Clinical Ophthalmology

Dovepress
Taylor & Francis Group

Open Access Full Text Article

ORIGINAL RESEARCH

Comparison of Four Lens Power Formulas for Sutureless Scleral-Fixated Carlevale Lens

Agnieszka Dyrda[1,2], Liliana Araujo-Diaz[1], Amanda Rey[1], Maria S Pighin[1], Marta Pazos[3], Ignasi Jürgens[1]

[1]Institut Català de Retina, Barcelona, Spain; [2]Facultat de Medicina i Ciències de la Salut, Universitat de Barcelona (UB), Barcelona, Spain; [3]Department of Ophthalmology, Hospital Clínic de Barcelona, Universitat de Barcelona (UB), Barcelona, Spain; Institut d'Investigacions Mèdiques August Pi i Sunyer (IDIBAPS), Barcelona, Spain

Correspondence: Agnieszka Dyrda, Institut Català de Retina, Ganduxer 117, Barcelona, 08022, Spain, Tel +34 93 378 23 19, Fax +34 93 418 78 57, Email agnieszkaannadyrda@wp.pl

Purpose: To assess the predictability of intraocular lens (IOL) power calculation formulas for sutureless scleral fixation (SSF) of the Carlevale IOL.

Methods: A prospective, single-center, interventional case series was conducted to compare predicted refractive outcomes using the SRK/T, Barrett II, Hoffer Q, and Holladay 1 formulas in patients undergoing SSF of the Carlevale IOL. The main outcomes included mean prediction error (PE), median absolute error (MedAE), mean absolute error (MAE), and the percentage of eyes with a PE within ±0.50 and ±1.0 diopters (D).

Results: Sixty-nine eyes of 69 patients were included. Only the Barrett II formula resulted in a systematic myopic error (p=0.014). The PE of SRKT, HofferQ, and Holladay 1 was closer to 0, indicating that the post-operative refractive outcome was nearer to the predicted value than that of Barrett II (p=0.002, p<0.001, p=0.003, respectively). MedAE and MAE ranged from 0.41 to 0.53 D and 0.6 to 0.67 D, respectively, without significant differences between the formulas. The percentages of eyes with PE within ±0.50 and ±1.00 D varied from 47.8 to 56.5% and 79.7 to 87%, respectively, showing no significant differences across the assessed formulas.

Conclusion: The SRK/T, Hoffer Q, and Holladay 1 formulas provide favorable refractive outcomes for the SSF of Carlevale IOL. The Barrett II formula is less accurate and is not recommended due to its systematic myopic refractive error.

Keywords: Carlevale IOL, sutureless scleral fixation, IOL power formula, refractive results, refractive prediction error

Introduction

There is no clear evidence of the optimal intraocular lens (IOL) implantation technique in the absence of capsular support,[1] though sulcus implantation is gaining traction.[2] In fact, the use of this technique for secondary IOL implantation has risen from 7% in 2015 to 64% in 2021.[2] Sutureless methods have emerged to mitigate long-term suture complications.

The recently introduced Carlevale IOL,[3] a sutureless scleral-fixated IOL (SSF-IOL), offers favorable safety and visual outcomes. However, limited evidence exists regarding optimal refractive prediction formulas for the SSF of the Carlevale IOL.

Additionally, there is an indirect assumption that the effective lens position (ELP) is the same as the one obtained in a standard in-the-bag IOL placement, which is very likely not the case. On the contrary, higher variability of the IOL position is anticipated, so the true accuracy of IOL power calculation may be lower than expected.[4–8]

This study assesses the accuracy of four popular formulas for SSF Carlevale IOL in patients with insufficient capsular support.

Received: 22 April 2025
Accepted: 16 September 2025
Published: 2 October 2025

Methods

This prospective, single-center, non-comparative, interventional case series included patients with insufficient capsular support undergoing secondary IOL implantation with Carlevale IOL combined with 25-gauge (25G) pars plana vitrectomy (PPV). The study was approved by the Research Committee of the Institut Català de Retina and the external independent Research Ethics Committee (REC)/ Institutional Review Board (IRB) of the Grupo Hospitalario Quironsalud-Catalunya. The study followed the principles of the Declaration of Helsinki, and written informed consent was obtained. Inclusion criteria were complete pre-operative biometric data and post-operative refractive information 3 months after the surgery, when refraction is considered stable,[9] corrected distance visual acuity (CDVA) of 20/40 or better, since refraction accuracy decreases with VA.[9] One eye was randomly selected if both eyes met the eligibility criteria.[9] Previously existing ophthalmological pathologies were not a reason for exclusion if the patients met the above-mentioned inclusion criteria.

Pre-Operative and Post-Operative Evaluation

All patients underwent a comprehensive ophthalmological examination, including manifest refraction, within one month before and at least three months after surgery.

Routine pre-operative optical low-coherence interferometry data from IOLMaster 700 (version 1.88.1.64861; Carl Zeiss) was extracted. Biometry data was imported to calculate 2-variable vergence formulas:[10] Sanders-Retzlaff-Kraff theoretical (SRK/T), Hoffer Q, and Holladay 1 results using IOLMaster EyeSuite software. Since most cases had an abnormal anterior chamber (AC), and AC depth (ACD) was lacking, the Haigis, Olsen, Hill-RBF, and Kane formulas could not be used for IOL calculation. Nevertheless, we included the Barrett Universal II formula since the online calculator of the Asia-Pacific Association of Cataract and Refractive Surgeons (https://www.apacrs.org/barrett_universal2/) allows us to perform lens power calculation despite lacking anterior segment data. The IOL constant for power calculation was provided by the manufacturer and optimized during our clinical practice before initiating this study.

The power of the implanted IOL for each patient was used to calculate the predicted refractive outcomes for each evaluated formula. All calculations assumed the same IOL position as in-the-bag implantation. The target refraction was set to emmetropia.

The prediction error (PE) was defined as the difference between measured and predicted post-operative refractive spherical equivalent (SE) (measured refraction minus predicted refraction). A negative PE indicated more myopic outcomes than predicted, and a positive PE indicated more hyperopic outcomes. Absolute error (AE) was calculated as the absolute value of the difference between the SE and predicted refraction. Additional metrics included mean PE, median AE (MedAE), mean AE (MAE), and percentages of eyes with a PE within ±0.25 D, ±0.50 D, ±1.00 D, and ±2.00 D as suggested.[9,10]

SRK/T, Hoffer Q, and Holladay are here referred to as the 2-variable vergence formula according to Koch et al classification.[10] However, they are also traditionally called the second-generation formula[10] or, recently, the thin lens vergence formula without artificial intelligence.[11]

Surgical Technique

All procedures were performed by four different surgeons using the previously described technique.[12] A complete 25G PPV (Constellation, Alcon Laboratories, Inc.) was conducted in all cases using three trocars. Two trocars were inserted through the sulcus 1.5 mm from the limbus at 0° and 180° underneath scleral flaps, while a third trocar was placed through the pars plana. If necessary, the extraction of the subluxated crystalline lens or intraocular lens (IOL), capsular tension ring, or cataract was performed. In some cases, an endoscope (Endo Optiks, Inc.) was also utilized. The Carlevale IOL (Soleko, Italy), a single-piece acrylic hydrophilic foldable lens, was implanted in all cases through a clear corneal incision. At the same time, the plugs were externalized via trocars positioned 1.5 mm from the limbus and were covered with a scleral flap.

Statistical Analysis

Sixty-eight patients were required to detect a significant difference in AE between the two formulas based on the differences found by Botsford et al[13] with a 10% loss in follow-up. Snellen VA was converted to the logarithm of the minimum angle of the resolution scale (logMAR) for the statistical analysis. The refractive prediction outcomes were reported in the following 3 ways: PE, MAE, and MedAE.[9,10]

The data were analyzed using SPSS (V-29.0) for Windows software (IBM Corp.2022) and Stata (V-14.1) (StataCorp, College Station, TX, USA). The variables were defined by frequency for qualitative values and mean ± standard deviation (SD) for quantitative values. A p-value <0.05 was considered significant. The normality of the data was checked using the Kolmogorov–Smirnov test. The Wilcoxon test was used to check post-operative CDVA gain. The 1-sample *t*-test was performed to evaluate whether the mean PE was statistically significantly different from zero. The Friedman test (with Wilcoxon signed-rank pairwise comparisons post-test) was used to evaluate differences in PE and MAE between formulas and the median test (Pearson´s chi-squared test) in MedAE. Bonferroni adjustment was used for multiple comparisons.[13,14] The Cochran Q test was performed to compare the percentage values within ±0.25, ±0.50, ±1.00 D, and ±2.00 D of PE.

Results

The study included 69 eyes of 69 patients (62.3% male) with a mean (SD) age of 71.6 (12.9) years. The mean (SD) axial length (AL), corneal power (K), and IOL implanted power were 25 (1.9) mm, 43.1 (2) D, and +17.6 (4.5) D, respectively. High myopia, previous PPV, and pseudoexfoliation syndrome were the primary predisposing factors (31.9%, 30.4%, and 29%, respectively), and IOL dislocation was the most common indication for surgery (76.8%). As mentioned, a complete 25G PPV was performed in all cases, with IOL exchange as the most frequent concurrent procedure (84.1%). Vitreous hemorrhage (n=5, 7.2%), mild, transient corneal edema (n=29, 42%), and cystic macular edema detected on OCT (n=20, 29%) were the most common intraoperative, early (<1 month), and late complications, respectively. No retinal detachment, endophthalmitis, or IOL subluxation was observed. Special attention was given to reverse pupillary block and iris or optic capture, as these complications can alter the IOL position, but were not detected in our cohort.

The mean (SD) follow-up was 12.1 (8.1) months. Demographic and clinical characteristics are summarized in Table 1.

Table 1 Baseline Characteristics

Characteristics	Data
Total No. of patients	69
Total No. of eyes	69
RE, No. (%)	39 (56.5)
LE, No. (%)	30 (43.5)
Gender, No. (%)	
Male	43 (62.3)
Female	26 (37.7)
Age (years)	
Mean±SD	71.6±12.9
Range	18, 93
AL (mm)	
Mean±SD	25.1±1.9
Range	21.7, 32.2
Short (<22.5), No. (%)	3 (4.3)
Avg (22.5, 25.5), No. (%)	44 (63.8)
Long (>25.5), No. (%)	22 (31.9)

(*Continued*)

 https://doi.org/10.2147/OPTH.S535925

Table 1 (Continued).

Characteristics	Data
WTW (mm)	
Mean±SD	12.1±0.5
Range	10.9, 13.1
Avg K (D)	
Mean±SD	43.1±2
Range	35.9, 46.6
IOL power (D)	
Mean±SD	17.6±4.5
Range	7, 26
Predisposing factors, No. (%)	
HM	22 (31.9)
PPV	21 (30.4)
PSX sd.	20 (29)
Ocular trauma	11 (15.9)
Complicated cataract surgery	4 (5.8)
Indication for secondary IOL, No. (%)	
Dislocated IOL	53 (76.8)
Aphakia	7 (10.1)
Subluxated crystalline lens	4 (5.8)
UGH sd.	4 (5.8)
Refractive surprise	1 (1.4)
Concurrent procedure, No. (%)	
25G PPV	69 (100)
IOL Exchange	58 (84.1)
CTR removal	9 (13)
Phacoemulsification	2 (2.9)
Endoscopy	20 (29)
VH removal	1 (1.4)
RD repair	4 (5.8)
Complications, No. (%)	
Intraoperative: VH, iris trauma, retinal tear	5 (7.2), 3 (4.3), 2 (2.9)
Early postop.: corneal edema, OHT, VH, CME, hypotony, uveitis	29 (42), 14 (20.3), 14 (20.3), 13 (18.8), 8 (11.6), 6 (8.7)
Late postop: CME, OHT, corneal edema	20 (29), 10 (20.3), 8 (11.6)
Follow-up, months	
Mean±SD	12.1±8.1
Range	3, 32

Abbreviations: 25G, 25 gauge; AL, axial length; Avg, average; CME, cystoid macular edema; CTR, capsular tension ring; D, diopter; HM, high myopia; IOL, intraocular lens; K, keratometry; LE, left eye; mm, millimetres; OHT, ocular hypertension; PPV, pars plana vitrectomy; PSX sd., pseudoexfoliation syndrome; RD, retinal detachment; RE, right eye; SD, standard deviation; UGH sd., uveitis-glaucoma-hyphema syndrome; VH, vitreous hemorrhage; WTW, white-to-white.

CDVA improved significantly from 0.43 (0.41) to 0.11 (0.12) logMAR ($p<0.001$). 85.5% of patients improved, 10.1% remained unchanged, and only 4.3% worsened the final CDVA due to recurrent cystoid macular edema. Post-operative SE averaged (SD) −0.25 (0.75) D, with a cylinder of −1.01 (0.81) D. No significant astigmatic change was observed in the IOL extraction group ($p=0.101$), whilst a significant decrease of astigmatism was observed when the endoscope was

Table 2 Refractive Accuracy of IOL Power Formulas

Formula	SRK/T	Barret II	Hoffer Q	Holladay 1
Constant	119.10	1.94	5.68	1.90
PE mean±SD	−0.11±0.92	−0.22±0.84	−0.07±0.84	−0.06±0.93
% of eyes within ±0.25 of PE	23.2	18.8	29	26.1
% of eyes within ±0.50 of PE	53.6	47.8	52.2	56.5
% of eyes within ±1.00 of PE	84.1	79.7	87	81.2
% of eyes within ±2.00 of PE	95.7	97.1	95.7	95.7
MAE mean±SD	0.65±0.66	0.67±0.53	0.6±0.60	0.65±0.68
MedAE	0.48	0.53	0.48	0.41

Abbreviations: AE, absolute error; IOL, intraocular lens; MAE, mean absolute error; MedAE, median absolute error; PE, predicted error.

used (p=0.040). Post-operative SE was within ±0.25 D, within ±0.5 D, within ±1.0 D, and within ±2.0 D of intended refraction in 28 of 69 patients (40.6%), 42 of 69 patients (60.9%), 61 of 69 patients (88.4%) and 68 of 69 patients (98.6%), respectively. These results were obtained with the SRK/T formula (A=119.10) used at the time of surgery as recommended by the manufacturer.

The refractive accuracy of IOL power formulas is displayed in Table 2, Figures 1 and 2. The negative refractive PE was statistically different from zero only for Barrett Universal II (a systematic myopic PE). The Friedman test revealed

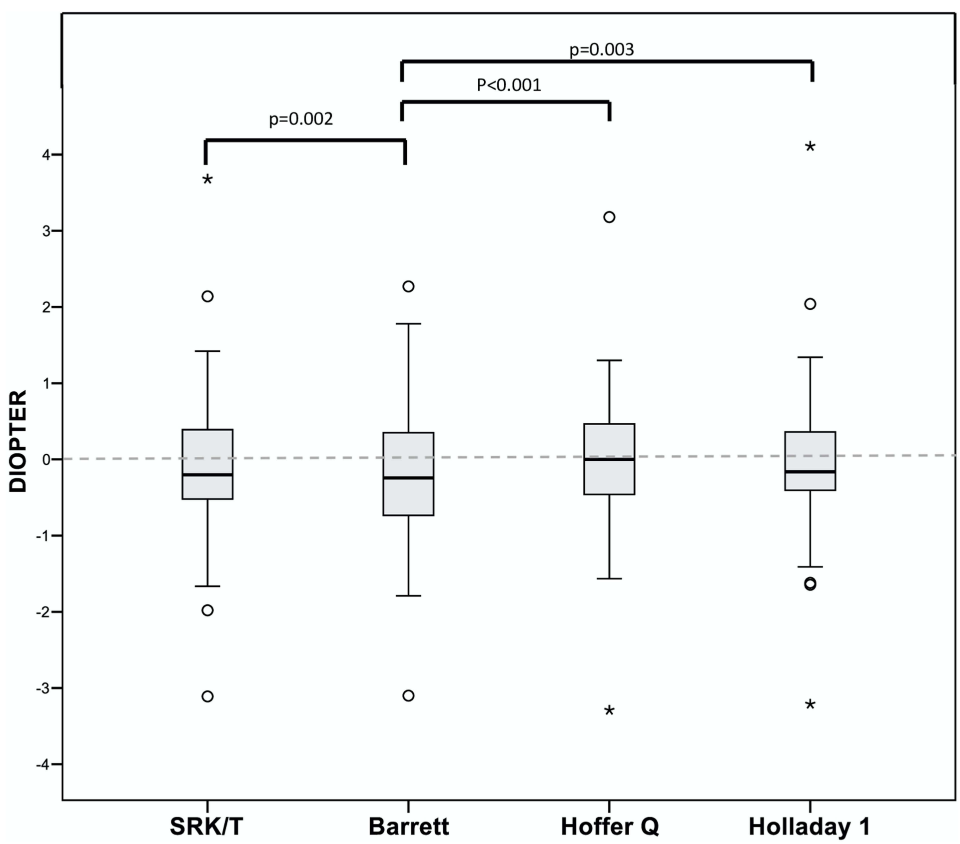

Figure 1 Box plot of the refractive prediction error for four lens power calculation formulas for the Carlevale.
Note: The gray dotted line represents emmetropia.

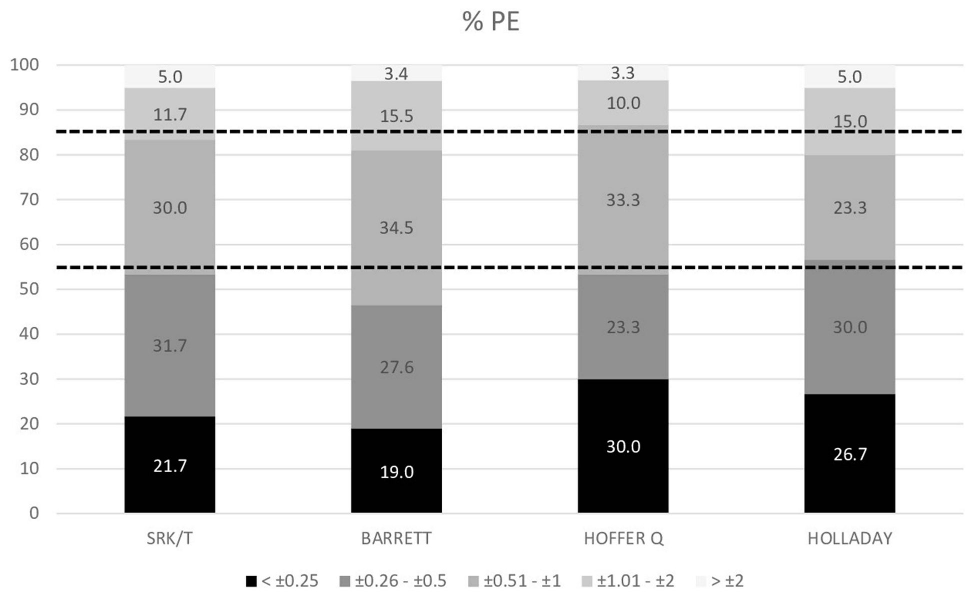

Figure 2 Histogram comparing the percentage of eyes with a given prediction error (PE).
Notes: The black dotted line represents 55% of eyes with PE for ±0.5D and 85% for ±1.0D from UK National Health Service guidelines.[15]

a significant difference in PE by formula (p=0.004). Post hoc analysis, using Wilcoxon signed-rank pairwise comparisons for nonparametric samples, demonstrated a significant difference between pairs: SRK/T and Barrett II (p=0.002), Hoffer Q and Barret II (p<0.001) and Holladay 1 and Barret II (p=0.003). When adjusted for multiple comparisons using Bonferroni correction, pairwise comparisons remained statistically significant (p<0.0083).

The SRK/T, Hoffer Q, and Holladay 1 formulas were significantly closer to target emmetropia (Figure 1).

MAE and MedAE did not differ significantly across formulas (p=0.145 and p=0.641, respectively).

The Cochran Q test did not reveal any significant difference regarding the percentage of eyes with a PE within ± 0.25 D (p=0.421), ± 0.50 D (p = 0.404), ±1.0 D (p= 0.232), and 2.0 D (p = 0.733) between formulas, as detailed in Table 2 and Figure 2.

Discussion

The secondary SSF of Carlevale IOL gained popularity due to its relative simplicity, short surgical time, safety profile, and ability to restore vision in patients with insufficient capsular support. However, limited data exist on the accuracy of IOL power calculation and refractive outcomes.

Over time, various IOL power calculation formulas have been developed for special situations, like phakic lens formulas or post-refractive formulas. However, no specific formula exists for aphakic patients. As a result, calculation formulas for in-the-bag IOLs are often used in patients without capsular support. Still, we expect higher variability in the ELP compared to standard in-the-bag implantation or sulcus placement with optic capture.[16]

Since ACD data were often missing, we relied on 2-variable vergence formulas (SRK/T, Hoffer Q, and Holladay 1). Those formulas are based on AL and K.[10,11] The Barrett II formula was also considered, as it has been used in other studies for calculating iris and scleral-fixated IOL power.[6,17] Its online platform permits lens power calculation even when the anterior segment data is missing. The application of different formulas with more variables was not possible because the necessary data could not be obtained in cases of dislocated IOL or aphakia. Furthermore, although "newer" is often better, it is not always the case; in more complex eyes, comparable accuracy was found between two 2-variable vergence formulas and newer formulas.[10,18] This may be the case with ELP prediction, which remains a challenge,[10] the fundamental issue, since the accuracy of the refractive power of the IOL implant depends not only on the accuracy of the preoperative biometric data but most of all on ELP estimation resulting from the selection of the appropriate formula.

Numerous case series studies have been reported on secondary IOL implantation in the sulcus. However, most studies are retrospective, involve small samples, employ various lens models and techniques, and lack a robust methodology for refractive analysis. Consequently, results are often contradictory, making precise conclusions challenging.

When placing the IOL in the sulcus, which position is more anterior, some recommend targeting an IOL that is 0.50 D to 1.00 D more hyperopic.[6,7,19–22] Brunin et al[23] reported that sutured scleral-fixated IOLs had the most myopic mean PE (SD) −0.23 (0.79) D compared to other IOL locations, though hyperopic PE (+0.08 D) has also been observed.[24]

For scleral-sutured IOLs, post-operative mean PE (SD) showed a slight myopic shift in all formulas: Barrett II: −0.15 (0.87) D, SRK/T: −0.10 (0.81 D), Holladay 2: −0.15 (0.84) D, Haigis: −0.28 (0.94) D, except Hoffer Q: +0.01 (0.80) D.[13] In long eyes (AL>25mm), PE was consistently myopic.[13] However, the statistical significance of these differences was not assessed.[13,23,24]

Sutureless intrascleral fixation of IOLs has emerged as an alternative to sutured scleral fixation of posterior chamber IOL. This procedure typically involves creating two scleral tunnels 180° apart to secure the haptics of a 3-piece IOL. Variations of this technique have shown mixed refractive outcomes, ranging from myopic shift (−0.21[25] and −0.57 D[26]) to hyperopic shift (from +0.04 to +0.85 D).[6–8,22] The hyperopic shift was observed for Holladay 2 and Barrett II (+0.78 and +0.04, respectively).[8]

The Carlevale IOL was recently introduced as an on-label lens for sutureless transscleral fixation. Of the limited studies reporting refractive outcomes with this lens,[4,27–32] most found mean (SD) myopic PE ranging from −0.04 (0.74) D[5] to −0.31 (0.71),[29,30] though mean (SD) hyperopic PE +0.46 (0.36) D[5,31] has also been observed. We noted negative mean PE (SD) across the cohort from −0.06 (0.93) to −0.22 (0.84) D, with Barrett II outcomes being significantly more myopic than expected.

The most used formula for Carlevale IOL power calculations is the SRK/T, followed by the Hoffer Q, Holladay 1, and Barrett II.[4,5,28,29,31,32] Previous studies by Vaiano et al,[4] Schranz et al[5] and Courat et al[31] found no significant differences between the 2-variable vergence formulas. Furthermore, no differences were observed when these formulas were compared to the Barrett II formula. However, these findings were based on studies involving a small number of eyes: 25, 29, and 30, respectively. In contrast, our study, which utilized a pre-calculated sample size, revealed that Barrett II was significantly less accurate than the SRK/T, Hoffer Q, and Holladay 1 formulas. Although the Barrett Universal II formula was originally designed to enhance IOL calculation precision using AC data, our findings indicate reduced accuracy when ACD is unavailable.

Although our cohort was larger than in previous studies, we could not evaluate formula performance in AL-dependent subgroups. Detecting statistically significant differences would require a minimum of 68 eyes per subgroup. More research is needed since some formulas demonstrate greater accuracy than others based on the AL data.[18,33] It would also be useful to investigate potential differences in the accuracy of IOL prediction formulas considering Carlevale IOL toricity, as this aspect has not been previously studied. However, as mentioned earlier, the number of toric IOLs implanted to date has been insufficient to draw a statistically significant conclusion.

The variability of the IOL position in the sulcus can impact refractive outcomes. Contributing factors include the distance of sclerotomies from the limbus, white-to-white distance, AL, IOL diameter, haptic angle, and whether anterior or posterior vitrectomy was performed.[22,34] Some studies suggest that pars plana vitrectomy (PPV) may lead to myopic outcomes[34] which were not observed with our 2-variable vergence formulas. Moreover, we did not detect a hyperopic shift, despite all plugs being positioned 1.5 mm from the limbus. In contrast, Abby et al reported a hyperopic shift of 0.23D when comparing the placement of a three-piece IOL at 1.5 mm versus 2 mm from the limbus. In scleral fixation techniques, the distance from the limbus varied from 1 mm to nearly 2.5 mm.[35,36]

Moreover, placing an IOL in the sulcus is a "blind" procedure without an endoscopic visualization. UBM studies have shown that only 55% of haptics sutured to the sclera were correctly positioned in the sulcus, with 27.5% placed more anteriorly and 17.5% posteriorly.[37] Misplacement of the Carlevale IOL[12,17] could similarly increase refractive variability.

Furthermore, surgical technique and experience significantly influence outcomes. Our study included cases operated on by four surgeons with varying expertise levels, enhancing our results' generalizability. This contrasts with single-surgeon studies[4,5] that may not reflect broader clinical practice.

High refractive accuracy is essential for patient satisfaction,[9] but is challenging in complicated cataract surgeries or secondary IOL implantation. The UK National Health Service recommends achieving PE within ±0.50 D for at least 55% and within ±1.00 D for 85% of eyes.[15] Our best results, reached with Holladay 1 and Hoffer Q, met these benchmarks.

However, outcomes for Carlevale IOL still lag those for uncomplicated in-the-bag IOL implantation,[38] highlighting the need for further optimization.

This study, the largest prospective analysis of Carlevale lens power calculations up to date, has several limitations: first, the relatively small sample despite statistical pre-specification; second, the absence of a control group for comparison with other scleral fixation techniques or other IOLs; third, low representation of short eyes in the sample, which may limit the generalization of our results in this kind of eye; and forth, the lack of heteroscedastic statistics to compare PE standard deviation as recommended by Holladay et al.[39]

In the era of refractive cataract surgery, the refractive outcomes have gained importance for both surgeons and patients. It is also relevant in complicated cases where the IOL must be fixed to the sclera, as those patients were spectacle-free before.

Although the results are not as good as those obtained with modern phacoemulsification combined with in-the-bag IOL implantation, our findings confirm that 2-variable vergence formulas are accurate for secondary Carlevale IOL implantation. Furthermore, the Barrett II formula demonstrated significantly lower precision and a higher tendency towards myopic outcomes compared to other formulas, suggesting that it should not be the preferred choice.

Further research is needed to optimize refractive results and explore underrepresented subgroups, such as toric IOLs and eyes with extreme AL.

Acknowledgment

The authors thank Néstor Ventura-Abreu, MD, Ph.D., and Antonio Morilla, Ph.D., for their statistical contributions.

Disclosure

Dr Marta Pazos reports grants and/or personal fees from Carl Zeiss Meditec, Abbvie, Thea, Glaukos, outside the submitted work. The authors report no other conflicts of interest in this work.

References

1. Shen JF, Deng S, Hammersmith KM, et al. Intraocular lens implantation in the absence of zonular support: an outcomes and safety update: a report by the American Academy of Ophthalmology. *Ophthalmology*. 2020;127(9):1234–1258. doi:10.1016/j.ophtha.2020.03.005
2. Kaufmann GT, Boucher N, Sharma C, Starr MR. Trends in secondary intraocular lens surgery among vitreoretinal surgeons. *Ophthalmol Retina*. 2023;7(11):965–971. doi:10.1016/j.oret.2023.07.008
3. Veronese C, Maiolo C, Armstrong GW, et al. New surgical approach for sutureless scleral fixation. *Eur J Ophthalmol*. 2020;30(3):612–615. doi:10.1177/1120672120902020
4. Vaiano AS, Hoffer KJ, Greco A, et al. Accuracy of IOL power calculation using the new Carlevale sutureless scleral fixation posterior chamber IOL. *J Refract Surg*. 2021;37(7):472–476. doi:10.3928/1081597X-20210401-01
5. Schranz M, Reumüller A, Kostolna K, Novotny C, Schartmüller D, Abela-Formanek C. Refractive outcome and lens power calculation after intrascleral intraocular lens fixation: a comparison of three-piece and one-piece intrascleral fixation technique. *Eye Vis*. 2023;10(1):1–12. doi:10.1186/s40662-023-00341-6
6. McMillin J, Wang L, Wang MY, et al. Accuracy of intraocular lens calculation formulas for flanged intrascleral intraocular lens fixation with double-needle technique. *J Cataract Refract Surg*. 2021;47(7):855–858. doi:10.1097/j.jcrs.0000000000000540
7. Aykut V, Esen F, Sali F, Oguz H. Refractive outcome of trocar-assisted sutureless scleral fixation with 3-piece intraocular lenses. *Int Ophthalmol*. 2021;41(8):2689–2694. doi:10.1007/s10792-021-01824-y
8. Yuan A, Mustafi D, Banitt MR, Rezaei KA. Long-term outcomes of modified glued versus flanged intrascleral haptic fixation techniques for secondary intraocular lenses. *Graefe's Arch Clin Exp Ophthalmol*. 2022;260(9):2887–2895. doi:10.1007/s00417-022-05647-0
9. Hoffer KJ, Aramberri J, Haigis W, et al. Protocols for studies of intraocular lens formula accuracy. *Am J Ophthalmol*. 2015;160(3):403–405.e1. doi:10.1016/j.ajo.2015.05.029
10. Koch DD, Hill W, Abulafia A, Wang L. Pursuing perfection in intraocular lens calculations: i. Logical approach for classifying IOL calculation formulas. *J Cataract Refract Surg*. 2017;43(6):717–718. doi:10.1016/j.jcrs.2017.06.006
11. Savini G, Hoffer KJ, Kohnen T. IOL power formula classifications. *J Cataract Refract Surg*. 2024;50(2):105–107. doi:10.1097/j.jcrs.0000000000001378
12. Dyrda A, Pighin MS, Jürgens I. Endoscope-assisted carlevale lens implantation in patients without capsular support: a novel surgical approach to ensure correct lens positioning. *Retina*. 2023;43(12):2084–2088. PMID: 35395658. doi:10.1097/IAE.0000000000003496
13. Botsford BW, Williams AM, Conner IP, Martel JN, Eller AW. Scleral fixation of intraocular lenses with gore-tex suture: refractive outcomes and comparison of lens power formulas. *Ophthalmol Retina*. 2019;3(6):468–472. doi:10.1016/j.oret.2019.02.005
14. Melles RB, Holladay JT, Chang WJ. Accuracy of intraocular lens calculation formulas. *Ophthalmology*. 2018;125(2):169–178. doi:10.1016/j.ophtha.2017.08.027
15. Gale RP, Saldana M, Johnston RL, Zuberbuhler B, McKibbin M. Benchmark standards for refractive outcomes after NHS cataract surgery. *Eye*. 2009;23(1):149–152. doi:10.1038/SJ.EYE.6702954

16. Millar ERA, Allen D, Steel DHW. Effect of anterior capsulorhexis optic capture of a sulcus-fixated intraocular lens on refractive outcomes. *J Cataract Refract Surg*. 2013;39(6):841–844. doi:10.1016/j.jcrs.2012.12.034
17. Mularoni A, Imburgia A, Forlini M, Rania L, Possati GL. In vivo evaluation of a 1-piece foldable sutureless intrascleral fixation intraocular lens using ultrasound biomicroscopy and anterior segment OCT. *J Cataract Refract Surg*. 2021;47(3):316–322. doi:10.1097/j.jcrs.0000000000000444
18. Hoffer KJ, Savini G. IOL power calculation in short and long eyes. *Asia-Pacific J Ophthalmol*. 2017;6(4):330–331. doi:10.22608/APO.2017338
19. Suto C, Hori S, Fukuyama E, Akura J. Adjusting intraocular lens power for sulcus fixation. *J Cataract Refract Surg*. 2003;29(10):1913–1917. doi:10.1016/S0886-3350(03)00250-5
20. Spokes DM, Norris JH, Ball JL. Refinement of lens power selection for sulcus placement of intraocular lens. *J Cataract Refract Surg*. 2010;36 (8):1436–1437. doi:10.1016/J.JCRS.2010.05.005
21. Dubey R, Birchall W, Grigg J. Improved refractive outcome for ciliary sulcus-implanted intraocular lenses. *Ophthalmology*. 2012;119(2):261–265. doi:10.1016/j.ophtha.2011.07.050
22. Abbey AM, Hussain RM, Shah AR, Faia LJ, Wolfe JD, Williams GA. Sutureless scleral fixation of intraocular lenses: outcomes of two approaches. The 2014 Yasuo Tano Memorial Lecture. *Graefe's Arch Clin Exp Ophthalmol*. 2014;253(1):1–5. doi:10.1007/s00417-014-2834-9
23. Brunin G, Sajjad A, Kim EJ, et al. Secondary intraocular lens implantation: complication rates, visual acuity, and refractive outcomes. *J Cataract Refract Surg*. 2017;43(3):369–376. doi:10.1016/j.jcrs.2016.12.024
24. Terveen DC, Fram NR, Ayres B, Berdahl JP. Small-incision 4-point scleral suture fixation of a foldable hydrophilic acrylic intraocular lens in the absence of capsule support. *J Cataract Refract Surg*. 2016;42(2):211–216. doi:10.1016/j.jcrs.2015.10.068
25. Yamane S, Sato S, Maruyama-Inoue M, Kadonosono K. Flanged intrascleral intraocular lens fixation with double-needle technique. *Ophthalmology*. 2017;124(8):1136–1142. doi:10.1016/j.ophtha.2017.03.036.24
26. Todorich B, Stem MS, Kooragayala K, et al. Structural analysis and comprehensive surgical outcomes of the sutureless intrascleral fixation of secondary intraocular lenses in human eyes. *Retina*. 2018;38(Suppl 1):S31–S40. doi:10.1097/IAE.0000000000001941
27. Barca F, Caporossi T, de Angelis L, et al. Trans-scleral plugs fixated IOL: a new paradigm for sutureless scleral fixation. *J Cataract Refract Surg*. 2020;46(5):716–720. doi:10.1097/j.jcrs.0000000000000135
28. Fiore T, Messina M, Muzi A, et al. Comparison of two different scleral fixation techniques of posterior chamber Carlevale lens. *Medicine*. 2021;100 (32):e26728. PMID: 34397876; PMCID: PMC8360456. doi:10.1097/MD.0000000000026728
29. Rouhette H, Meyer F, Pommier S, et al. FIL-SSF Carlevale intraocular lens for sutureless scleral fixation: 7 recommendations from a serie of 72 cases. MICA study (Multicentric Study of the Carlevale IOL). *J Fr Ophtalmol*. 2021;44(7):1038–1046. doi:10.1016/j.jfo.2021.05.002
30. Seknazi D, Colantuono D, Tahiri R, Amoroso F, Miere A, Souied EH. Secondary sutureless posterior chamber lens implantation with two specifically designed IOLs: iris claw lens versus sutureless trans-scleral plugs fixated lens. *J Clin Med*. 2021;10(10):2216. doi:10.3390/jcm10102216
31. Courat N, Gobert F, Naudin T, Ducloux A, Alleyrat C, Leveziel N. Refractive outcomes after scleral fixation of the carlevale intraocular lens. *J Refract Surg*. 2024;40(8):e527–e532. doi:10.3928/1081597X-20240611-04
32. Fiore T, Messina M, Muzi A, et al. A novel approach for scleral fixation using Carlevale lens. *Eur J Ophthalmol*. 2021;31(6):2947–2954. doi:10.1177/1120672121991358
33. Röggla V, Langenbucher A, Leydolt C, et al. Accuracy of common IOL power formulas in 611 eyes based on axial length and corneal power ranges. *Br J Ophthalmol*. 2021;105(12):1661–1665. doi:10.1136/BJOPHTHALMOL-2020-315882
34. Byrne S, Ng J, Hildreth A, Danjoux JP, Steel DH. Refractive change following pseudophakic vitrectomy. *BMC Ophthalmol*. 2008;8:19. doi:10.1186/1471-2415-8-19
35. Duffey RJ, Holland EJ, Agapitos PJ, Lindstrom RL. Anatomic study of transsclerally sutured intraocular lens implantation. *Am J Ophthalmol*. 1989;108(3):300–309. doi:10.1016/0002-9394(89)90121-9
36. Pavlin CJ, Rootman D, Arshinoff S, Harasiewicz K, Foster FS. Determination of haptic position of transsclerally fixated posterior chamber intraocular lenses by ultrasound biomicroscopy. *J Cataract Refract Surg*. 1993;19(5):573–577. doi:10.1016/S0886-3350(13)80002-8
37. Sewelam A, Ismail AM, El Serogy H. Ultrasound biomicroscopy of haptic position after transscleral fixation of posterior chamber intraocular lenses. *J Cataract Refract Surg*. 2001;27(9):1418–1422. doi:10.1016/S0886-3350(01)00791-X
38. Behndig A, Montan P, Stenevi U, Kugelberg M, Zetterström C, Lundström M. Aiming for emmetropia after cataract surgery: Swedish National Cataract Register study. *J Cataract Refract Surg*. 2012;38(7):1181–1186. doi:10.1016/j.jcrs.2012.02.035
39. Holladay JT, Wilcox RR, Koch DD, Wang L. Review and recommendations for univariate statistical analysis of spherical equivalent prediction error for IOL power calculations. *J Cataract Refract Surg*. 2021;47(1):65–77. doi:10.1097/J.JCRS.0000000000000370