Calculation of Intraocular Lens in Patients after Previous Laser Refractive Surgery

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SUMMARY

Aim: The incidence of cataract surgery in patients after previous laser refractive surgery is increasing worldwide. However, the resulting uncorrected distance visual acuity (UDVA) after cataract surgery in these patients is less frequently satisfactory. The aim of this article is to present the results of cataract surgery in a group of patients who had undergone previous laser refractive surgery, in whom the IOL power was calculated only according to the currently measured values, and to compare them with the results from other workplaces.

Material and Methods: Our group incorporates 69 eyes of 43 patients. The data collection took place over a period of 33 months. The group included patients who attended at least one follow-up examination in the postoperative period. The resulting postoperative vision was considered to be vision determined at least 1 month after cataract surgery. Data were collected retrospectively.

Results: The resulting postoperative average monocular best corrected distance visual acuity (BCDVA) in the patients from our cohort was 0.024 LogMAR in the group of initially myopic patients and 0.030 LogMAR in the group of initially hypermetropic patients. Thus, BCDVA in myopic was better than in hypermetropic patients, without a statistically significant difference. Conversely, the resulting mean manifest spherical equivalent (MSE) was higher for myopic patients (-0.844) than for hypermetropic patients (-0.658), and this difference was evaluated as statistically significant. A refractive result above ±0.5 Dsf was present in 14 eyes, above ±1.0 Dsf in 6 eyes.

Conclusion: In 90% of patients we achieved an average MSE up to ±1.0 Dsf postoperatively. The results from our report regarding postoperative monocular BCDVA, BCNVA, mean SE and MSE are consistent with those from other reports dealing with this issue, although our cohort included a much smaller group of patients.

Key words: IOL power calculation, corneal laser refractive surgery, residual refractive error

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INTRODUCTION

Cataract surgery with implantation of an intraocular lens (IOL) is the most widespread surgical procedure worldwide (3.7 million/year in the USA, 7 million/year in Europe and 20 million/year worldwide) [1]. The number of cataract operations worldwide is increasing due to the ageing population, more available healthcare and global population growth. Together with this, the number of patients undergoing a corneal laser refractive procedure due to a refractive error is also increasing. In the last 30 years corneal laser refractive surgery has been the most commonly used surgical method for correcting refractive errors in younger patients who are not yet of presbyopic age [2]. As patients after prior laser refractive surgery grow older they require cataract surgery with increasing frequency [3]. Many of these patients report to an ophthalmology center earlier for correction of presbyopia using the Prelex method (presbyopic lens exchange), in which a clear intraocular lens is replaced with a multifocal lens.

At present the most commonly used keratorefractive procedure is unequivocally laser in situ keratomileusis (LASIK) [4], both because of its effectiveness and also for its rapid rehabilitation of sight and therefore minimal discomfort caused to the patient in comparison with other methods. During LASIK, after the initial folding of the surface lamella in myopic patients, photoablation of the central part of the superficial corneal stroma by excimer laser is performed, which leads to a flattening of the central part of the cornea, whereas in hypermetropic patients photoablation of the peripheral part of the corneal stroma si performed, thereby leading to an increase in steepness of the central part of the cornea [5]. The original method, though now used less frequently, is photorefrac-

tive keratectomy (PRK), in which photoablation of the corneal stroma is performed following the initial removal of the superficial epithelium [4]. One of the most modern laser refractive methods for correction of myopia is Small Incision Lenticule Extraction (ReLEx SMILE), in which following the creation of a stromal lenticule with a femtosecond laser it is extracted via a small lateral vertical incision [4]. The majority of patients undergoing cataract surgery or refractive lens exchange at present have undergone PRK or LASIK procedure in the past.

In patients who have undergone a previous laser procedure (LASIK, PRK) using the standard formulae for calculation of the IOL, errors occur which lead to the selection of falsely higher/lower value of IOL and subsequently to the onset of postoperative myopia or hypermetropia. While post-myopic patients experience postoperative hypermetropia [3,6–9], post-hypermetropic patients suffer postoperative myopia [5,10]. A number of the main errors in calculation of the IOL in these patients have been described, leading to the onset of a postoperative refractive error. The first is a keratometric index error. The ratio between the anterior and posterior curvature of the cornea is fixed in eyes without a laser anamnesis, and enables calculation of the dioptric power of the cornea with the aid of standard keratometric index, which is 1.3375. In eyes that have undergone a laser refractive procedure, the anterior surface is flattened, the ratio is altered and the keratometric index is no longer the same as previously. As a result, use of the standard index leads to an incorrect calculation of the dioptric power of the cornea. The second is an error of corneal radius measurement. This error occurs when the optic zone created by the laser is small or decentered, and the corneal radius is therefore not measured along the axis of vision but in a region where corneal curvature is probably different. The third main described error is a formula error. Most formulae use the dioptric power of the cornea to predict the effective position of the lens. The performance of the cornea is altered by excimer laser, and the use of its postoperative value leads to an incorrect calculation of the effective position of the lens [5,6].

The total size of the refractive error following cataract surgery in post-hypermetropic patients is described as smaller than in post-myopic patients for a number of reasons. The first is the fact that after central ablation flattening of the cornea leads to a reduction of the axial length of the eyeball and depth of the anterior chamber in myopic patients [5], whereas in hypermetropic patients these parameters are altered only to a small degree by peripheral ablation. The second described reason is that hyperopic ablation usually corrects a smaller hypermetropic error in comparison with myopia [5].

Due to the unsatisfactory postoperative results in patients following a previous corneal refractive procedure upon the use of the generally used formulae of a 3rd or 4th generation for calculation of the IOL (SRK/T, Holladay, Haigis, Hoffer I, Hoffer II and others), over the course of time a whole series of new formulae have been invented and tested for calculating the IOL for these patients [11]. However, at present there is no universal consensus concerning which formula is the most precise and should be considered the gold standard [12]. Methods of calculation of IOLs in patients following a laser refractive procedure can be divided into two basic groups [9,10,13]. The first group consists of methods by which calculation of the IOL is performed with knowledge of the original refraction and topography of the patient's cornea before the laser refractive procedure. We also include in this group regressive methods based on estimations of certain values of the cornea upon calculation of the IOL on the basis of "regressive formulae". The regressive formulae are based on already obtained data and the results of specific tested cohorts of patients [14]. The second group comprises methods in which calculation of the IOL is performed without knowledge of the aforementioned prior anamnestic data, only according to the current values of biometry and the patient's corneal optical density. The latest methods of calculation of the IOL include, for example, ray tracing using anterior segment OCT based on physical measurement of the eye [14].

At present the online calculator of the American Society of Cataract and Refractive Surgery (ASCRS) is used as standard for calculation of the optical density of the IOL in patients following a laser refractive procedure [12], which contains multiple formulae, for example Wang-Koch-Maloney, Shammas, Barret true-K and Haigis-L [12,15,16]. The ASCRS online calculator then provides a clear summary of the calculations according to the corresponding formulae on the basis of the entered data [12,15]. Optical biometers also include certain formulae for calculation of the IOL in patients following a previous refractive procedure. For example Lenstar (Haag-Streit Diagnostics) contains the Shammas formula, IOL Master (Carl Zeiss Meditec) the Haigis L formula and Argos (Alcon Laboratories Inc.) the Barret true-K formula.

The aim of this article is to present the results of cataract surgery in a group of patients who had undergone a previous laser refractive procedure, in whom the power of the IOL was calculated only according to the current values of biometry and corneal optical density, with the aid of the ASCRS online calculator. We also wish to compare our results with the results of other studies focusing on this issue.

MATERIAL AND METHOD

Upon calculation of the IOL before cataract surgery it was originally necessary to know two values [17], namely axial length of the eye and corneal optical density. In addition to these two values, depth of anterior chamber is also now used in modern formulae [18]. Axial length of the eye can be determined with the aid of optical or older acoustic biometry. Corneal optical density can be determined according to corneal topography or optical biometry. Depth of anterior chamber can also be determined with the aid of optical biometry. At our center we determine axial length of the eye and depth

of anterior chamber by optical biometry using the instrument Lenstar LS 900 (Haag-Streit Diagnostics), Argos (Alcon Laboratories Inc.) or IOL MASTER 700 (Carl Zeiss Meditec), for corneal optical density we evaluate the results from the two aforementioned methods of measurement, corneal topography is measured on the instrument Pentacam (Oculus) and optical biometry on the instrument Lenstar (Haag-Streit Diagnostics), Argos (Alcon Laboratories Inc.) or IOL MASTER (Carl Zeiss Meditec). For calculation of the IOL we use the ASCRS online calculator, version 4.9. Our cohort incorporated 69 eyes of 43 patients, of whom 19 are women and 24 men. The cohort incorporated 27 originally myopic patients (46 eyes) and 16 originally hypermetropic patients (23 eyes). A multifocal IOL was implanted in 47 eyes and a monofocal IOL in 22 eyes. The data collection took place over a period of 33 months (from November 2021 to July 2024). The cohort included patients who had undergone at least one follow-up examination in the postoperative period. Visual acuity (VA) determined at least 1 month after cataract surgery was considered to constitute resulting postoperative visual acuity. The data were collected retrospectively.

Statistical analysis

Firstly a Shapiro-Wilk test was conducted to assess the normality of the data distribution, on the basis of which both parametric and nonparametric tests of significance were subsequently used to test the individual parameters. Upon normal data distribution, a two-sample Student t-test was used for testing the differences between the groups. In the opposite case a non-parametric Mann-Whitney test that did not require normality of data was used for comparison of the medians of two independent groups. The statistical analyses were conducted in the software IBM SPSS Statistics (version 19, SPSS, Inc.) and Microsoft Excel (Microsoft Corp.). All the statistical tests were performed on a standard level of significance of $p = 0.05$.

RESULTS

We divided the patients from our cohort into two groups, myopic and hypermetropic. The resulting average postoperative monocular best corrected distance visual acuity (BCDVA) in the patients in our cohort was 0.024 LogMAR in the group of originally myopic patients and 0.030 LogMAR in the group of originally hypermetropic patients. The resulting average postoperative monocular uncorrected distance visual acuity (UDVA) was 0.101 LogMAR in the group of originally myopic patients and 0.120 LogMAR in the group of originally hypermetropic patients. The resulting average postoperative monocular best corrected near visual acuity (BCNVA) was 0.080 LogMAR in the group of originally myopic patients and 0.104 LogMAR in the group of originally hypermetropic patients. For further comparison an analysis of preoperative BCDVA was also conducted. The average preoperative monocular BCDVA was 0.041 LogMAR in the originally hypermetropic eyes and 0.102 LogMAR in the originally myopic eyes. No statistically significant difference between the groups of originally myopic and originally hypermetropic eyes was found in the parameters of preoperative monocular BCDVA, postoperative monocular BCDVA, UDVA and BCNVA (all Mann-Whitney test, preoperative monocular BCDVA $p = 0.155$, postoperative monocular BCDVA $p = 0.325$, UDVA $p = 0.711$, BCNVA $p = 0.249$).

The resulting average spherical equivalent (SE) in the entire cohort was -1.210 (from -3.88 to +4.13), in which it was lower in the originally hypermetropic patients than in the originally myopic patients (+0.095 in hypermetropic patients vs -0.565 in myopic patients). The resulting average manifest spherical equivalent (MSE) was -0.807 (from -2.88 to +0.75), in which it was lower in the originally hypermetropic patients than in the originally myopic patients (-0.658 in hypermetropic patients vs -0.844 in myopic patients). No statistically significant difference between the groups of originally myopic and originally hypermetropic eyes was found in the parameters of SE and MSE (both Student t-test, SE $p = 0.031$, MSE $p = 0.840$). The statistical evaluation of all the examined parameters is synoptically presented in Tables 1 to 6. For a graphic illustration of the comparison of postoperative monocular BCDVA, UDVA and MSE between myopic and hypermetropic patients see Graphs 1 to 3. Resulting refraction above the limit of ±0.5 of spherical diopters (Dsf) was present in 14 eyes (in 11 originally myopic eyes and 3 originally hypermetropic eyes), and above the limit of ±1.0 Dsf in 6 eyes (in 5 originally myopic eyes and 1 originally hypermetropic eye).

DISCUSSION

The resulting average postoperative monocular BCDVA in our cohort was better in the originally myopic patients than in the originally hypermetropic patients. This correlates with the results of the large retrospective study conducted by Cobo-Soriano et al., which compared 867 eyes undergoing cataract surgery following a previous corneal refractive procedure. In the aforementioned study ave-

Table 1. Statistical evaluation of preoperative CDVA

	Hypermetropic eyes (n = 23)	Myopic eyes (n = 46)
Minimum	0.00	0.00
Lowerquartile	0.00	0.00
Mean	0.041	0.102
Median	0.00	0.00
Std. deviation	0.082	0.164
Modus	0.00	0.00
Upperquartile	0.05	0.16
Maximum	0.30	0.70

CDVA – best corrected distance visual acuity

rage BCDVA was also better in the originally myopic patients than in the originally hypermetropic patients [19], with average BCDVA of 0.04 LogMar in myopic patients and 0.06 LogMAR in hypermetropic patients. In this article it is also described that the resulting BCDVA in myopic patients is the same regardless of the level of original

Table 2. Statistical evaluation of postoperative CDVA

	Hypermetropic eyes (n = 23)	Myopic eyes (n = 46)
Minimum	0.00	0.00
Lowerquartile	0.00	0.00
Mean	0.030	0.024
Median	0.00	0.00
Std. deviation	0.039	0.042
Modus	0.00	0.00
Upperquartile	0.05	0.05
Maximum	0.10	0.15

CDVA – best corrected distance visual acuity

Table 3. Statistical evaluation of postoperative UDVA

	Hypermetropic eyes (n = 23)	Myopic eyes (n = 46)
Minimum	0.00	0.00
Lowerquartile	0.00	0.00
Mean	0.120	0.101
Median	0.05	0.05
Std. deviation	0.238	0.141
Modus	0.00	0.00
Upperquartile	0.10	0.15
Maximum	1.00	0.50

UDVA – best uncorrected distance visual acuity

Table 4. Statistical evaluation of postoperative CNVA

	Hypermetropic eyes (n = 23)	Myopic eyes (n = 46)
Minimum	0.00	0.00
Lowerquartile	0.00	0.00
Mean	0.104	0.080
Median	0.10	0.00
Std. deviation	0.119	0.126
Modus	0.00	0.00
Upperquartile	0.20	0.10
Maximum	0.50	0.70

CNVA – best corrected near visual acuity

Table 5. Statistical evaluation of postoperative SE

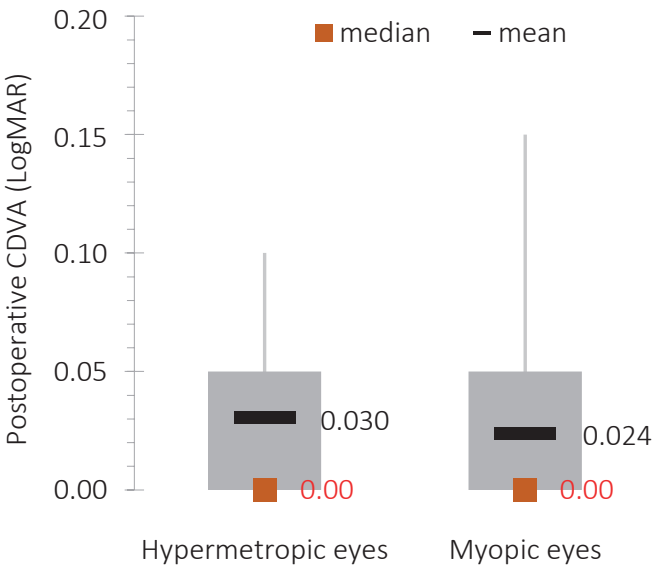
	Hypermetropic eyes (n = 23)	Myopic eyes (n = 46)
Minimum	-2.88	-3.88
Lowerquartile	-0.50	-1.13
Mean	0.095	-0.565
Median	0.00	-0.75
Std. deviation	1.150	1.186
Modus	0.37	-1.13
Upperquartile	0.50	0.00
Maximum	2.75	4.13

SE – spherical equivalent

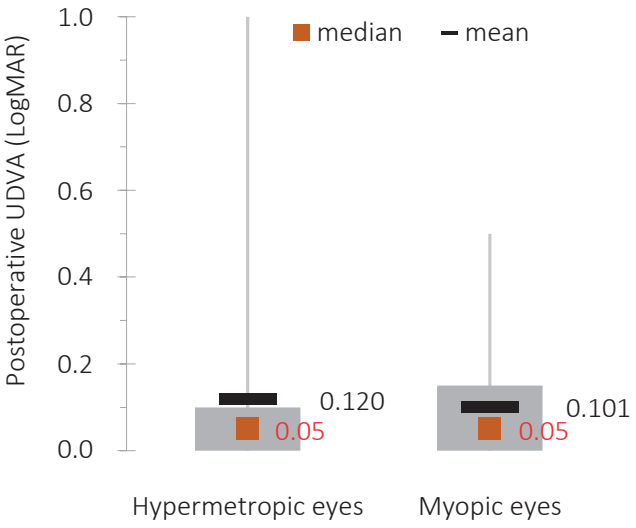
Table 6. Statistical evaluation of postoperative MSE

	Hypermetropic eyes (n = 23)	Myopic eyes (n = 46)
Minimum	-2.88	-2.13
Lowerquartile	-2.41	-1.00
Mean	-0.658	-0.844
Median	-0.25	-0.88
Std. deviation	1.671	0.621
Modus	-2.88	-1.00
Upperquartile	0.69	-0.50
Maximum	0.75	0.25

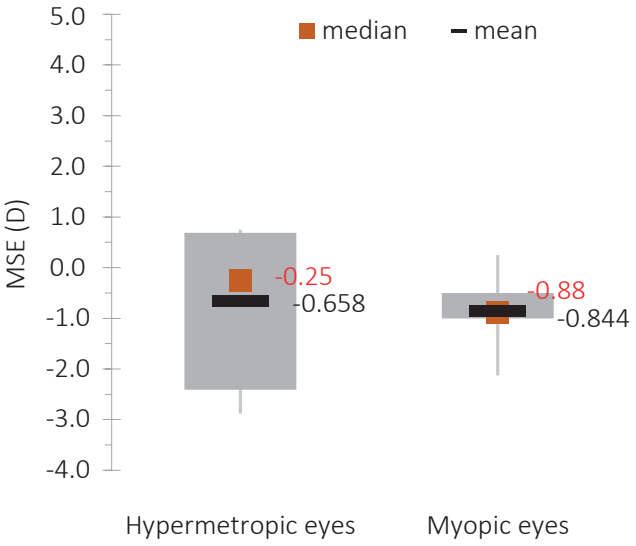
MSE – manifest spherical equivalent



Graph 1. Comparison of postoperative CDVA between hypermetropic and myopic patients
CDVA – best corrected distance visual acuity



Graph 2. Comparison of postoperative UDVA between hypermetropic and myopic patients
UDVA– best uncorrected distance visual acuity



Graph 3. Comparison of postoperative MSE between hypermetropic and myopic patients
D – diopter, MSE – manifest spherical equivalent

refraction before the corneal laser refractive procedure, whereas in hypermetropic patients the resulting BCDVA is worse the higher the original correction of the patient before the laser refractive procedure. With respect to the small number of hypermetropic patients in our cohort (16 patients), we did not test this hypothesis.

The resulting average UDVA in our cohort was again better in the originally myopic patients than in the originally hypermetropic patients (0.101 LogMAR in myopic patients, 0.120 LogMAR in hypermetropic patients), whereas in the aforementioned study by Cobo-Soriano et al. the resulting average UDVA was practically the same in myopic and hypermetropic patients [19]. The different results in our study are probably due to the size of the observed cohort of patients, which is far smaller in our case.

It is also interesting to compare preoperative and postoperative BCDVA in the patients from our cohort. Postoperative BCDVA was better than preoperative in all the patients, which is the overall aim of cataract surgery in general. Whereas preoperative BCDVA was better in the originally hypermetropic patients than in the originally myopic patients (0.041 LogMAR in hypermetropic patients vs 0.102 LogMAR in myopic patients), postoperative BCDVA was better in the originally myopic patients (0.024 LogMAR in myopic patients vs 0.030 LogMAR in hypermetropic patients) than in the originally hypermetropic patients. In the originally myopic patients cataract surgery also brought about an overall more pronounced improvement of BCDVA than in the originally hypermetropic patients.

The resulting average MSE in our cohort was better in the originally hypermetropic patients than in the originally myopic patients, which correlates with the results of the study conducted by Cobo-Soriano et al. [19], where the average MSE in hypermetropic patients was -0.17, compared with -0.38 in myopic patients. In myopic patients a dependency of the size of postoperative average MSE on the size of the original correction before the corneal laser refractive operation was described, in which the higher the original myopic refraction, the higher the resulting average MSE. Brenner et al. in their study present the results of cataract surgery in patients following a previous corneal refractive procedure in 241 eyes, the results of which are in accordance with the results of our study [20]. Brenner et al. explain the greater precision or better resulting average MSE in the originally hypermetropic patients in connection with the greater reliability of measurement of central keratometry, ensuing from the smaller geometric changes of the cornea following a laser refractive procedure in hypermetropic patients in comparison with myopic patients [5,20]. Our cohort incorporated 43 patients, and the results therefore may not have such high predicative value as the large cohorts of patients from the aforementioned study, even though our results correspond with them. Resulting refraction above the limit of ±0.5 Dsf was present predominantly in the originally myopic eyes (11 myopic eyes vs 3 hypermetropic eyes). This corresponds with the study conducted by Brenner et al., in which the calculation of IOL is more precise in the originally hypermetropic patients than in the originally myopic patients, see above.

Cobo-Soriano also notes that according to the results of the study aspherical intraocular lenses are more suitable for originally myopic patients, whereas by contrast spherical intraocular lenses are more suitable for originally hypermetropic patients [19]. Measurement of corneal aberrations before surgery and monitoring thereof was not the subject of our observation. In our cohort aspherical IOLs were implanted in all eyes, in which in 13 cases these were monofocal lenses and in 14 cases multifocal.

As stated above, at our center we perform calculation of IOLs with the aid of the ASCRS online calculator according to the current values of biometry and corneal optical

density, which is in accordance with the other modern international centers engaged in cataract surgery [21]. Although there is a whole series of methods for calculation of IOLs based on knowledge of the original refraction and biometry of the patient, we can name at least the method of clinical anamnesis, the Feiz-Mannis method and the double-K method [8,22], which are considered outmoded today. This is primarily because previous anamnestic data cannot be obtained from a large proportion of patients. The patients had often undergone a refractive procedure at a different center from where they later wished to undergo cataract surgery. They also come for surgery several years after the original corneal refractive procedure, and with only a few exceptions they do not have any previous medical report at their disposal, in which precisely this time factor plays an important role.

CONCLUSION

In 90% of the patients we achieved average postoperative MSE up to ±1.0 Dsf. In some patients the resulting refraction was complicated by the presence of astigmatism or a narrower or decentered ablation zone, or a combination of these factors simultaneously. A refractive result above the limit of ±0.5 Dsf was present in 20% of the eyes in the cohort, a refractive result above the limit of ±1.0 Dsf in 8.7% of the eyes. The resulting value of monocular BCDVA, UDVA and BCNVA after cataract surgery in patients following a previous laser refractive procedure in our cohort was better in the originally myopic patients than in the originally hypermetropic patients. The resulting postoperative average SE and MSE was better in the originally hypermetropic patients than in the originally myopic patients, in which the calculation of the IOL was performed according to current biometry and corneal optical density without knowledge of the patient's previous anamnestic data. With regard to postoperative BCDVA, BCNVA, SE and MSE, the results of our study correlate with the results of other studies dealing with this issue [19,20], even if our cohort incorporated a far smaller group of patients.

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