviation (SD), the mean absolute error (MAE) and its SD and the percentage of eyes with a PE within ±0.50 D and ±1.00 D were calculated for the 1107 eyes in the entire series, and in 4 groups based on the BCFVA measured in LogMAR (≤0.00, 0.02–0.10, 0.12–0.20, 0.22–0.30).

Statistical Analysis

All analyses were performed by a statistician using R (version 4.4.0, The R Foundation for Statistical Computing, Vienna, Austria). Comparisons between the groups were made using the heteroscedastic methods suggested by Holladay et al.[11] A final $p < 0.05$ was considered significant. Post-hoc power was 89% for comparing the prediction errors.

Results

We analyzed 1107 eyes of 1107 consecutive patients, 637 females (57.6%) and 469 males (42.4%) ranging in age from 23 to 94 years (average of 70.8±8.5 years). The operated eyes comprised 557 right eyes (50.3%) and 550 left eyes (49.7%).

Table 1 shows the baseline demographics and biometric data of all 1107 eyes and in the 4 groups. Data included the displayed axial length (AL), anterior chamber depth (ACD), lens thickness (LT), corneal diameter (CD) and average keratometric readings (Ks). Patients that achieved an FVA ≤0.00 LogMAR were relatively younger with slightly longer eyes. The differences between these values in all 4 groups were not statistically significant ($p>0.05$).

Table 1 Baseline Demographics and Biometric Measurements

BCFVA	ALL	≤0.00	0.02–0.10	0.12–0.20	0.22–0.30
Number	1107	199	407	399	102
Sex (%F)	57.6%	55.8%	58.5%	58.9%	52.0%
Side (%R)	50.3%	51.3%	51.6%	49.4%	47.1%
AL	23.49±0.96	23.66±0.92	23.50±0.93	23.38±0.99	23.54±0.95
ACD	3.18±0.38	3.24±0.40	3.20±0.36	3.12±0.40	3.15±0.36
LT	4.63±0.45	4.53±0.44	4.61±0.45	4.69±0.45	4.67±0.46
Ks	43.80±1.58	43.53±1.52	43.85±1.53	43.93±1.63	44.20±1.60
CD	12.20±0.54	12.28±0.52	12.21±0.54	12.15±0.57	12.14±0.51

Abbreviations: BCFVA, best-corrected final visual acuity in LogMAR; %F, percentage of females; %R, percentage of right eyes; AL, axial length in mm; ACD, anterior chamber depth in mm; LT, lens thickness in mm; Ks, average keratometric readings in diopters; CD, corneal diameter in mm.

The MPE for the entire series was 0.00±0.361 D (Table 2). We also calculated the MPE in the 4 groups based on BCFVA of LogMAR ≤0.00 (n=199), 0.02–0.10 (n=407), 0.12–0.20 (n=399) and 0.22–0.30 (n=102). MPE was −0.030±0.321, −0.018 ±0.353, 0.015±0.369 and 0.070±0.421 D, respectively, MAE was 0.263±0.186, 0.282±0.213, 0.301±0.214 and 0.354±0.236 D, respectively, and the percentage of eyes within ±0.50D was 85.9%, 82.6%, 81.5% and 75.5%, respectively.

The eyes that achieved a BCFVA of 0.22–0.30 LogMAR exhibited a relatively higher SD of the MPE, a higher MAE and a lower percentage of eyes within 0.50 D than the other 3 groups. Table 3 shows that the difference between the eyes that achieved a 0.22–0.30 LogMAR and the eyes that achieved a ≤0.00 LogMAR was statistically significant (p=0.04) but the difference between the eyes that achieved a 0.22–0.30 LogMAR and the eyes that achieved a 0.12–0.20 and 0.22–0.30 LogMAR was not statistically significant (p=0.27).

Table 2 Prediction Errors and Refractive Outcomes

	N	MPE±SD	MAE±SD	Range	Prediction [N (%)] Within	
					±0.50D	±1.00D
Entire series	1107	0.000±0.361	0.292±0.212	−0.882, 1.267	909 (82.1%)	1104 (99.7%)
Errors according to BCFVA in LogMAR						
≤0.00	199	−0.030±0.321	0.263±0.186	−0.793, 0.804	171 (85.9%)	199 (100%)
0.02–0.10	407	−0.018±0.353	0.282±0.213	−0.834, 1.078	336 (82.6%)	405 (99.5%)
0.12–0.20	399	0.015±0.369	0.301±0.214	−0.882, 0.919	325 (81.5%)	399 (100%)
0.22–0.30	102	0.070±0.421	0.354±0.236	−0.826, 1.267	77 (75.5%)	101 (99.0%)
Subgroup of all eyes with BCFVA of 0.20 LogMAR or better						
≤0.20	1005	−0.007±0.354	0.285±0.209	−0.882, 1.078	832 (82.8%)	1003 (99.8%)

Abbreviations: N, number of eyes; MPE, mean prediction error; MAE, mean absolute error; SD, standard deviation; BCFVA, best corrected final visual acuity.

Table 3 Matrix of Standard Deviations of Prediction Errors According to the Best Corrected Final Visual Acuity. P-values Were Computed Using the Heteroscedastic Method

BCFVA	SD	≤0.00	0.02–0.10	0.12–0.20	0.22–0.30
≤0.00	0.321	1			
0.02–0.10	0.353	0.36	1		
0.12–0.20	0.369	0.24	0.38	1	
0.22–0.30	0.421	**0.04**	0.27	0.27	1

Note: The bold number denotes statistical significance.
Abbreviations: BCFVA, best corrected final visual acuity in LogMAR; SD, standard deviation.

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We also analyzed a subgroup of 1005 eyes with a BCFVA of ≤0.20 LogMAR. This subgroup included all the eyes of the 3 groups with a BCFVA of ≤0.00, 0.02–0.10 and 0.12–0.20 LogMAR. MPE was −0.070±0.354 D, MAE was 0.285 ±0.209 D with 82.8% of eyes within ±0.50D. The difference between this subgroup of eyes with BCFVA ≤0.20 and the group of eyes with BCFVA 0.22–0.30 was statistically significant (p<0.001).

Discussion

In the present study, the Mean Prediction Error's SD and the MAE were higher in eyes with a BCFVA exceeding 0.20 LogMAR (worse than 20/32) than in eyes with a BCFVA of 0.20 LogMAR (20/32) or better. The difference between the two groups was statistically significant (p=0.01). Table 1 shows no major differences in the demographic and biometric data between the 4 groups. This is especially true for AL since it has been noted that changes in AL affect the refractive prediction errors.[12] It is worth noticing that eyes with BCFVA ≤0.00 LogMAR included more younger myopic patients with a slightly lower average age and a slightly higher mean AL. This is easily explained by the fact that myopic patients with healthy retinas might develop cataracts at a younger age; these patients are expected to end up with an excellent BCFVA. Also, the Barrett Universal II formula has been found to yield accurate refractive results in these myopic eyes that meet the benchmark criteria.[13]

The authors are postulating that eyes with a BCFVA exceeding 0.20 LogMAR exhibit greater inaccuracies during refractive measurements. Norrby[9] looked at all potential errors in IOL power calculations and reported a 26.98% relative error contribution from the postoperative refraction. Leinonen et al[14] evaluated the reproducibility of refractive error measurements in a mixed group (n=99) of healthy (n=22), cataractous (n=41) and pseudophakic eyes (n=36). Test–retest differences in determining the refractive error were within 0.50 D in 88% of the cases; this was true in 95% (56/59) of the cases when vision was ≤0.3 LogMAR and only in 68% (15/22) of the cases when vision was >0.30 LogMAR.

The decreased visual acuity in these older patients is often due to retinal changes. Complex retinal pathologies are correlated with lower contrast sensitivity and greater tolerance to defocus, resulting in increased test–retest variability during refraction. Rosser et al[15] demonstrated that optical defocus significantly increases the test-retest variability in visual acuity measurements, suggesting that eyes with lower visual acuity are more susceptible to greater defocus and therefore increased refractive variability. In our study, the refractive variability was minimized by first performing an objective evaluation by autorefraction[16] followed by a subjective evaluation by an optometrist or an ophthalmologist.[2]

Leung et al[17] showed that higher order aberrations and meridional anisotropy are more pronounced in patients with higher astigmatic error leading to larger variability in refractive measurements and overall visual performance. In their evaluation of the accuracy of intraocular lens calculation formulas in 18501 eyes following cataract surgery, Melles et al[8] excluded all eyes with keratometric cylinder >4.00 D. In our study, corneal topography was not routinely performed to exclude Form fruste keratoconus that might have been missed on slit-lamp examination.

A potential limitation to the study is the fact that the final refraction was usually performed 4 to 6 weeks after surgery. This time limit has been acceptable and used in most manuscripts. Some authors[18] believe that stabilization does not occur till 3 to 6 months after surgery. We believe that stabilization occurs much sooner with our less traumatic modern surgery and smaller corneal incisions.

In the present study, the MPE's SD and MAE were markedly higher when BCFVA is worse than 0.20 LogMAR (~20/32) than when BCFVA is 0.20 LogMAR or better (Table 2); the difference between the two groups was statistically significant (p=0.01). We recommend that all studies regarding IOL power calculations include only eyes with the BCFVA of 0.20 LogMAR or better. By doing so, the results will represent a more precise evaluation of the prediction errors by eliminating those cases with poorer BCFVA prone to a higher variability in the post-operative refraction process.

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Disclosure

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References

1. Hoffer KJ, Aramberri J, Haigis W, et al. Protocols for studies of intraocular lens formula accuracy. *Amer J Ophthalmol*. 2015;160:403–405. doi:10.1016/j.ajo.2015.05.029
2. Hoffer KJ, Savini G. Update on intraocular lens power calculation study protocols. The better way to design and report clinical trials. *Ophthalmology*. 2021;128:e115–e120. doi:10.1016/j.ophtha.2020.07.005
3. Wang LW, Koch DD, Hill W, Abulafia A. Pursuing perfection in intraocular lens calculations: III. Criteria for analyzing outcomes. *J Cataract Refract Surg*. 2017;43:999–1002. doi:10.1016/j.jcrs.2017.08.003
4. Kane JX, Van Heerden A, Atik A, Petsoglou C. Intraocular lens power formula accuracy: comparison of 7 formulas. *J Cataract Refract Surg*. 2016;42:1490–1500. doi:10.1016/j.jcrs.2016.07.021
5. Darcy K, Gunn D, Tavassoli S, Kane JX, Kane JX. Assessment of the accuracy of new and updated intraocular lens power calculation formulas in 10930 eyes from the UK national health service. *J Cataract Refract Surg*. 2020;46:2–7. doi:10.1016/j.jcrs.2019.08.014
6. Shammas HJ, Shammas MC, Jivrajka RV, Cooke DL, Potvin R. Effects on IOL power calculation and expected clinical outcomes of axial length measurements based on multiple vs refractive indices. *Clin Ophthalmol*. 2020;14:1511–1519. doi:10.2147/OPTH.S256851
7. Taroni L, Hoffer KJ, Pellegrini M, Lupardi E, Savini G. Comparison of the new Hoffer QST with 4 modern accurate formulas. *J Cataract Refract Surg*. 2023;49:378–384. doi:10.1097/j.jcrs.0000000000001126
8. Melles RB, Holladay JT, Chang WJ. Accuracy of intraocular lens calculation formulas. *Ophthalmology*. 2018;125:169–178. doi:10.1016/j.ophtha.2017.08.027
9. Norrby S. Sources of error in intraocular lens power calculation. *J Cataract Refract Surg*. 2008;34:368–376. doi:10.1016/j.jcrs.2007.10.031
10. Barrett GD. An improved universal theoretical formula for intraocular lens implants. *J Cataract Refract Surg*. 1993;19:713–720. doi:10.1016/S0886-3350(13)80339-2
11. Holladay JT, Wilcox RR, Koch DD, Wang L. Review and recommendations for univariate statistical analysis of spherical equivalent prediction error for IOL. *J Cataract Ref Surg*. 2021;47;(1):65–77
12. Shammas HJ, Taroni L, Pellegrini M, Shammas MC, Jivrajka RV. Accuracy of newer intraocular lens power formulas in short and long eyes using sum-of-segments biometry. *J Cataract Refract Surg*. 2022;48:1113–1120. doi:10.1097/j.jcrs.0000000000000958
13. Abulafia A, Barrett GD, Rotemberg M, et al. Intraocular lens power calculation for eyes with an axial length greater than 26.0 mm: comparison of formulas and methods. *J Cataract Refract Surg*. 2015;41:548–556. doi:10.1016/j.jcrs.2014.06.033
14. Leinonen J, Laakkonen E, Laatikainen L. Repeatability (test-retest variability) of refractive error measurement in clinical settings. *Acta Ophthalmol Scand*. 2006;84:532–536. doi:10.1111/j.1600-0420.2006.00695.x
15. Rosser DA, Murdoch IE, Cousens SN. The effect of optical defocus on the test-retest variability of visual acuity measurements. *Invest Ophthalmol Vis Sci*. 2004;45:1076–1079. doi:10.1167/iovs.03-1320
16. Lior O, Angela J, Barrett GD. Autorefraction as an objective method to evaluate accuracy of intraocular lens calculation formulas. *J Refract Surg*. 2022;38:580–586. doi:10.3928/1081597X-20220715-01
17. Leung TW, Li RW, Kee CS. Meridional anisotropy of foveal and peripheral resolution acuity in adults with emmetropia, myopia, and astigmatism. *Invest Ophthalmol Vis Sci*. 2021;62:11. doi:10.1167/iovs.62.10.11
18. Fernandez J, Rodriguez-Vallejo M, Pinero DP. Correspondence re: Hoffer et al. update on intraocular lens power calculation study protocol: the better way to design and report clinical trials. *Ophthalmology*. 2021;128:e17–e18. doi:10.1016/j.ophtha.2020.10.035