American Journal of Ophthalmology Case Reports 34 (2024) 102037

Contents lists available at ScienceDirect

American Journal of Ophthalmology Case Reports

journal homepage: www.ajocasereports.com/

Intraocular lens power calculation using total keratometry and ray tracing in eyes with previous small incision lenticule extraction – A case series

Roman Lischke [a,b], Rainer Wiltfang [c,d], Martin Bechmann [c,d], Thomas C. Kreutzer [a], Siegfried G. Priglinger [a,e], M. Dirisamer [a,e], Nikolaus Luft [a,e,*]

[a] University Eye Hospital, Ludwig-Maximilians-University, Munich, Germany
[b] Department of Ophthalmology and Optometry, Medical University of Innsbruck, Austria
[c] SMILE Eyes Clinic, Munich, Germany
[d] SMILE Eyes Clinic, Trier, Germany
[e] SMILE Eyes Clinic, Austria

ARTICLE INFO

Keywords:
SMILE
Cataract
IOL calculation
Ray tracing
Total keratometry (TK)

ABSTRACT

Purpose: To assess the IOL power calculation accuracy in post-SMILE eyes using ray tracing and a range of total keratometry based IOL calculation formulae.

Observations: Ray tracing showed excellent predictability in IOL power calculation after SMILE and its accuracy was clinically comparable with the Barrett TK Universal II and Haigis TK formula.

Conclusions and importance: Incorporating posterior corneal curvature measurements into IOL power calculation after SMILE seems prudent. The ray tracing method as well as selected TK-based formulae yielded excellent accuracy and should be favored in post-SMILE eyes.

1. Introduction

Corneal refractive surgery is becoming increasingly popular. Small incision lenticule extraction (SMILE) is a method that has become indispensable in this field. Internationally released in 2011, more than 8 million procedures have already been performed worldwide.[1] As corneal refractive surgery is typically performed in a pre-cataract age population and the SMILE procedure itself is a relatively young method when compared with Excimer-based keratorefractive procedures (e.g. LASIK), there is currently a lack of data regarding accurate intraocular lens (IOL) calculation in cataractous eyes after SMILE. In the peer-reviewed literature, there are only two case reports,[2,3] as well as a more recent study published by our group including eleven eyes, which investigated IOL power calculation accuracy in actually performed cataract surgeries of post-SMILE eyes.[4] The residual body of evidence on post-SMILE IOL power calculation is limited by its purely theoretical approach as these reports do not include results from actually performed cataract surgeries.[5–7] In the foreseeable future, the number of patients with prior SMILE treatment requiring cataract surgery is expected to increase exponentially in light of the rising popularity of the SMILE technique as well as demographic developments. Inevitably, ophthalmologists will be challenged by accurate IOL power calculations for these patients.

Recently, total keratometry (TK) was introduced for total corneal power measurements, which incorporate measurements of the anterior and posterior corneal radii by using a combination of telecentric keratometry and swept-source optical coherence tomography.[8,9] The use of TK-based IOL power calculation has been proven to be beneficial not only in eyes with untreated corneas[10,11] but particularly in eyes that have undergone previous myopic excimer-based keratorefractive surgery.[6,10,12,13] In addition to these empirical formulae, the physical ray tracing approach, which does not require any prior clinical history, has also shown excellent outcomes in IOL power calculation for untreated[14] and post-keratorefractive surgery eyes,[15–18] including a previous report of our group on post-SMILE eyes undergoing cataract surgery.[4]

As of today, however, only theoretical data on the validity of TK-based IOL power calculation formulae for post-SMILE eyes are available.[19] Hence, the aim of this study was to evaluate the accuracy of different IOL power calculation formulae utilizing TK as well as the ray tracing method in post-SMILE eyes that underwent actual cataract surgery.

* Corresponding author. Department of Ophthalmology, Ludwig-Maximilians-University, Mathildenstraße 8, 80336, Munich, Germany.
E-mail address: nikolaus.luft@med.uni-muenchen.de (N. Luft).

https://doi.org/10.1016/j.ajoc.2024.102037
Received 8 October 2023; Received in revised form 24 January 2024; Accepted 28 February 2024
Available online 29 February 2024

2. Findings

This multicenter cross-sectional case series included six eyes of five patients that had previously undergone small incision lenticule extraction (SMILE) for treatment of myopia and/or myopic astigmatism and later underwent cataract surgery with IOL implantation. The study was conducted at the University Eye Hospital of the Ludwig-Maximilians-University (Munich, Germany), the SMILE Eyes Clinic Munich Airport (Germany) and the SMILE Eyes Clinic Linz (Austria).

2.1. SMILE and cataract surgery with IOL implantation

All SMILE procedures were performed by highly experienced corneal surgeons utilizing the VisuMax 500-kHz femtosecond laser platform (Carl Zeiss Meditec AG, Jena, Germany) according to the local standards of the participating centers. Surgical principles of the SMILE technique have been previously described in detail.[20] Cataract surgery, including the selection and insertion of an intracapsular IOL was conducted in accordance with the protocols established by the participating centers. The implanted IOL models and powers are summarized in Table 1.

2.2. IOL power calculation

Post-hoc IOL power calculation was performed utilizing dedicated ray tracing software (Okulix; Panopsis, Mainz, Germany, Version 9.01) based on preoperative corneal tomography scans (Pentacam HR; Oculus Optikgeräte GmbH, Wetzlar, Germany) as well as preoperative biometry and anterior chamber depth measurements (IOLMaster 700; Carl Zeiss Meditec AG, Jena, Germany). Moreover, the Barrett True K online calculator (Version 2.5 http://calc.apacrs.org/Barrett_True_K_Universal_2105/; last accessed April 27, 2023), the EVO formula online calculator (Version 2.0 https://www.evoiolcalculator.com/calculator.aspx; last accessed April 27, 2023) and the IOL calculation software onboard the IOL Master 700 were used to calculate the predicted residual refractive error using the following formulae: Barrett True K with TK, Barrett TK Universal II, Haigis TK and Emmetropia Verifying Optical (EVO) with TK.

2.3. Statistical analysis

The study evaluated the accuracy of IOL power calculation formulae by comparing the predicted residual refraction to the actual residual refraction. The difference between the two was defined as the prediction error (PE), and the mean of all PEs was called the mean error (ME). To calculate the mean absolute error (MAE) and median absolute error (MedAE), all negative errors were converted to positive. The study also reported the standard deviation, minimum and maximum of the PE, as well as the percentage of eyes with PEs of ±0.25, ±0.50, ±0.75 and ± 1.00 diopters (D). Boxplots were used to visualize differences in PE among different calculation formulae. Additionally, the variance of ME was calculated to assess the consistency of each formula. The statistical analyses were conducted using SPSS 29.0.0.0 for Windows (IBM Corp.; Armonk, NY, USA).

Table 1
Implanted IOL models and powers.

Eye ID	Implanted IOL Model	Manufacturer	IOL Power (spherical equivalent, Diopters)
1	CT Asphina 409 MP	Carl Zeiss Meditec AG (Jena, Germany)	22.0
2	enVista MX60	Bausch & Lomb (Rochester, USA)	17.0
3	AcrySof IQ Toric SN6AT2/3	Alcon GmbH (Freiburg, Swiss)	25.0
4	AcrySof IQ Toric SN6AT2/3	Alcon GmbH (Freiburg, Swiss)	24.75
5	Polylens Y 50 P	Polytech Domilens GmbH (Roβdorf, Germany)	18.5
6	CT Asphina 409 MP	Carl Zeiss Meditec AG (Jena, Germany)	19.0

3. Results

A total of 6 eyes of 5 patients [2 (40%) female] were included with a mean follow up after cataract surgery of 60 ± 21 days (range 32–91). The mean interval between SMILE and cataract surgery was 36 ± 26 months (range 12–85). Subjects' baseline characteristics are summarized in Table 2. The mean pre- and post-SMILE spherical equivalent (SE) was −5.10 ± 1.33 diopters (D; range: −6.50 to −3.00 D) and −0.44 ± 0.62 D (range: −1.63 to +0.38 D), respectively. The mean preoperative SE before cataract surgery was −3.00 ± 3.35 D (range: −10.25 to −0.50 D). After cataract surgery, the mean SE amounted to −0.69 ± 0.70 D (range: −2.00 to +0.13 D).

The performance of the investigated IOL power calculation formulae including physical ray tracing is summarized in Table 3 and visualized by boxplots (Figs. 1 and 2) and a stacked histogram in Fig. 3. Ray tracing yielded the lowest ME of 0.01 ± 0.39 D (range −0.38 to 0.74 D). Of all investigated TK-based formulae, the Haigis TK formula yielded the smallest ME (0.07 ± 0.49 D, range −0.57 to 0.83 D). The Barrett TK Universal II (0.29 ± 0.29 D; range −0.06 to 0.58 D), Barrett True-K with

Table 2
Subjects' characteristics.

Parameter		Mean	Median	SD	Range
Age at SMILE (years)		50	51	6	41 to 56
Age at cataract surgery (years)		53	54	6	44 to 59
SMILE	Preoperative Manifest Refraction (D)				
	Sphere	−4.83	−5.13	1.28	−6.25 to −2.75
	Cylinder	−0.54	−0.50	0.22	−1.00 to −0.25
	Spherical Equivalent	−5.10	−5.50	1.33	−6.50 to −3.00
	Postperative Manifest Refraction (D)				
	Sphere	−0.21	−0.13	0.57	−1.25 to 0.50
	Cylinder	−0.46	−0.38	0.22	−0.75 to −0.25
	Spherical Equivalent	−0.44	−0.31	0.62	−1.63 to 0.38
Cataract surgery	Preoperative Keratometry (D)				
	K mean	39.65	39.19	1.37	38.05 to 42.24
	PK mean	5.68	5.63	0.26	5.42 to 6.18
	TK mean	39.09	39.02	1.45	37.25 to 41.73
	Preoperative Manifest Refraction (D)				
	Sphere	−2.63	−1.5	3.21	−9.50 to 0.00
	Cylinder	−0.75	−0.75	0.46	−1.50 to −0.25
	Spherical Equivalent	−3.00	−1.88	3.35	−10.25 to −0.50
	Postperative Manifest Refraction (D)				
	Sphere	−0.38	−0.25	0.88	−2.00 to 0.75
	Cylinder	−0.63	−0.63	0.38	−1.25 to 0.00
	Spherical Equivalent	−0.69	−0.56	0.70	−2.00 to 0.13

Table 3
Formula performance in comparison.

Formula		Predicition error (D)				Absolute Error (D)		% of eyes within PE range indicated			
		Mean	SD	Range	Variance (D^2)	Mean	Median	±0.25D	±0.50D	±0.75D	±1.0D
Ray tracing		0.01	0.07	−0.38 to 0.74	0.15	0.25	0.15	67	83	100	100
TK based formulae	Barrett TK Universal II	0.29	0.29	−0.06 to 0.58	0.09	0.32	0.35	50	50	100	100
	Haigis TK	0.07	0.49	−0.57 to 0.83	0.24	0.37	0.33	33	67	83	100
	EVO TK	0.52	0.27	0.09 to 0.81	0.07	0.52	0.53	17	33	67	100
	Barret True-K with TK	0.51	0.29	−0.01 to 0.85	0.08	0.52	0.57	17	33	83	100

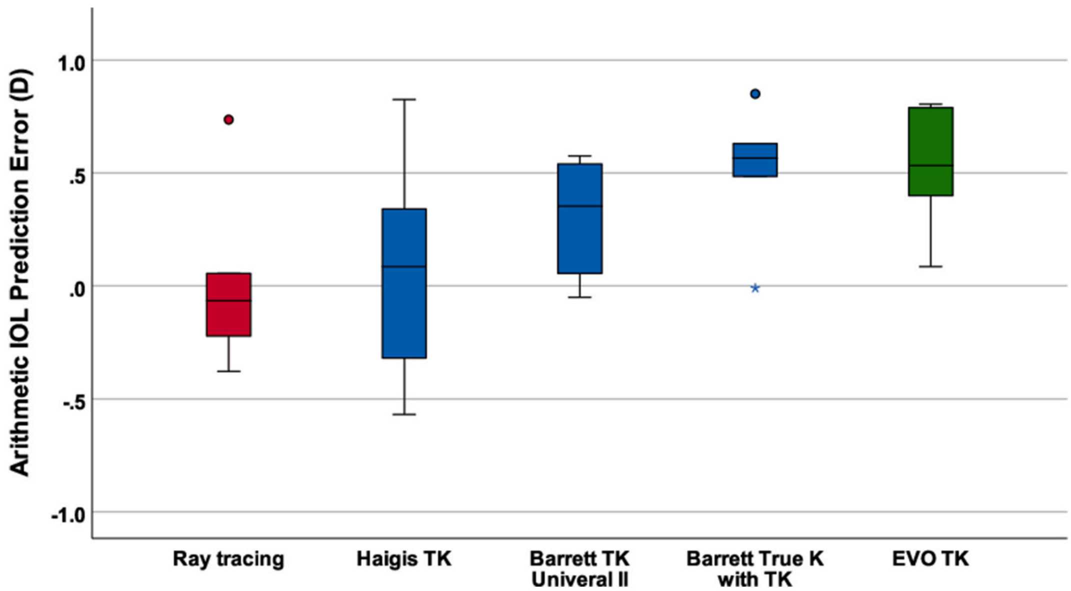

Fig. 1. Prediction errors of IOL power calculation formulae. The red boxplot represents ray tracing. The green boxplot shows the EVO TK formula, the other formulae are shown in blue. IOL power calculation formulae ranked from left to right according to their arithmetic prediction errors. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

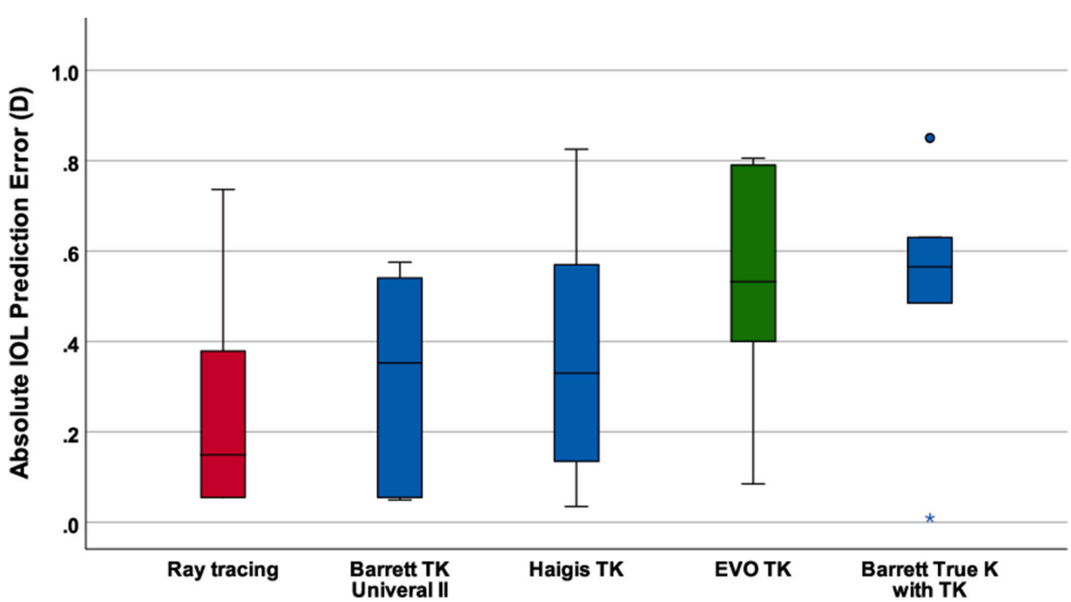

Fig. 2. Prediction errors of IOL power calculation formulae. The red boxplot represents ray tracing. The green boxplot shows the EVO TK formula, the other formulae are shown in blue. IOL power calculation formulae ranked from left to right according to their MAE. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

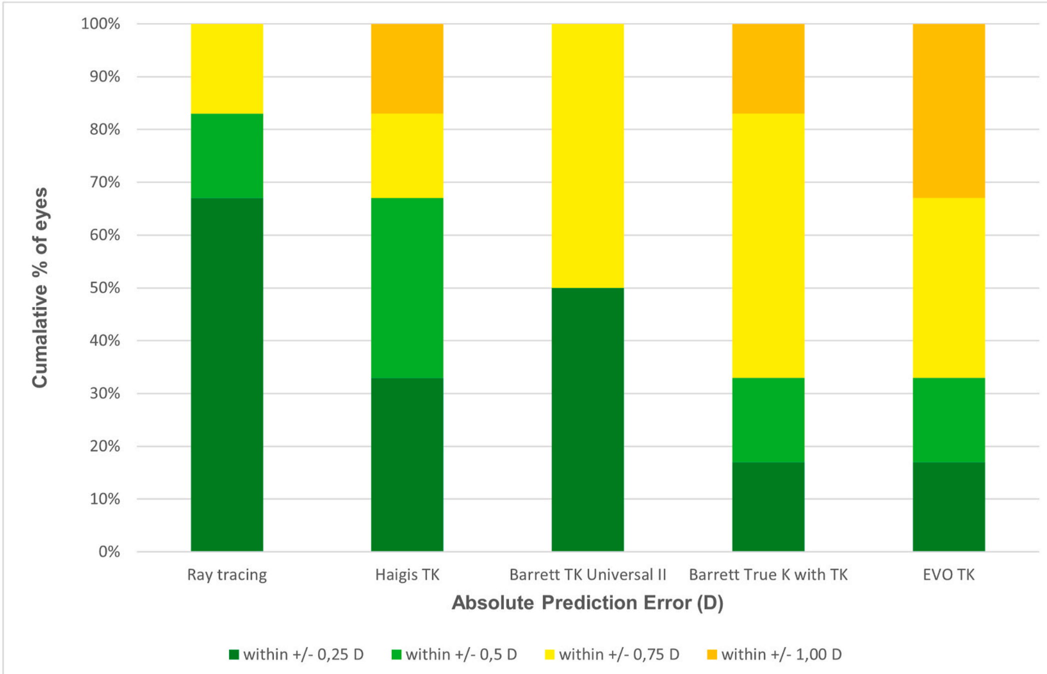

Fig. 3. Stacked histogram analysis comparing the percentage of eyes within given prediction error ranges. The formulas were sorted by the proportion of eyes within ±0.25 D in descending order.

TK (0.51 ± 0.29 D; range −0.01 to 0.85 D) and EVO TK (0.52 ± 0.27 D; range 0.09–0.81 D) showed a more pronounced propensity towards underestimating the required IOL power, translating into a hyperopic residual refractive error in relation to the intended target refraction.

With respect to MAE and MedAE, ray tracing achieved the smallest MAE (0.25 D) and MedAE (0.15 D) of all examined methods. Of the various TK-based formulae, the Barrett TK Universal II formula yielded the smallest MAE (0.32 D) followed by the Haigis TK formula (0.37 D). The Haigis TK formula achieved the smallest MedAE (0.33 D) of all TK-based formulae. Regarding the variance of ME, the EVO TK formula showed the smallest variance (0.07 D^2), followed by the Barrett True K with TK (0.08 D^2) and Barrett TK Universal II (0.09 D^2) formulae.

All investigated formulae showed a ±1.00 D accuracy of 100%. With 67%, ray tracing yielded the highest percentage of eyes within a refractive prediction error of ±0.25 D (Fig. 2) followed by the Barrett TK Universal II formula (50%). Ray tracing also showed the highest ±0.50 D accuracy of 83% tailed by the Haigis TK formula (67%).

4. Discussion

In this case series, the first descriptive analysis of ray tracing and four modern TK-based formulae for IOL power calculation in post-SMILE eyes is presented. In a previous study of our group we showed that it might be advisable to consider alternatives to regression-based formulae like those accessible in the American Society of Cataract and Refractive Surgeons (ASCRS) online calculator for post-SMILE eyes.[4,5] This is due to the fact that these formulae are optimized for corneas with prior Excimer laser ablation procedures, which show a different corneal aberrometric profile than post-SMILE eyes.[21]

Accurate intraocular lens calculation in eyes after keratorefractive treatment is generally challenging due to the altered ratio between the anterior and posterior corneal surface ("refractive index error").[22] In traditional keratometry, corneal radii are only measured for the anterior corneal curvature with the posterior corneal curvature radii being empirically extrapolated based on the assumption that the ratio between the anterior and posterior corneal curvature is constant. This wrongful assumption in case of post-keratorefractive surgery eyes can lead to overestimation of the total corneal refractive power and consequently to unpleasant hyperopic refractive error after IOL implantation. Hence, incorporating actual posterior corneal curvature measurements into IOL power calculation after keratorefractive surgery seems prudent.

The use of ray tracing, which is a purely physical approach based on Snell's law, provides several advantages over conventional keratometry-based IOL power calculation in eyes that had undergone keratorefractive surgery. Unlike regression-based formulae that are empirically optimized, ray tracing avoids reliance on fictitious keratometric indices or "fudge factors." Instead, it utilizes measurements of both the anterior and posterior corneal radii to determine the true total corneal power. Consequently, there is no need for empirical optimization, clinical history, or preoperative refractive data.

Several theoretical studies previously compared ray tracing with empirical IOL calculation formulae in eyes after SMILE. Lazaridis et al. used an arithmetic model including virtual IOL implantation to evaluate PEs between ray tracing and conventional IOL power calculation formulae.[7] In their analysis, ray tracing yielded the smallest theoretical ME of −0.06 ± 0.40 D and a theoretical ±0.50 D accuracy of 82%. Moreover, the lowest ME variance (as an indicator of the consistency of an IOL power calculation method), was achieved by ray tracing.[7] A more recent study from their group employed the same theoretical methodology to compare ray tracing with TK-based IOL calculation formulae in 98 post-SMILE eyes. Ray tracing and Haigis TK showed the highest theoretical ±0.50 D accuracies of 79% and 73%, respectively.[6]

Their theoretical data is in excellent agreement with our clinical data, which showed ±0.50 D accuracies for ray tracing and Haigis TK of 83% (82% in a previous study[4]) and 67%, respectively. In this previous study of our group, we compared ray tracing with six established IOL power calculation formulae available in the ASCRS online calculator in post-SMILE eyes undergoing cataract surgery. That analysis revealed that ray tracing exhibited the highest level of accuracy in IOL power calculation, with a ME of 0.18 ± 0.48 D.[4] In the present case series, we observed a virtually plano (0.01 ± 0.39 D) ME for ray tracing in post-SMILE eyes. The Haigis TK and Barrett TK Universal II showed favorable and clinically comparable MEs of 0.07 ± 0.49 D and 0.29 ± 0.29 D. Thus, our clinical data endorses previous theoretical studies and clearly suggest that the implementation of posterior corneal curvature into IOL power calculation offers significant advantages in post-SMILE eyes.

The Barrett Universal II and the Barrett True K diverge in terms of the mathematical models and variables they integrate. The True K formula places its primary reliance on corneal power measurements, with a stronger dependence on valid keratometry readings. In contrast, the Universal II formula takes into account additional parameters, such as axial length and anterior chamber depth, thereby utilizing a more comprehensive mathematical approach. Despite the fact that the Barrett True K formula was specifically developed for post-keratorefractive surgery eyes, in this initial post-SMILE cases series, the Barrett Universal II formula appeared to demonstrate slightly greater prediction accuracy when utilizing TK.

One of the latest IOL power calculation formulae, the EVO formula, has demonstrated its efficacy when compared to established conventional formulae in treatment-naive eyes.[23,24] A more recent publication by the author of the formula demonstrated superiority of the EVO formula equipped with TK (EVO TK) over several conventional formulae equipped with TK in 64 post-myopic Excimer ablation eyes.[25] In the present case series of post-SMILE eyes, however, the EVO TK formula resulted in the largest ME (0.52 ± 0.27 D) and the smallest fraction of eyes (33%) within ±0.50 D from target refraction.

Limitations of this study should be acknowledged. Its primary limitation is the small sample size. Nonetheless, this study represents only the second clinical case series involving post-SMILE patients undergoing cataract surgery and the first to investigate the value of TK-based formulae. Moreover, the scarcity of post-SMILE cataract cases in Austria and Germany, where the SMILE technique originated over a decade ago, necessitated the inclusion of both eyes from one patient into analysis. For the same reason, the multicenter approach and the inclusion of multiple IOL types, surgeons, and surgical protocols was deemed reasonable.

5. Conclusion

This clinical case series represents the first descriptive analysis of IOL power calculation using ray tracing and TK based formulae in post-SMILE eyes undergoing cataract surgery. Ray tracing yielded highly accurate IOL power calculation and should be interpreted in conjunction with the Barrett TK Universal II formula and Haigis TK formula for IOL power selection after SMILE. Future larger-scaled studies of IOL implantation after SMILE are eagerly awaited to corroborate the findings of this study.

Patient consent

Informed consent to use their data for analysis and publication was obtained from all subjects and all study-related procedures adhered to the tenets outlined in the Declaration of Helsinki. This case series does not contain any personal information that could lead to the identification of the patient.

Funding

No funding or grant support.

CRediT authorship contribution statement

Roman Lischke: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Validation, Visualization, Writing – original draft, Writing – review & editing. **Rainer Wiltfang:** Investigation, Resources, Validation, Writing – review & editing. **Martin Bechmann:** Investigation, Resources, Validation, Writing – review & editing. **Thomas C. Kreutzer:** Investigation, Resources, Validation, Writing – review & editing. **Siegfried G. Priglinger:** Investigation, Resources, Validation, Writing – review & editing. **M. Dirisamer:** Investigation, Resources, Validation, Writing – review & editing. **Nikolaus Luft:** Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Resources, Supervision, Writing – review & editing.

Declaration of competing interest

The authors have no proprietary or financial or any other competing interest in any of the materials or equipment mentioned in this study. Rainer Wiltfang: Member scientific board Carl Zeiss Meditec AG. Siegfried G. Priglinger: Novartis Pharma GmbH - advisory board/honoraria; Pharm Allergan - advisory board/honoraria; Zeiss - advisory board/honoraria; BVI - advisory board/honoraria; Bayer - advisory board/honoraria; Alcon - advisory board/honoraria; B&L – honoraria; Oxurion – honoraria; Örtli – honoraria; Vitrequ – honoraria. M. Dirisamer: Carl Zeiss Meditec AG: Lecture honoraria, Travel expenses. N. Luft: Carl Zeiss Meditec AG: Lecture honoraria. Other authors: None.

Acknowledgements

None.

References

1. Zeiss Surpasses 8 Million Eyes Treated with SMILE Worldwide. Eyewire+. Accessed September 15, 2023 https://eyewire.news/news/zeiss-surpasses-8-million-eyes-treated-with-smile-worldwide.
2. Ganesh S, Brar S, Sriprakash K. Post-small incision lenticule extraction phacoemulsification with multifocal IOL implantation: a case report. *Indian J Ophthalmol.* 2019;67(8):1353–1356. https://doi.org/10.4103/ijo.IJO_2069_18.
3. Li X, Li S, Li L, Liu C, Li Q. Myopic outcome after intraocular lens implantation in a patient who previously had small-incision lenticule extraction. *JCRS Online Case Rep*. 2022;10(2). https://journals.lww.com/jcro/fulltext/2022/04000/myopic_outcome_after_intraocular_lens_implantation.5.aspx.
4. Lischke R, Sekundo W, Wiltfang R, et al. IOL power calculations and cataract surgery in eyes with previous small incision lenticule extraction. *J Clin Med.* 2022;11(15). https://doi.org/10.3390/jcm11154418.
5. Luft N, Siedlecki J, Schworm B, et al. Intraocular lens power calculation after small incision lenticule extraction. *Sci Rep.* 2020;10(1):5982. https://doi.org/10.1038/s41598-020-63118-0.
6. Meziane Elotmani A, Messerschmidt-Roth A, Nehme A, Müller HH, Sekundo W. Comparison of intraocular lens power calculation formulas with and without total keratometry and ray tracing in patients with previous myopic SMILE. *J Cataract Refract Surg.* 2023;49(5):467–473. https://doi.org/10.1097/j.jcrs.0000000000001139.
7. Lazaridis A, Schraml F, Preußner PR, Sekundo W. Predictability of intraocular lens power calculation after small-incision lenticule extraction for myopia. *J Cataract Refract Surg.* 2021;47(3):304–310. https://doi.org/10.1097/j.jcrs.0000000000000405.
8. Akman A, Asena L, Güngör SG. Evaluation and comparison of the new swept source OCT-based IOLMaster 700 with the IOLMaster 500. *Br J Ophthalmol.* 2016;100(9):1201–1205. https://doi.org/10.1136/bjophthalmol-2015-307779.
9. LaHood BR, Goggin M. Measurement of posterior corneal astigmatism by the IOLMaster 700. *J Refract Surg Thorofare NJ 1995*. 2018;34(5):331–336. https://doi.org/10.3928/1081597X-20180214-02.
10. Fabian E, Wehner W. Prediction accuracy of total keratometry compared to standard keratometry using different intraocular lens power formulas. *J Refract Surg Thorofare NJ 1995*. 2019;35(6):362–368. https://doi.org/10.3928/1081597X-20190422-02.
11. Qin Y, Liu L, Mao Y, et al. Accuracy of intraocular lens power calculation based on total keratometry in patients with flat and steep corneas. *Am J Ophthalmol*. 2023;247:103–110. https://doi.org/10.1016/j.ajo.2022.11.011.
12. Galzignato A, Galvis V, Tello A, et al. Accuracy of Haigis formula using total keratometry for IOL power calculation in eyes with previous myopic and hyperopic LASIK and PRK. *Photonics*. 2023;10(6). https://doi.org/10.3390/photonics10060624.
13. Wang L, Spektor T, de Souza RG, Koch DD. Evaluation of total keratometry and its accuracy for intraocular lens power calculation in eyes after corneal refractive surgery. *J Cataract Refract Surg.* 2019;45(10):1416–1421. https://doi.org/10.1016/j.jcrs.2019.05.020.
14. Ghaffari R, Abdi P, Moghaddasi A, Heidarzadeh S, Ghahvhechian H, Kasiri M. Ray tracing versus thin-lens formulas for IOL power calculation using swept-source optical coherence tomography biometry. *J Ophthalmic Vis Res*. 2022;17(2):176–185. https://doi.org/10.18502/jovr.v17i2.10788. Published 2022 Apr 29.
15. Rabsilber TM, Reuland AJ, Holzer MP, Auffarth GU. Intraocular lens power calculation using ray tracing following excimer laser surgery. *Eye Lond Engl.* 2007;21(6):697–701. https://doi.org/10.1038/sj.eye.6702300.

16. Savini G, Bedei A, Barboni P, Ducoli P, Hoffer KJ. Intraocular lens power calculation by ray-tracing after myopic excimer laser surgery. *Am J Ophthalmol*. 2014;157(1): 150–153.e1. https://doi.org/10.1016/j.ajo.2013.08.006.
17. Savini G, Calossi A, Camellin M, Carones F, Fantozzi M, Hoffer KJ. Corneal ray tracing versus simulated keratometry for estimating corneal power changes after excimer laser surgery. *J Cataract Refract Surg*. 2014;40(7):1109–1115. https://doi.org/10.1016/j.jcrs.2013.11.032.
18. Saiki M, Negishi K, Kato N, Torii H, Dogru M, Tsubota K. Ray tracing software for intraocular lens power calculation after corneal excimer laser surgery. *Jpn J Ophthalmol*. 2014;58(3):276–281. https://doi.org/10.1007/s10384-014-0304-x.
19. Lischke R, Mayer WJ, Feucht N, et al. Total keratometry for determination of true corneal power after myopic small-incision lenticule extraction. *J Cataract Refract Surg*. 2021;47(10):1285–1289. https://doi.org/10.1097/j.jcrs.0000000000000630.
20. Sekundo W, Kunert KS, Blum M. Small incision corneal refractive surgery using the small incision lenticule extraction (SMILE) procedure for the correction of myopia and myopic astigmatism: results of a 6 month prospective study. *Br J Ophthalmol*. 2011;95(3):335–339. https://doi.org/10.1136/bjo.2009.174284.
21. Gyldenkerne A, Ivarsen A, Hjortdal JØ. Comparison of corneal shape changes and aberrations induced by FS-LASIK and SMILE for myopia. *J Refract Surg Thorofare NJ 1995*. 2015;31(4):223–229. https://doi.org/10.3928/1081597X-20150303-01.
22. Hoffer KJ. Intraocular lens power calculation after previous laser refractive surgery. *J Cataract Refract Surg*. 2009;35(4):759–765. https://doi.org/10.1016/j.jcrs.2009.01.005.
23. Melles RB, Kane JX, Olsen T, Chang WJ. Update on intraocular lens calculation formulas. *Ophthalmology*. 2019;126(9):1334–1335. https://doi.org/10.1016/j.ophtha.2019.04.011.
24. Savini G, Hoffer KJ, Balducci N, Barboni P, Schiano-Lomoriello D. Comparison of formula accuracy for intraocular lens power calculation based on measurements by a swept-source optical coherence tomography optical biometer. *J Cataract Refract Surg*. 2020;46(1):27–33. https://doi.org/10.1016/j.jcrs.2019.08.044.
25. Yeo TK, Heng WJ, Pek D, Wong J, Fam HB. Accuracy of intraocular lens formulas using total keratometry in eyes with previous myopic laser refractive surgery. *Eye Lond Engl*. 2021;35(6):1705–1711. https://doi.org/10.1038/s41433-020-01159-5.