(42)

Optical low-coherence reflectometry in the calculation of intraocular lens power in silicone oil-filled eyes

Obliczanie za pomocą optycznej niskokoherentnej reflektometrii mocy soczewek wewnątrzgałkowych w oczach wypełnionych olejem silikonowym

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Abstract: Purpose: To evaluate the refractive outcome after combined surgery of silicone oil removal with phacoemulsification and intraocular lens implantation. We calculated ocular lens implantation power with optical low-coherence reflectometry (Lenstar LS900; Haag Streit, Köniz, Switzerland) in silicone oil-filled eyes.

Methods: Prospective, comparative study. The intraocular lens power of 35 silicone oil-filled eyes of 35 patients was calculated with a Lenstar LS900 laser biometer. In all cases we performed a combined procedure of pars plana vitrectomy with silicone oil removal and phacoemulsification with intraocular lens implantation. We analyzed the spherical equivalent of predicted and postoperative refractive error. A control group consisted of 25 cases of cataract extraction and intraocular lens implantation in non-vitrectomized eyes.

Results: The mean deviation of the final refraction was -0.03 ± 1.06 diopters and did not differ significantly from non-vitrectomized eyes (P < 0.05). 68.6% eyes had a deviation of ± 1 diopter. There were no differences between high myopic and emmetropic silicone oil-filled eyes (-0.05 ± 1.33 diopters vs. -0.03 ± 1.00 diopters; P < 0.05).

Conclusions: Optical low-coherence reflectometry enables accurate intraocular lens power calculations in silicone oil-filled eyes. The refractive outcome is as accurate as in non-vitrectomized eyes.

Key words: biometry, interferometry, silicone oil, intraocular lens.

Abstrakt: Cel: ocena pooperacyjnej refrakcji po łączonym zabiegu usunięcia oleju silikonowego oraz fakoemulsyfikacji z wszczepieniem sztucznej soczewki wewnątrzgałkowej. Za pomocą optycznej niskokoherentnej reflektometrii (Lenstar LS900; Haag Streit, Köniz, Switzerland) obliczano moc soczewki wewnątrzgalkowej w oczach wypełnionych olejem silikonowym.

Metody: badanie prospektywne porównawcze. W 35 oczach wypełnionych olejem silikonowym obliczono moc soczewki wewnątrzgałkowej za pomocą laserowego biometru Lenstar LS900. We wszystkich przypadkach oceniano ekwiwalent sferyczny przewidywanej i pooperacyjnej refrakcji po łączonej operacji usunięcia oleju silikonowego, usunięcia zaćmy z jednoczasowym wszczepieniem sztucznej soczewki wewnątrzgałkowj. Grupę kontrolną stanowiło 25 zdrowych oczu, które poddano fakoemulsyfikacji zaćmy z wszczepieniem soczewki wewnątrzgałkowej.

Wyniki: średnie odchylenie wartości pooperacyjnej refrakcji wobec wartości refrakcji przewidywanej wynosiło -0,03 ± 1,06 Dsph i nie różniło się statystycznie od wartości refrakcji u badanych z grupy kontrolnej (P < 0,05). W 68,6% różnica refrakcji wynosiła ± 1,0 Dsph. (-0,05 ± 1,33 Dsph wobec -0,03 ± 1,00 Dsph; P < 0,05). W oczach wypełnionych olejem silikonowym, zarówno normowzrocznych, jak i z wysoką krótkowzrocznością, wartości pooperacyjnej refrakcji nie różniły się istotnie statystycznie.

Wnioski: optyczna niskokoherentna reflektometria umożliwia dokładne obliczanie mocy soczewek wewnątrzgałkowych w oczach wypełnionych olejem silikonowym. Wyniki pooperacyjnej refrakcji nie różnią się od wyników uzyskiwanych w oczach uprzednio niepoddawanych witrektomii.

Słowa kluczowe: biometria, interferometria, olej silikonowy, soczewki wewnątrzgałkowe.

Introduction

Lens opacification is one of the most frequent long-term complications of vitreoretinal procedures in which silicone oil is used as a tamponade agent (1). Cataract formation is a consequence of silicone oil use, but also of vitrectomy alone. Cataract deteriorates patients' vision and impairs fundus visualization during follow up or subsequent vitreoretinal procedures. Therefore, cataract surgery becomes necessary and, in many cases, it may be combined with silicone oil removal. However, calculating the final intraocular lens (IOL) power is difficult, as it is hard to take accurate ultrasound measurements of the axial length (AL) in eyes with silicone oil in the vitreous chamber. This is due to the differences between the speed of sound wave, emitted by the conventional ultrasound biometry probe, in silicone oil and in vitreous.

Lenstar LS900 (Haag Streit, Köniz, Switzerland) is an optical non-contact biometer, which captures axial dimensions of the eye using the optical low-coherence reflectometry (OLCR). Lenstar measurements include corneal thickness, anterior chamber depth, lens thickness, axial length, keratometry, white-to-white distance and pupil diameter. This method relies on an infrared light interference technique measuring the echo delay and intensity of light reflected back from tissue interfaces. The speed of light is also affected by silicone oil as the refractive index of this medium is different than the one of vitreous, but AL calculation in silicone oil-filled eye is adjusted by internal specific formulas integrated in the Lenstar software.

The purpose of this study was to evaluate the accuracy of intraocular lens power calculation measured using OLCR in silicone oil-filled eyes. The refractive outcome of the combined cataract extraction and silicone oil removal procedure was also analyzed.

Material and methods

In this prospective study we enrolled consecutive eyes with cataract and silicone oil in the vitreous cavity.

Before surgery, IOL power was calculated using an optical low-coherence biometer, Lenstar LS900 by one experienced examiner (MB). 5 consecutive measurements in mydriasis were taken in each eye. A single examination yielded a total of 16 scans. Each scan utilized optical low-coherence reflectometry to determine keratometry, pupil diameter, axial dimensions of the cornea, anterior chamber and lens as well as the axial length (AL) of the eye. The calculation formula for silicone oil-filled eyes is integrated in the Lenstar software. IOL power was calculated using the SRK/T biometry formula.

Combined surgery was performed with small-incision phacoemulsification through a clear corneal tunnel followed by the implantation of a foldable acrylic IOL in the capsular bag (Z-flex 690, A constant 118.20, Medicontour, Hungary). Subsequently, 20-gauge pars plana vitrectomy was performed with silicone oil removal during the same procedure.

Postoperative visual acuity and refraction measurements were carried out using Topcon TRK-1P, Topcon, Tokyo, Japan. The predicted and actual postoperative spherical equivalents of refractive errors were measured.

The control group consisted of 25 eyes of 25 non-vitrectomized patients, meeting the eligibility criteria for cataract surgery. In each case IOL power was assessed with the Lenstar device according to the same protocol and by the same examiner as in the study group.

Statistical analysis was performed using Stata/Special Edition 12.1 for Windows (StataCorp LP, College Station, Texas, USA) package. The Wilcoxon rank-sum test was utilised and a P value of < 0.05 was considered statistically significant.

Results

35 consecutive silicone oil-filled eyes (18 right eyes and 17 left eyes) of 35 patients were examined (Table I). The study group included 22 men and 13 women at the mean age of 56.17 $\pm$ 16.16 ($\pm$ standard deviation, SD; range 20 to 84 years old). The indications for silicone oil tamponade included rhegmatogenous retinal detachment (16 eyes), tractional retinal detachment (6 eyes), vitreous hemorrhage (9 eyes) and macular hole (4 eyes). Pars plana vitrectomy was preceded by scleral buckling in 13 eyes with rhegmatogenous retinal detachment. 8 eyes were identified as highly myopic (22.86%). High myopia was defined as AL $>$ 25.5 mm. The target postoperative refractive error was 0 Dsph in all eyes.

The control group consisted of 25 eyes of 10 male and 15 female patients (mean age $\pm$ SD: 62.80 $\pm$ 13.18, range from 19 to 87 years old) without silicone oil. The same evaluation protocol was followed in all controls and all diagnostic procedures were carried out by the same examiner. High myopia was diagnosed in 6 eyes (24%) and emmetropia was the target refraction in all eyes.

Biometry was performed according to the protocol in all cases. The mean AL obtained with Lenstar was 24.40 $\pm$ 2.27 mm in silicone oil-filled eyes and did not differ from the control group (24.45 $\pm$ 2.28 mm; $P < 0.05$; Fig. 1). The calculated IOL power ranged from 2.50 to 26.00 Dsph (mean $\pm$ SD, 18.64 $\pm$ 5.91 Dsph) and the power of actually implanted IOLs was in line with the pre-operative estimation (Fig. 2). In the control group, IOL power ranged from 1.50 to 26.00 Dsph (mean $\pm$ SD: 17.48 $\pm$ 6.65 Dsph; $P < 0.05$).

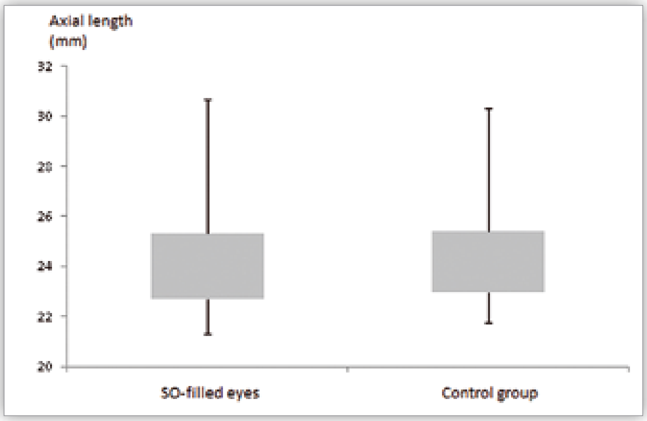

Fig. 1. Axial length (AL) measurements using Lenstar before surgery: range and interquartile range.

Ryc. 1. Długość osiowa (AL) mierzona za pomocą Lenstar przed operacją.

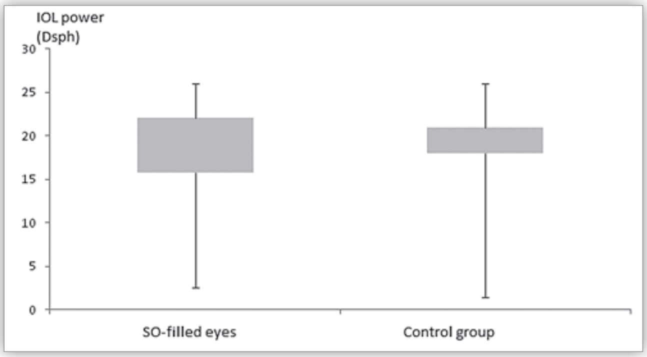

Fig. 2. Intraocular lens (IOL) power calculated using Lenstar before surgery: range and interquartile range.

Ryc. 2. Moc soczewki wewnątrzgałkowej obliczona za pomocą Lenstar przed operacją.

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No/ Lp.	Age/ Years Wiek/ Lata	Sex/ Płeć	Eye/ Oko	Primary disease/ Schorzenie	Axial length mm/ Długość osiowa mm	Measured IOL power/ Zmierzona moc IOL Dsph	Power of implanted IOL/ Moc wszczepio-nej IOL Dsph	Visual acuity/ Ostrość wzroku Snellen	Postoperative refraction/ Refrakcja pooperacyjna			Eifference be-tween predicted and actual re-fraction/ Różnica przewidywanej i otrzymanej refrakcji Dsph
									Dsph	Dcyl	Dsph +Dcyl	
EMMETROPIA/ NORMOWZROCZNOŚĆ												
1	60	M	OS	PDR, VH	24.34	19	19	0.4	-1	0	**-1**	**-1**
2	75	F	OS	MH	22.69	21	21	0.1	0.75	0	**0.75**	**0.75**
3	74	F	OS	MH	25.46	15.5	15.5	0.2	0	1.25	**0.62**	**0.62**
4	72	M	OS	PDR, RD	21.3	26	26	0.1	-0.5	-1.5	**-1.25**	**-1.25**
5	69	M	OD	RD	23.3	23	23	0.2	0.5	-0.5	**0.25**	**0.25**
6	51	M	OD	PDR, VH	24.71	22	22	0.4	-1	0	**-1**	**-1**
7	20	F	OS	RD, cerclage	23.54	16	16	0.4	-0.5	-1	**-1**	**-1**
8	65	M	OS	MH	23.23	21.5	21.5	0.1	-0.75	2	**0.25**	**0.25**
9	65	M	OS	PDR, VH	24.91	22	22	0.6	-0.5	0	**-0.5**	**-0.5**
10	23	M	OD	RD	25.02	22.5	22.5	0.3	2.75	-1.75	**1.87**	**1.87**
11	59	F	OD	PDR, RD	22.2	23.5	23.5	0.1	0.5	0	**0.5**	**0.5**
12	43	F	OS	PDR, RD	22.82	20.5	20.5	0.15	0.25	-3	**-1.25**	**-1.25**
13	78	M	OD	RD, cerclage	24.81	17	17	0.2	-0.5	-0.5	**-0.75**	**-0.75**
14	59	F	OS	PDR, RD	21.8	23.5	23.5	0.1	-0.5	-1.5	**-1.25**	**-1.25**
15	56	F	OS	RD, cerclage	23.25	21	21	0.1	2.75	-1.75	**1.87**	**1.87**
16	49	M	OD	RD, cerclage	23.4	21	21	0.5	-0.5	0	**-0.5**	**-0.5**
17	81	F	OD	PDR, VH	21.67	25.5	25.5	0.1	-0.5	-1.5	**-1.25**	**-1.25**
18	63	M	OD	PDR, VH	24.12	21	21	0.05	-0.5	0	**-0.5**	**-0.5**
19	56	M	OD	PDR, RD	22.52	22	22	0.3	-0.25	1	**0.25**	**0.25**
20	65	M	OD	RD, cerclage	25.21	18.5	18.5	0.2	-0.5	0	**-0.5**	**-0.5**
21	34	M	OD	PDR, RD	22.77	21.5	21.5	0.01	-0.5	0	**-0.5**	**-0.5**
22	57	M	OD	PDR, VH	22.61	22	22	0.2	0.25	3.25	**1.87**	**1.87**
23	66	F	OS	PDR, VH	22.35	21.5	21.5	0.2	0.75	-1.25	**0.12**	**0.12**
24	74	M	OD	MH	23.78	21.5	21.5	0.1	1.75	-1.25	**1.12**	**1.12**
25	30	F	OS	PDR, VH	21.78	25	25	0.5	2.5	-2.25	**1.37**	**1.37**
26	84	M	OD	RD, cerclage	24.97	20	20	0.2	0	-0.25	**-0.12**	**-0.12**
27	55	M	OS	PDR, VH	23.55	21	21	0.2	0	-0.5	**-0.25**	**-0.25**
HIGH MYOPIA/ WYSOKA KRÓTKOWZROCZNOŚĆ												
28	35	M	OD	RD, cerclage	30.69	2.5	2.5	0.1	0	-3	**-1.5**	**-1.5**
29	56	M	OS	RD, cerclage	26.65	14.5	14.5	0.5	0	0.5	**0.25**	**-0.25**
30	48	F	OS	RD	28.51	4.5	4.5	0.5	-0.25	-1	**-0.75**	**-0.75**
31	45	M	OS	RD, cerclage	29.97	3.5	3.5	0.6	0.5	-1.5	**-0.75**	**-0.25**
32	34	F	OS	RD, cerclage	26.69	11	11	0.04	3.5	-1.25	**2.85**	**2.85**
33	65	M	OD	RD, cerclage	25.92	14.5	14.5	0.4	-0.25	-1	**-0.75**	**-0.75**
34	56	M	OD	RD, cerclage	27.2	12	12	0.1	-1	1	**-0.5**	**-0.5**
35	44	F	OD	RD, cerclage	26.15	15.5	15.5	0.2	0.75	0	**0.75**	**0.75**

M – male/ mężczyzna, F– female/ kobieta, OD – right eye/ oko prawe, OS – left eye/ oko lewe, PDR – proliferative diabetic retinopathy/ retinopatia cukrzycowa proliferacyjna, VH – vitreous hemorrhage/ krwotok do ciała szklistego, RD – retinal detachment/ odwarstwienie siatkówki, MH – macular hole/ otwór w plamce, IOL – intraocular lens/ soczewka wewnątrzgałkowa.

Tab. I. Patients characteristics.
Tab. I. Chrakterystyka pacjentów.

The mean deviation of the final spherical refractive error from the predicted value was -0.03 ± 1.06 Dsph (range from -1.50 to 2.85 Dsph). It did not differ significantly from refraction outcomes in non-vitrectomized eyes (mean ± SD: -0.17 ± 0.48; range from -0.75 to 0.75 Dsph; $P < 0.05$; Fig. 3).

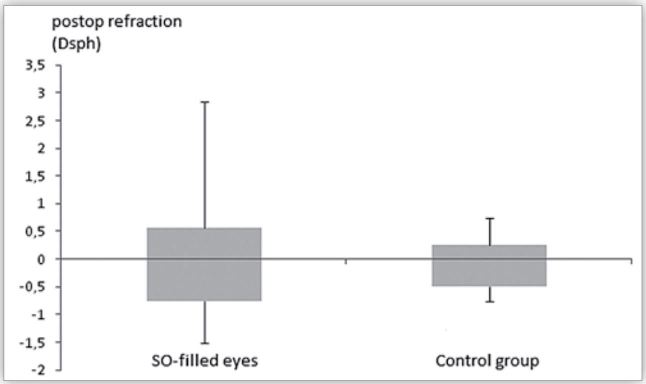

Fig. 3. Difference between the predicted and actual postoperative refraction after a combined phacoemulsification, intraocular lens implantation and silicone oil removal procedure in SO-filled eyes and after phacoemulsification with intraocular lens implantation in controls: range and interquartile range.

Ryc. 3. Różnica między przewidywaną a ostateczną refrakcją po operacji jednoczasowego usunięcia oleju silikonowego, fakoemulsyfikacji i wszczepienia sztucznej soczewki wewnątrzgałkowej u pacjentów z badanej grupy oraz po fakoemulsyfikacji zaćmy z wszczepieniem sztucznej soczewki u osób z grupy kontrolnej.

In 23 cases (68.6%), the difference between the pre-determined and final refraction was 1.00 Dsph or less. Eleven eyes (28.6%) had a deviation of 1.00 to 2.00 Dsph. The final refractive error in controls was below 0.75 Dsph in 100% of eyes.

We did not observe a statistically significant difference in deviation of refraction parametres between myopic and emmetropic eyes in our cohort (-0.05 ± 1.33 Dsph vs. -0.03 ± 1.00 Dsph; $P < 0.05$; Fig. 4).

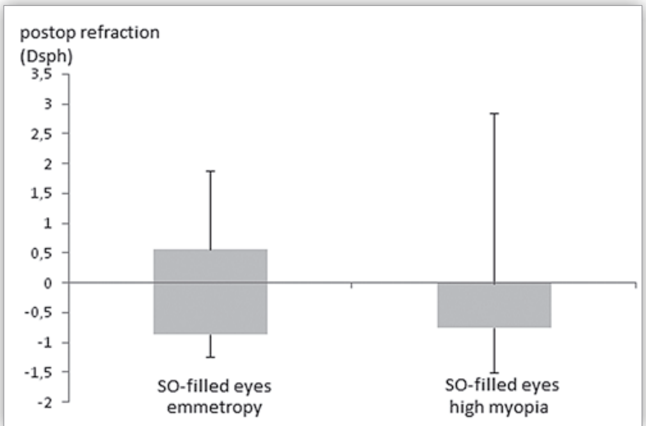

Fig. 4. Difference between the predicted and actual postoperative refraction after a combined phacoemulsification, intraocular lens implantation and silicone oil removal procedure in emmetropic SO-filled eyes vs. myopic SO-filled eyes: range and interquartile range.

Ryc. 4. Różnica między przewidywaną a ostateczną refrakcją po operacji jednoczasowego usunięcia oleju silikonowego, fakoemulsyfikacji i wszczepienia sztucznej soczewki wewnątrzgałkowej w oczach normowzrocznych i w oczach z wysoką krótkowzrocznością u pacjentów z badanej grupy.

Discussion

In this study, we confirmed that IOL power calculation with optical low-coherence biometry is accurate for silicone oil-filled eyes. The results achieved in emmetropic and highly myopic eyes may be equally favourable and are comparable to those obtained in non-vitrectomized eyes.

Silicone oil is commonly used in the treatment of numerous serious eye conditions such as retinal detachment. Secondary lens opacification is inevitable in silicone oil-filled eyes (1, 2). The proposed mode of action involves the effect of silicone oil on lens metabolism (3). In these cases, cataract may be extracted with the maintained tamponade, after silicone oil removal or during a combined procedure. The latter seems the method of choice for the sake of patient convenience and minimizing the number of surgical intervention.

Multiple studies compared intra- and postoperative complications in pars plana vitrectomy and phacoemulsification with intraocular lens implantation. The results of a one-step procedure of silicone oil removal with phacoemulsification and IOL implantation proved to be as good as with two separate procedures and the long-term complication rates remain similar (4–7). However, precise IOL power calculation in silicone oil-filled eyes still remains a clinical challenge. Accurate measurements of ocular dimensions are essential for achieving good uncorrected visual acuity after cataract surgery. The presence of the silicone oil tamponade significantly hinders the assessment of AL in ultrasound biometry, which is crucial for IOL power calculations. The velocity of sound waves in the vitreous and silicone oil is 1532 m/s and 987 m/s, respectively. It is further modified by the viscosity of the silicone oil used (8). The velocity decrease in a medium heavier than the vitreous, as seen in eyes after silicone oil tamponade, yields an imprecise axial length measurement, which is longer than the actual length. As a result, the postoperative hyperopic shift follows. Thus, specific calculation formulas need to be used, which allow for the necessary adjustments. Furthermore, if the eye is under-filled, the accuracy of calculation results may be additionally limited. Therefore, some postulate obtaining ocular measurements prior to each pars plana vitrectomy. However, this is impossible in eyes with retinal detachment involving the posterior pole. Furthermore, axial length may change after encircling procedures or pars plana vitrectomy with silicone oil. Several methods reportedly overcome this problem.

Ghoraba et al. presented the results of IOL evaluation after sound wave velocity drop to 987 m/sec in vitreous cavity and before the combined procedure of silicon oil removal and cataract extraction (9). The refractive error exceeded 2.00 Dsph in over 70% of cases with significantly lower measurement accuracy in patients with high myopia. Therefore, conversion factors were proposed to calculate the actual ocular axial dimension during ultrasound biometry, in order to achieve refractive errors below 1.00 Dsph after IOL implantation (10).

Another possibility to estimate the power of IOL is to use the fellow eye biometry results, provided that the refraction was similar in both eyes before the vitreoretinal surgery. This method has some limitations, though. Olsen proved that the prediction error of the first eye may be used to improve the prediction for the second eye in IOL power calculations made by Lenstar

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LS900 in eyes with normal vitreous (11). The validity of this approach may be questioned especially when the encircling surgeries were used prior to silicone oil tamponade. In Nepp's study in silicone oil-filled eyes, less than 50% of patients had similar AL of the eye after tamponade and the fellow eye when measured with IOL Master (12). However, his report revealed equal reliability of calculations using ultrasound and low-coherence biometry in silicone oil-filled eyes.

Kunavisarut also described the use of optical reflectometry in silicone oil-filled eye biometry (13). In his study, unlike Nepp's report, partial coherence interferometry technique used in IOL Master yielded more accurate predictive postoperative refractive error with less deviation, as compared to ultrasound measurements with A-scan immersion in SO-filled eyes. The mean deviation in predictive postoperative refractive error was 0.60 ± 0.23 Dsph (range, -2.74 to 2.33 Dsph) and a higher postoperative refractive error was associated with aphakic lens status in Kunavisarut's study. In our study, though, the optical low-coherence reflectometry yielded the mean deviation of -0.05 ± 1.07 Dsph (range from -1.50 to 2.85 Dsph).

Lenstar LS900 is based on optical low-coherence reflectometry and uses a broadband light source (20–30 nm) with a centre wavelength of 820 μm. The detection of light reflections from different eye structures allows several dimensions, including AL, to be acquired in a single examination. The excellent repeatability of Lenstar enabled us to achieve a predicted postoperative refractive error below ± 0.20 Dsph in over 95% of cases for the first time in eyes with cataract and normal vitreous body (14). In present study, the final refractive deviation was below ± 0.75 Dsph in 100% of the non--vitrectomized eyes in the control group.

The first comparative clinical study of Lenstar and IOL Master conducted by Rohrer et al. proved good agreement for measuring all examined parameters, including AL (15). 14 silicone oil-filled eyes were enrolled and no statistically significant differences were found in this subgroup. However, the authors analyzed the measured axial dimensions of the eyes only, disregarding IOL power calculations and refractive outcomes.

Cruysberg et al. demonstrated minor yet significant differences in several eye dimensions measured using Lenstar and IOL Master (16). Nevertheless, they did not lead to clinically significant IOL power changes, and both studied devices obtained excellent reproducibility. This study was performed only in eyes with normal vitreous (16).

Consecutive studies confirmed that Lenstar provided precise and valid measurements with similar refractive results as its predicate device, IOL Master partial coherence biometer by Zeiss, and that it could be used for preoperative examination of cataract patients (17, 18).

The interference of low-coherence light reflected from different eye structures is influenced by the refractive index of silicone oil. The formulas calculating axial distances in silicone oil-filled eyes integrated in Lenstar software are proprietary information of Haag-Streit. As previously mentioned, Rohrer's study is the only one to have examined the accuracy of measurements in silicone oil-filled eyes and it revealed no significant alterations in comparison to healthy eyes (15). To the best of our knowledge, ours is the first study, which evaluates the accuracy of low-coherence reflectometer biometry in eyes undergoing the combined procedure of silicone oil removal and cataract extraction with IOL implantation.

Biometry assessed using the low-coherence reflectometry did not demonstrate statistically significant differences between eyes with and without silicone oil tamponade. The success rates defined as achieving the pre-planned emmetropia were equal in both groups.

Ultrasound biometry was considered not always reliable in highly myopic non-vitrectomized eyes with AL over 27 mm (19). Ultrasound biometry in silicone oil-filled eyes was also reported to yield incorrect AL measurements, which adversely affected refractive outcomes (9,10). In our study using optical biometry we did not observe differences in refractive outcomes between highly myopic and emmetropic silicone oil-filled eyes.

Conclusions

The refractive error deviation did not differ significantly between silicone oil-filled and non-vitrectomized eyes. Optical low--coherence reflectometry may become a new standard method for obtaining biometric measurements essential for intraocular lens power calculation in patients with silicone oil tamponade after pars plana vitrectomy.

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