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Factors for good near and distance visual outcomes of multifocal intraocular lens with inferior segmental near add

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Abstract

Purpose This study was conducted to investigate factors related to postoperative good near and distance visual outcomes in the Lentis Mplus LS-313 MF20 (Oculentis Gmbh, Berlin, Germany) intraocular lens (IOL)-implanted eye.

Methods A retrospective cross-sectional study analyzed a total of 198 eyes of 198 patients. Patients with 20/20-or-more uncorrected distance visual acuity (UDVA, 5 m) and J2-or-more uncorrected near visual acuity (UNVA, 40 cm) were distributed into the good visual outcome (GVO) group ($n = 96$), and the remaining patients were distributed into the moderate visual outcome (MVO) group ($n = 102$). Differences between the two groups were compared for patient age, preoperative measurements (kappa distance, kappa angle, and pupil size), and postoperative measurements (residual sphere, cylinder, and spherical equivalent) to explore factors related to good visual outcomes after IOL implantation.

Results The average age of the GVO group (56.2 years) was significantly lower than that of the MVO group (58.6 years), and the average kappa distance of the former was significantly smaller than that of the latter. However, there were no significant differences between the two groups in kappa angle and pupil size. Notably, multivariate binary regression analysis revealed that multiple factors including age, residual cylinder, and spherical equivalent were associated with good visual outcomes. Based on the receiver operating characteristic curve, cutoff values regarded as good visual outcome following cataract surgery were calculated to be − 0.38 CD in residual cylinder and − 0.32 D in residual spherical equivalent.

Conclusions Patients with implanted Lentis Mplus LS-313 MF20 IOL who are young, had small kappa distance, and had low levels of postoperative residual cylinder and spherical equivalent tended to exhibit good vision at both near and distance. These results imply that surgeons should minimize postoperative residual cylinder and spherical equivalent to provide good visual outcomes to patients with implanted Lentis Mplus LS-313 MF20 IOL.

Keywords Visual outcomes · Refractive · Multifocal · Intraocular lens · Kappa distance · Residual refractive error

Introduction

Patient vision after cataract surgery depends on the intraocular lens (IOL) implanted into the eye. Multifocal IOLs (MIOLs) are recommended for presbyopia correction after cataract surgery since they improve not only distance vision, but also intermediate and near vision [1]. MIOLs, developed by diverse technologies to provide good visual outcomes at several distances, can be subdivided into diffractive and refractive MIOLs. A variety of MIOLs including two types of optical designs (diffractive and refractive lenses) are available in the clinic [1, 2].

The optical surface of refractive MIOLs comprises two parts, distance and near segments. Refractive MIOLs can be divided into rotational symmetric and asymmetric IOLs according to design characteristics [1]. Due to these structural features, postoperative quality of vision in refractive MIOL-implanted eyes is affected by pupil size, IOL decentration [3, 4], kappa distance, and kappa angle [1, 5].

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Lentis Mplus IOLs (Oculentis GmbH, Berlin, Germany) are rotational asymmetric refractive MIOLs, and previous studies have revealed that Lentis Mplus IOLs exhibit good vision and refraction outcomes [6–8]. In particular, they produced less photopic phenomena and provided outstanding intermediate vision compared to diffractive MIOLs [6, 8]. Accordingly, we investigated factors related to postoperative good visual outcomes at both distance and near in patients with implanted Lentis Mplus LS-313 MF20 IOL.

Materials and methods

Study population

This retrospective cross-sectional study was approved by the Public Institutional Bioethics Committee (no. P01-202003-21-002) and the Institutional Review Board of the Korea University Ansan Hospital (IRB no. 2020AS0015). The medical records of patients who were admitted to the BGN World Tower Eye Clinic from 1 January to 30 September 2019, underwent cataract surgery, and then were implanted with Lentis Mplus LS-313 MF20 IOLs were retrospectively analyzed. Finally, a total of 198 eyes of 198 patients were enrolled. To investigate factors related to postoperative good near and distance visual outcomes, one eye per one patient was used in this study. Even if both eyes that underwent cataract surgery were eligible for this study, only one eye was randomly selected. The inclusion criteria comprised patients whose retina and optic nerve were not abnormal on either fundoscopic examination and Spectralis HRA-OCT (Heidelberg Engineering, Heidelberg, Germany) examination conducted before cataract surgery and who had nothing in the anterior segment of the eye (except cataract) that may affect vision. The exclusion criteria comprised patients with astigmatism greater than 1.5 D, amblyopia, complications during or after cataract surgery, past medical history of corneal refractive surgery such as LASIK and LASEK, and additional corneal refractive surgeries to correct residual refractive errors following cataract surgery.

Patient examination

Preoperative comprehensive ocular examinations were conducted for all patients by slit-lamp biomicroscopy, autorefractor/keratometery (Canon RK-F2 Full Auto Ref-Keratometer; Canon, Tokyo, Japan), fundoscopy, and non-contact specular microscopy (Perseus; CSO, Firenze, Italy). A variety of variables including pupil size, kappa distance, and kappa angle was measured using a single Scheimpflug camera (Pentacam; Oculus Optikgeräte GmbH, Wetzler, Germany), and ocular biometry measures such as preoperative keratometry (K), anterior chamber depth (ACD), and axial length (AL) were measured using an IOLMaster 700 (Carl Zeiss Meditec, Jena, Germany). In the right eye, nasal kappa angle was defined as a kappa angle of 0 ± 45°, superior kappa angle was defined as 90 ± 45°, temporal kappa angle was defined as 180 ± 45°, and inferior kappa angle was defined as 270 ± 45°, depending on the meridian. In the left eye, nasal kappa angle was defined as kappa angle of 180 ± 45°, and temporal kappa angle was defined as 0 ± 45°. IOL power was selected based on a target refraction of negative values near zero using the SRK/T and Barrett Universal II formulas. The A-constant of the IOL was 118.5.

Surgical technique

All surgeries were femtosecond laser-assisted cataract surgery using a LenSx (Alcon Laboratories, Inc., Fort Worth, TX, USA) with 5.5 mm CCC performed by an experienced surgeon (J.W.K.) under local anesthesia with 0.5% proparacaine hydrochloride. Phacoemulsification was conducted using a standard technique after hydrodissection, and the capsular tension ring (CTR, Ringject; Ophtec, Groningen, Netherlands) was inserted into the capsular bag in all patients. Next, a Lentis Mplus LS-313 MF20 IOL was inserted in the bag using an injector system, and the near add segment of the IOL was placed inferiorly.

Preoperative and postoperative medication

From 3 days before surgery to 1 month after surgery, all patients were instructed to instill 1.5% levofloxacin hydrate (Cravit®, Santen, Osaka, Japan) and 1% prednisolone acetate (Prednilone; Daewoo Pharmaceutical Co., Seoul, Korea) every 6 h and 0.1% bromfenac sodium hydrate (Bronuck®, Taejoon Pharm., Seoul, Korea) every 12 h.

Patient evaluation

Following autorefraction conducted using an autorefractor/keratometer between 6 and 10 weeks after cataract surgery, uncorrected distance visual acuity (UDVA) and corrected distance visual acuity (CDVA) by manifest refraction (MR) were measured at a 5 m distance. In the same period, uncorrected near visual acuity (UNVA) was measured at 40 cm distance using a near vision chart of Johnson & Johnson Company. When UDVA measured at 5 m and UNVA measured at 40 cm were 20/20 (0.0 logMAR) or more and J2 (0.1 logMAR) or more, respectively, these results were defined as good visual outcome. The remaining results were considered moderate visual outcomes. Based on this definition, all patients were categorized into two groups, good visual outcome (GVO) group and moderate visual outcome (MVO) group. The factors associated with good visual outcomes were explored after Lentis Mplus LS-313 MF20 IOL implantation by comparing the two groups. Monocular distance-corrected defocus curves were measured in each patient between − 4.00 D and + 1.00 D in 0.50 D steps at 5 m distance after MR. If visual acuity was measured as 20/20, no further visual acuity measurements were conducted when measuring the defocus curve.

Refractive prediction error was defined as the difference between preoperatively predicted refraction by the IOLMaster 700 using the SRK/T and Barrett Universal II formulas and the postoperative manifest refractive spherical equivalent measured between 6 and 10 weeks. Median absolute error (MedAE) was defined as the median absolute value of the refractive prediction error.

Questionnaire

Postoperative patient satisfaction and dependence on glasses were assessed with a questionnaire answered at 6 to 10 weeks after cataract surgery [9]. This questionnaire is commonly used for patients who underwent MIOL implantation during cataract surgery in the BGN World Tower Eye Clinic and is administered only after patient agreement. Overall postoperative patient satisfaction was rated on a 1–5 scale: 1, Very Dissatisfied; 2, Dissatisfied; 3, Neutral; 4, Satisfied; 5, Very Satisfied. In addition, need for farsighted and nearsighted glasses was assessed [10].

Statistical analysis

Data from all patients were statistically analyzed with the Statistical Package for Social Sciences Statistics Standard 20 (IBM Corp., Armonk, NY, USA). The relationship between UDVA, UNVA, and pupil size was evaluated using linear regression analyses. Student's *t* tests and Fisher's exact tests were performed to compare the clinical characteristics and Pentacam and IOLMaster 700 measurements between GVO and MVO groups. Multivariate binary logistic regression analysis was performed for the odds ratio of factors associated with good visual outcomes in patients with implanted Lentis Mplus IOL. Receiver operating characteristic (ROC) curve analysis was performed to assess cutoff values of factors associated with good visual outcomes of patients with implanted Lens Mplus IOL. Spearman's rank correlation analysis was used to evaluate the correlations between satisfaction score and values of factors associated with good visual outcomes of patients with implanted Lentis Mplus IOL. P values < 0.05 were considered statistically significant.

Results

The mean age of the 198 enrolled patients was 57.5 ± 5.9 years (range, 41–73 years). There were 157 women (79.3%) and 101 right eyes (51.0%). Mean kappa distance was 0.19 ± 0.10 mm (range, 0.03–0.67 mm) in all patients and kappa distance was lower than 0.31 mm in 90% of patients. Preoperative measurements including pupil size, kappa angle, K, corneal astigmatism, and IOL power implanted are summarized in Table 1.

Mean postoperative residual sphere, cylinder, and spherical equivalent were − 0.14 ± 0.29 D, − 0.26 ± 0.34 CD, and − 0.27 ± 0.31 D, respectively. The MedAE predicted by the SRK/T formula was 0.27 D, and that predicted by the Barrett Universal II formula was 0.25 D. Although IOL constant optimization was not performed, the percentage of eyes that achieved postoperative refractive prediction error within ± 0.50 D was 85.9% for the SRK/T formula and 90.9% for the Barrett Universal II formula.

Mean postoperative UDVA and UNVA were 0.05 ± 0.07 logMAR and 0.08 ± 0.09 logMAR, respectively. As shown in the defocus curve (Fig. 1), there was a peak at 0 D defocus, no second peak, and a tendency for visual acuity to slightly decrease with increase defocus. The mean visual acuity was 0.2 logMAR or more between + 0.50D to − 2.00D in the defocus curve. UDVA tended to decline as pupil size increased ($Y = 0.020X - 0.011$, $R^2 = 0.021$, $P = 0.041$; Fig. 2a), but UNVA was not correlated with pupil size (Fig. 2b). Moreover, neither UDVA nor UNVA correlated with kappa distance.

Among a total of 198 patients, 116 (58.5%) had UDVA of 0.0 logMAR or more, 154 (77.8%) had UNVA of 0.1 logMAR or more, and 96 (48.5%) met these two conditions

Table 1 Clinical characteristics of patients with cataract and their eyes in a study of factors indicating good visual outcomes of multifocal intraocular lens with an inferior segmental near add ($n = 198$)

Parameter	Mean ± SD	Range
Age, years	57.5 ± 5.9	41–73
Sex		
Male/female, *n* (%)	41 (20.7):157 (79.3)	
Laterality		
Right eye/left eye, *n* (%)	101 (51.0):97 (49.0)	
Pupil size, mm[a]	2.81 ± 0.54	1.15–4.77
Kappa distance, mm[a]	0.19 ± 0.10	0.03–0.67
Kappa angle, °[a]	161.7 ± 98.2	0.0–358.4
Corneal power, D[b]	44.12 ± 1.34	40.25–47.88
Corneal astigmatism, CD[b]	0.58 ± 0.34	0.00–1.50
Anterior chamber depth, mm[b]	3.14 ± 0.31	2.26–3.99
Axial length, mm[b]	23.64 ± 1.13	21.01–29.50
IOL power, D	20.0 ± 3.2	2.0–30.0

D diopters, *CD* cylindrical diopters, *IOL* intraocular lens, *SD* standard deviation

Data are mean ± SD except for sex and laterality, which are *n* (%)

[a] Pupil size and Kappa distance and angles measured by Pentacam

[b] Corneal power, corneal astigmatism, anterior chamber depth, and axial length measured by IOLMaster 700

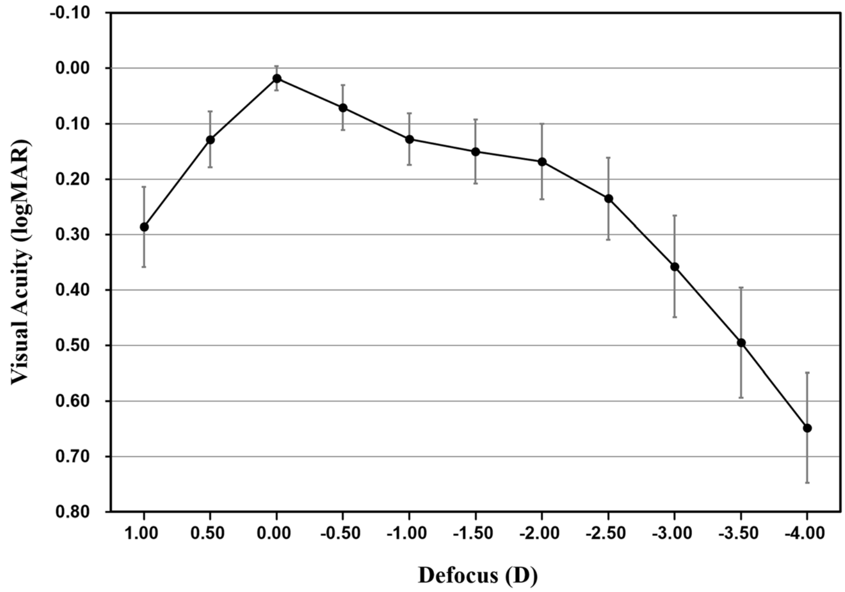

Fig. 1 Mean monocular distance-corrected defocus curves at 6 to 10 weeks after cataract surgery in a study on factors for good visual outcomes of multifocal intraocular lens with inferior segmental near add

and showed good visual outcomes. The mean age of the GVO group was 56.2 ± 5.8 years, which was significantly lower than that of the MVO group (58.6 ± 5.8 years). Preoperative corneal astigmatism and postoperative residual cylinder and spherical equivalent measurements in the GVO group (− 0.52 CD, − 0.16 CD, and − 0.19 D, respectively) were significantly lower than those in the MVO group (− 0.64 CD, − 0.34 CD, and − 0.35 D). Conversely, there was no significant difference in pupil size between the two groups. The average kappa distance of the GVO group (0.18 mm) was significantly smaller than that of the MVO group (0.21 mm) (Table 2). Among all patient eyes, 20 had nasal kappa angle, 57 had superior kappa angle, 86 had temporal kappa angle, and 35 had inferior kappa angle. There was no difference between the two groups in position distribution of kappa angles (Table 3).

Multivariate binary logistic regression analysis was performed using variables related to good visual outcomes obtained by univariate analysis. Of preoperative corneal astigmatism and postoperative residual cylinder, residual cylinder was employed in multivariate analysis because the two variables showed multicollinearity. Multiple factors including age (odds ratio [OR], 0.940; 95% confidence interval [CI], 0.891–0.992; $p = 0.023$), residual cylinder (OR, 2.939; 95% CI, 1.039–8.315; $p = 0.042$), and residual spherical equivalent (OR, 3.163; 95% CI, 1.057–9.468; $p = 0.040$) were related to good visual outcomes (Table 4).

According to the ROC curve, cutoff values regarded as good visual outcome were calculated to be − 0.32 D [area under the curve (AUC), 0.643; 95% CI, 0.565–0.722] in residual spherical equivalent and − 0.38 CD (AUC, 0.635; 95% CI, 0.558–0.713) in residual cylinder. However, good visual outcomes could not be predicted based on age and kappa distance, since their AUCs were less than 0.5 (Fig. 3).

Of all enrolled patients, 153 (77.3%) answered the postoperative questionnaire. A total of 76 patients (49.7%) belonged to the GVO group, and 77 patients (50.3%) were in the MVO group. The mean satisfaction score of surveyed patients was 3.3 ± 1.0. The need for farsighted and nearsighted glasses expressed as a proportion was 8.5% (13 patients) and 11.8% (18 patients) of surveyed patients, respectively. The mean satisfaction score of the GVO group was 3.6 ± 0.9, which was significantly higher than that of the MVO group (3.1 ± 1.0) ($P = 0.001$). There were 3 (3.9%) and 7 (9.2%) patients in the GVO group who needed farsighted and nearsighted glasses, respectively. This result was lower than that of the MVO group (10 patients (13.0%) and 11 patients (14.3%), respectively), although there was no significant difference between the two groups. Correlation analysis revealed a positive correlation between satisfaction score and residual cylinder ($\rho = 0.189$, $P = 0.019$). However, satisfaction score did not correlate with age, kappa distance, or residual spherical equivalent (Table 5).

Discussion

In this study, we investigated factors related to postoperative good visual outcomes of eyes implanted with Lentis Mplus LS-313 MF20 IOL in cataract surgery. Our results indicate that young age and low levels of postoperative residual cylinder and spherical equivalent were related to good visual outcomes. The ROC curve showed that residual cylinder less than − 0.38 CD and residual spherical equivalent less than − 0.32 D could provide excellent vision at both near and far distances. In addition, postoperative satisfaction of the GVO group was significantly higher than that of the MVO group. These results indicate that good visual outcomes are improved by

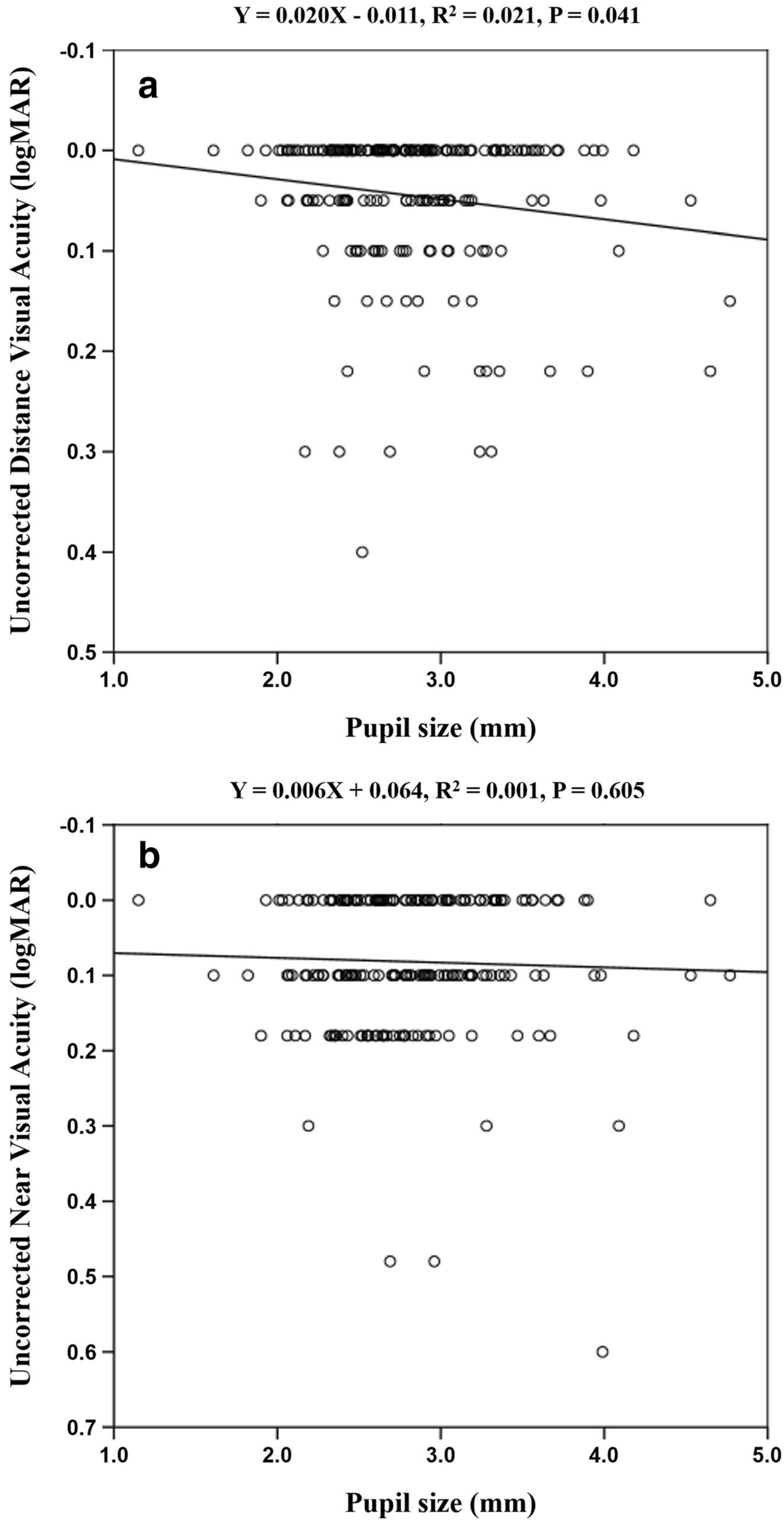

Fig. 2 Linear regression analysis of relationships between pupil size and uncorrected distance visual acuity (**a**) or near visual acuity (**b**)

minimization of residual cylinder and spherical equivalent, which can increase patient satisfaction. Similar to this study, a previous study demonstrated that postoperative emmetropia and low levels of residual cylinder are the most crucial factors

Table 2 Comparison of preoperative and postoperative parameters and intraocular lens power between good and moderate visual outcomes groups ($n = 198$)

Parameters	Visual outcomes		*P* value[c]
	Good ($n = 96$)	Moderate ($n = 102$)	
Age, years	56.2 ± 5.8	58.6 ± 5.8	*0.004*
Sex			
Male/female, *n* (%)	24 (25.0):72 (75.0)	17 (16.7):85 (83.3)	0.164[d]
Laterality			
Right eye/left eye, *n* (%)	46 (47.9):50 (52.1)	55 (53.9):47 (46.1)	0.477[d]
Preoperative data			
Pupil size, mm[a]	2.76 ± 0.51	2.86 ± 0.57	0.177
Kappa distance, mm[a]	0.18 ± 0.09	0.21 ± 0.11	*0.009*
Kappa angle, °[a]	163.6 ± 104.2	159.8 ± 92.8	0.789
Corneal power, D[b]	43.99 ± 1.37	44.25 ± 1.31	0.165
Corneal astigmatism, CD[b]	0.52 ± 0.31	0.64 ± 0.35	*0.015*
Anterior chamber depth, mm[b]	3.19 ± 0.30	3.10 ± 0.31	0.051
Axial length, mm[b]	23.78 ± 1.04	23.50 ± 1.20	0.081
Postoperative data			
Visual acuity			
UDVA, logMAR	0.00 ± 0.00	0.09 ± 0.08	*< 0.001*
UNVA, logMAR	0.03 ± 0.05	0.13 ± 0.10	*< 0.001*
Residual refractive error, D			
Sphere	− 0.11 ± 0.22	− 0.17 ± 0.34	0.122
Cylinder	− 0.16 ± 0.28	− 0.34 ± 0.37	*< 0.001*
Spherical equivalent	− 0.19 ± 0.23	− 0.35 ± 0.36	*< 0.001*
IOL power, D	19.7 ± 2.9	20.4 ± 3.5	0.136

D diopters, *CD* cylindrical diopters, *logMAR* logarithm of minimum angle of resolution, *IOL* intraocular lens, *SD* standard deviation

Data are mean ± SD except for sex and laterality, which are n (%). Statistically significant differences are indicated in italics font

[a] Pupil size and kappa distance and angles measured by Pentacam

[b] Corneal power, corneal astigmatism, anterior chamber depth, and axial length measured by IOLMaster 700

[c] Student's *t* test

[d] Fisher's exact test

in terms of postoperative satisfaction in refractive MIOL-implanted patients [11]. In effect, blurred vision was the greatest cause of dissatisfaction in MIOL-implanted patients [12]. Another previous study showed that UDVA was a strong

Table 3 Comparison of proportion of kappa angle meridian between good visual outcomes and moderate visual outcomes in eyes with multifocal intraocular lens with inferior segmental near add ($n = 198$)

	Good ($n = 96$)	Moderate ($n = 102$)	*P* value[a]
Nasal kappa angle, *n* (%)	11 (11.5)	9 (8.8)	0.146
Superior kappa angle, *n* (%)	30 (31.3)	27 (26.5)	
Temporal kappa angle, *n* (%)	34 (35.4)	52 (51.0)	
Inferior kappa angle, *n* (%)	21 (21.9)	14 (13.7)	

In right eyes, nasal kappa angle was defined as kappa angle of 0 ± 45°, superior kappa angle was defined as 90 ± 45°, temporal kappa angle was defined as 180 ± 45°, and inferior kappa angle was defined as 270 ± 45° depending on meridian

In left eyes, nasal kappa angle was defined as kappa angle of 180 ± 45°, and temporal kappa angle was defined as 0 ± 45°

[a] Fisher's exact test

Table 4 Multivariate binary logistic regression analysis of factors associated with good visual outcomes of multifocal intraocular lens with inferior segmental near add

	Odds ratio	95% confidence interval	*P* value
Age	0.940	0.891–0.992	*0.023*
Kappa distance[a]	0.048	0.002–1.099	0.057
Residual cylinder	2.939	1.039–8.315	*0.042*
Residual spherical equivalent	3.163	1.057–9.468	*0.040*

[a] Kappa distance measured by Pentacam. Statistically significant differences are indicated in italics font

predictive factor of postoperative visual discomfort in rotationally symmetric refractive MIOL-implanted patients [13].

Lentis Mplus LS-313 MF20 IOL is a rotationally asymmetric refractive MIOL with + 2.0 D near addition in the lower part. The results of this study reveal a tendency to exhibit good visual outcomes at both distance and near along with decreasing kappa distance, although kappa distance had a borderline *p* value in the multivariate binary logistic regression analysis. If eyes have large kappa distance and inferior kappa angle, the visual axis is more likely to pass the near add segment of the lens, which may decrease distant vision. Conversely, if eyes have large kappa distance and superior kappa angle, the visual axis is more likely to pass the distant-vision zone, and near vision may decrease. Thus, Lentis Mplus IOL may not provide good visual outcomes at both distance and near with increased Kappa distance. Notably, a prior study of Lentis Mplus IOLs reported that preoperative photopic kappa angle was associated with photic phenomena such as glare and halos after IOL implantation [14].

A previous comparative study of the relationship between near-segment position and visual performance revealed that the position of the near-segment did not affect visual performance in the Lentis Mplus IOL-implanted eye [15]. Similarly, comparative analysis revealed no significant difference in visual outcomes by Kappa angle position in this study. The Lentis Mplus IOL included a lenslet with 1.15 mm center diameter. The mean Kappa distance of all patients was 0.19 mm, and 90% of them showed Kappa distance less than 0.31 mm on average in this study. In this regard, there might be limitations in conducting a study evaluating the effect of Kappa angle and distance on visual performance in a study group containing fewer large kappa distances.

A previous study that evaluated the effect of patient age on the visual outcomes of eyes with diffractive multifocal IOLs showed that older patients have worse corrected visual acuities and contrast sensitivity [16]. Low mesopic contrast sensitivity function of eyes with Lentis Mplus IOL was similar to that of eyes with diffractive AT LISA trifocal and FiveVision IOLs [17]. The results of this study showed that younger patients with Lentis MPlus IOL might have better uncorrected distance and near visual acuity. However, the age difference is small between the GVO and MVO groups, and both groups are relatively young. In addition, according to the ROC curve, residual cylinder and spherical equivalent are mainly associated with better uncorrected distance and near acuity in eyes with Lentis Mplus IOL. Thus, a large-scale prospective study is needed to evaluate the effect of patient age on the visual outcomes of eyes with refractive multifocal IOL such as Lentis MPlus IOL.

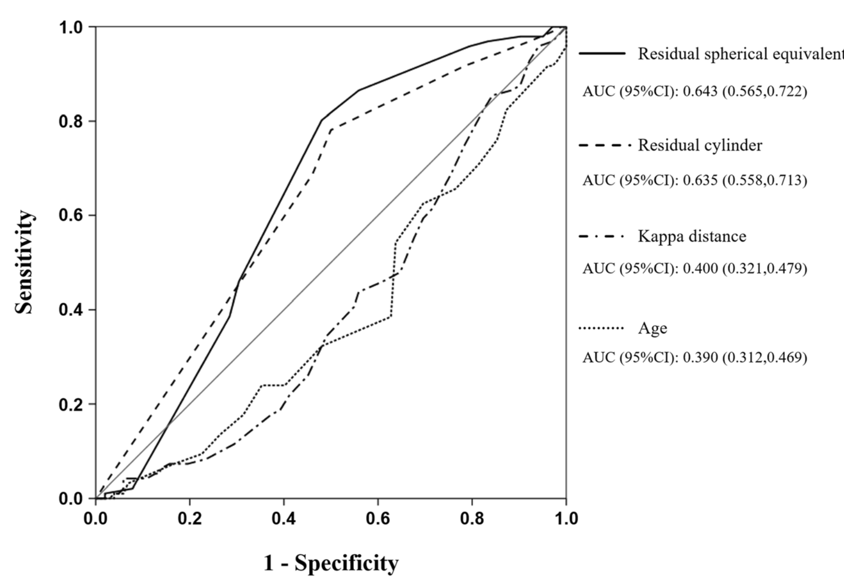

Fig. 3 Graph of receiver operating characteristic (ROC) curve to assess cutoff values of factors associated with good visual outcomes of patients with implanted Lens MPlus IOL

Table 5 Correlation coefficients (ρ) and P values of univariate analysis for satisfaction score, age, kappa distance, residual cylinder, and residual spherical equivalent

Parameters	Satisfaction score	
	ρ	P
Age	0.045	0.583
Kappa distance[a]	− 0.019	0.818
Residual cylinder	0.189	*0.019*
Residual spherical equivalent	0.080	0.326

[a] Kappa distance measured by Pentacam. Statistically significant differences are indicated in italics font

Patients with implanted MIOL are more likely to reach the desired refractive state after cataract surgery with improved biometric devices, precision cataract surgical skills, and accurate IOL power calculation, [18] which can increase visual outcomes and satisfaction [19]. In this study, preoperative biometry was measured using a IOLMaster 700, and cataract surgery was precisely performed by an experienced surgeon. Consequently, patients with refractive error less than 0.50 D accounted for 85.9% and 90.9% of the total by SRK/T and Barret Universal II formulas, respectively. By virtue of this excellent prediction of refractive errors, the percentage of patients with good visual performance for both distance and near vision can increase.

Consistent with a previous result [20], the defocus curve analysis of this study demonstrated visual acuity in eyes with implanted Lentis Mplus LS-313 MF20 IOL is 0.2 logMAR or greater between + 0.50 D and − 2.00 D defocus. This result indicates that Lentis Mplus LS-313 MF20 IOL has similar performance to extended depth of focus (EDOF) IOLs. In another previous study conducted with Lentis Mplus LS-312 MF30 IOLs with + 3.0 D near add power, visual acuity was 0.2 logMAR or greater even at a wider interval of 0.0 D to − 3.5 D defocus. [7]

The results of this study showed that 91.5% and 88.2% of patients did not require farsighted or nearsighted glasses, respectively. A prior study of Lentis Mplus X IOL with + 3.0 D near add power reported that 92% of patients did not require nearsighted glasses [21]. For AT LISA Tricfocal diffractive IOLs, 88% of patients did not require nearsighted glasses [22]. The Lentis Mplus IOL used in this study has + 2.0 D near add power, which is weaker than that of previous studies. However, it showed similarly high rates of spectacle independence.

This study has several limitations. First, visual acuity was not further measured if it was first measured as 20/20. However, the results of this study reflect visual performance in patients with implanted Lentis Mplus IOL in actual clinical situations. Second, IOL centration was not evaluated after pupil dilation following cataract surgery. However, CCC was created using a Lensx femtosecond laser in this study. A previous study showed that femtosecond laser capsulotomy has better IOL centration than in eyes with CCCs obtained using a manual technique [23]. In addition, CTRs were inserted into the capsular bag of all enrolled patients. Insertion of CTRs into the bag improves positional stability of IOLs by preventing posterior capsule opacification and anterior capsule contraction [24, 25]. Indeed, a previous study of the Lentis Mplus IOL reported that simultaneous implantation of the IOL and CTR, compared to implantation of the IOL alone, led to better IOL positional stability and exhibited better results on the defocus curve [8].

Conclusion

The present study demonstrated that age, postoperative residual cylinder, and spherical equivalent were associated with good distance and near visual outcomes in eyes with implanted Lentis Mplus LS-313 MF20 IOL. The performance of the Lentis Mplus LS-313 MF20 is expected to be maximized by minimizing residual cylinder and spherical equivalent. Accordingly, surgeons should minimize residual cylinder and spherical equivalent to provide both good near and distance vision to patients scheduled for Lentis Mplus LS-313 MF20 implantation in cataract surgery.

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Compliance with ethical standards

Conflict of interest All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements) or non-financial interest (such as personal or professional relationships, affiliations, knowledge, or beliefs) in the subject matter or materials discussed in this manuscript.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the Public Institutional Bioethics Committee (no. P01-202003-21-002) and the Institutional Review Board of Korea University Ansan Hospital (IRB no. 2020AS0015) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent According to the IRB standard operating procedures on retrospective clinical study, the Ethics Committee ruled that subject consent was not required for this study.

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