Influence of Near-Segment Positioning in a Rotationally Asymmetric Multifocal Intraocular Lens

In Seok Song, MD; Sam Young Yoon, MD, PhD; Jae Yong Kim, MD, PhD; Myoung Joon Kim, MD, PhD; Hungwon Tchah, MD, PhD

ABSTRACT

PURPOSE: To compare visual performance and higher order aberrations (HOAs) based on the position of the near segment in eyes with rotationally asymmetric multifocal intraocular lenses (IOLs).

METHODS: Asymmetric multifocal IOLs (Lentis Mplus LS-313; Oculentis Optikgeräte GmbH, Wetzlar, Germany) were implanted with the near segment positioned either inferiorly, superiorly, or temporally. Uncorrected distance (UDVA), intermediate (UIVA), and near (UNVA) visual acuity, corrected distance visual acuity (CDVA), and distance-corrected intermediate (DCIVA) and near (DCNVA) visual acuity, contrast sensitivity, HOAs, and subjective symptom questionnaires were compared at 1 month postoperatively.

RESULTS: Forty-five eyes from 45 patients were evaluated (n = 25, 9, and 11 eyes in the inferior, superior, and temporal groups, respectively). No significant differences in UDVA, UIVA, UNVA, CDVA, DCIVA, or DCNVA were found between the three groups ($P > .05$). The temporal group showed the best results in UDVA, CDVA, and DCNVA, but the inferior group showed the best results in DCIVA and UNVA and the superior group showed the best results in UIVA. Contrast sensitivity and the subjective symptom questionnaire also did not demonstrate any significant differences ($P > .05$). Total HOA and spherical aberration did not demonstrate any statistically significant differences ($P > .05$), but vertical coma and horizontal coma demonstrated significant differences based on near segment position ($P < .001$).

CONCLUSIONS: The position of the near segment in eyes with rotationally asymmetric multifocal IOLs demonstrates no significant effect on visual performance.

[*J Refract Surg.* 2016;32(4):238-243.]

The Lentis Mplus (Oculentis Optikgeräte GmbH, Wetzlar, Germany) is a refractive rotationally asymmetric multifocal intraocular lens (IOL) with an additional sector-shaped near-vision zone.[1] This IOL was recently introduced to clinical practice and its clinical outcomes have been extensively reported.[1-16] Other researchers have mostly investigated the IOL's clinical results in comparison with other presbyopia-correcting IOLs and the positional stability of the capsular tension ring and plate-haptic design. Placement of an additional sector-shaped near-vision zone was usually inferior,[2-5,15,16] slightly nasally deviated,[6] or definite positional remarks were absent. Inferior placement of the near segment is recommended by the manufacturer.[2] However, one case report that showed good results after superior rotation of the near segment in the eye with inferior corneal scar implies the possibility that different positioning of the near segment could be better than or comparable with inferior placement depending on the cornea's status.[17] The authors thought that placement of the near segment in any direction within the pupillary area could result in good far and near focus in the eyes with normal corneas without much irregularity.

The aim of the current study was to compare both visual performance and higher order aberrations (HOAs) depending on the position of the near segment in eyes with rotationally asymmetric multifocal IOLs.

PATIENTS AND METHODS

Study Design

This retrospective, comparative clinical study was performed at the Department of Ophthalmology, University of Ul-

From the Department of Ophthalmology, Hanyang University Medical Center, Seoul, Korea (ISS); the Department of Ophthalmology, Kangdong Sacred Heart Hospital, Hallym University College of Medicine, Seoul, Korea (SYY); and the Department of Ophthalmology, University of Ulsan College of Medicine, Asan Medical Center, Seoul, Korea (JYK, MJK, HT).

Submitted: June 17, 2015; Accepted: January 15, 2016

The authors have no financial or proprietary interest in the materials presented herein.

Correspondence: Hungwon Tchah, MD, PhD, Department of Ophthalmology, University of Ulsan College of Medicine, Asan Medical Center, 88, Olympic-ro 43-gil, Songpa-gu, Seoul 138-736, Korea. E-mail: hwtchah@amc.seoul.kr

doi:10.3928/1081597X-20160217-06

san College of Medicine, Asan Medical Center, Seoul, Korea. Patients who had undergone cataract surgery with rotationally asymmetric multifocal IOLs between January 2012 and March 2014 were enrolled. The study was approved by the hospital's institutional review board and followed the tenets of the Declaration of Helsinki. All patients provided written informed consent.

Patients

Patients with moderate cataracts (NO2, C2, P1, or more severe cataracts according to the Lens Opacity Classification System III) (ie, significant reduction of visual quality) and who preferred not to use reading glasses were included. Exclusion criteria included age younger than 50 years or older than 85 years (to avoid a confounding bias due the relationship between age and retinal health status), axial length greater than 26 mm, corneal astigmatism greater than 1.50 diopters (D), intraoperative complications, and ocular disease other than cataracts. Eyes with topographically irregular corneas were also excluded.

All patients underwent a full ophthalmologic examination, including visual acuity, tonometry, refractive status, slit-lamp evaluation, topography (Orbscan; Bausch & Lomb, Inc., Rochester, NY), specular microscopy, and funduscopy. After considering corneal curvature, axial length, and anterior chamber depth, IOL power was determined using the SRK II, SRK/T, Haigis, or Hoffer Q formula and IOLMaster optical biometer (Carl Zeiss Meditec AG, Jena, Germany).

IOL and the Position of the Near Segment

The Lentis Mplus is a single-piece refractive multifocal IOL made of hydrophilic acrylic with a hydrophobic surface. This IOL is constructed based on the concept of rotational asymmetry, in which two refractive zones are both on the optical axis of the IOL: aspheric distance-vision zone combined with a near addition of +3.00 D posterior sector-shaped near-vision zone. The LS-313 with a plate-haptic design was used in this study. The direction of the near segment of this IOL was one of the three directions: inferior, superior, or temporal.

Surgical Technique

All operations were performed on the superior side of the patient's head by one surgeon (HT). After the application of topical anesthesia (0.5% proparacaine hydrochloride), a continuous curvilinear capsulorhexis marker with a 6-mm diameter was used as a reference to the corneal plane. The diameter was approximately 5 mm on the IOL plane. A 2.2-mm limbal incision was made at a steep axis to reduce corneal astigmatism. Continuous curvilinear capsulorhexis and hydrodissection were then performed. Microcoaxial phacoemulsification and polishing were performed, and the rotationally asymmetric multifocal IOL was implanted in the capsular bag with good centration through an enlarged 2.75-mm incision. Stromal hydration of the incision site was performed using a balanced salt solution, and surgery was completed without sutures. Postoperative 1.0% gatifloxacin and rimexolone eye drops were administered four times per day for 4 weeks.

Postoperative Assessment

Approximately 1 month after surgery, uncorrected visual acuity was measured, including distance, intermediate, and near (UDVA, UIVA, and UNVA). After assessing manifest refraction, corrected distance visual acuity was also measured, including distance, intermediate, and near (CDVA, DCIVA, and DCNVA). Near and intermediate visual acuity were measured using a Landolt C ring chart at 40 cm for near and 70 cm for intermediate. Contrast sensitivity under photopic and mesopic conditions was measured using a vision contrast sensitivity test (Vistech Consultants, Inc., Dayton, OH). Ocular higher order aberrations (HOAs) were measured using a Zywave II wavefront analyzer (Bausch & Lomb, Inc.) over a 5-mm pupil.

Patients completed a questionnaire designed to assess subjective symptoms with the eye treated (**Figure A**, available in the online version of this article). Patient satisfaction was assessed at three levels (very satisfied, moderately satisfied, or unsatisfied). Postoperative glare and halo were evaluated at three levels (none to minimal, moderate, or severe), and each patient's dependency on reading glasses was evaluated (never, sometimes, or always). Patients were instructed to answer the questions regarding the one eye treated. Patient recommendations for the procedure were also evaluated.

Statistical Analysis

Data are presented as the mean ± standard deviation. Statistics were analyzed using SPSS for Windows software (version 21.0; SPSS, Inc., Chicago, IL). The included eyes were divided into three groups depending on the position of the near segment. The Kruskal–Wallis test was used to compare three independent sample groups. Categorical data were analyzed using the chi-square or Fisher exact test. Two-sided *P* values less than .05 are considered statistically significant.

RESULTS

A total of 45 eyes from 45 patients who underwent unilateral cataract surgery were included in this study. The inferior group consisted of 25 eyes, the superior group consisted of 9 eyes, and the temporal group con-

TABLE 1
Preoperative Patient Characteristics

Characteristic	Inferior Group	Superior Group	Temporal Group	P[a]
Eyes (n)	25	9	11	–
Age (y)	67.44 ± 8.71	66.67 ± 7.16	64.27 ± 12.60	.733
Sphere (D)	0.30 ± 1.79	-0.62 ± 2.41	0.06 ± 1.88	.444
Cylinder (D)	1.05 ± 0.48	0.94 ± 0.32	1.01 ± 0.70	.936
MRSE (D)	0.82 ± 1.74	-0.17 ± 2.48	0.55 ± 1.90	.471
UDVA (logMAR)	0.48 ± 0.29	0.43 ± 0.30	0.42 ± 0.20	.972
CDVA (logMAR)	0.24 ± 0.24	0.19 ± 0.11	0.16 ± 0.12	.755
IOL power (D)	19.86 ± 2.22	19.50 ± 2.36	18.83 ± 1.85	.483

D = diopters; MRSE = manifest refraction spherical equivalent; UDVA = uncorrected distance visual acuity; CDVA = corrected distance visual acuity; IOL = intraocular lens
[a]Kruskal–Wallis test.

TABLE 2
Postoperative Refractive and Visual Acuity (logMAR) Outcomes

Parameter	Inferior Group	Superior Group	Temporal Group	P[a]
Sphere (D)	-0.43 ± 0.58	-0.56 ± 0.33	-0.61 ± 0.45	.248
Cylinder (D)	0.66 ± 0.51	0.61 ± 0.25	0.70 ± 0.38	.746
MRSE (D)	-0.10 ± 0.60	-0.25 ± 0.32	-0.26 ± 0.49	.356
UDVA	0.09 ± 0.09	0.13 ± 0.11	0.06 ± 0.07	.415
CDVA	0.02 ± 0.05	0.03 ± 0.05	0.01 ± 0.03	.575
UIVA	0.32 ± 0.18	0.31 ± 0.12	0.39 ± 0.13	.361
DCIVA	0.29 ± 0.17	0.34 ± 0.15	0.31 ± 0.09	.643
UNVA	0.30 ± 0.21	0.37 ± 0.10	0.35 ± 0.12	.318
DCNVA	0.28 ± 0.15	0.30 ± 0.07	0.27 ± 0.10	.807

D = diopters; MRSE = manifest refraction spherical equivalent; UDVA = uncorrected distance visual acuity; CDVA = corrected distance visual acuity; UIVA = uncorrected intermediate visual acuity; DCIVA = distance corrected intermediate visual acuity; UNVA = uncorrected near visual acuity; DCNVA = distance corrected near visual acuity.
[a]Kruskal–Wallis test.

sisted of 11 eyes. The preoperative clinical characteristics of each group are summarized in **Table 1**. There were no significant differences in age, preoperative refraction, UDVA, CDVA, or power of the implanted IOL. Postoperative refraction and visual acuity outcomes demonstrated no significant differences between the three groups (**Table 2**). Refraction in the temporal group was slightly more myopic than the other groups, but a statistically significant difference was not found between the three groups and manifest refraction corrected visual acuity also demonstrated no significant differences. Although UDVA and UNVA were slightly worse in the superior group than the other groups, statistically significant differences were not found.

Figure 1 shows contrast sensitivity under photopic and mesopic conditions in the three groups. All three groups of eyes demonstrated good contrast sensitivity under photopic and mesopic conditions. There were no statistically significant differences at any spatial frequency ($P > .05$; Kruskal–Wallis test).

Table 3 lists the postoperative ocular HOAs. Total HOA and spherical aberration demonstrated no statistically significant differences, but vertical coma and horizontal coma demonstrated significant differences between the three groups ($P = .000$ and .001, respectively; Kruskal–Wallis test). Vertical coma values in the inferior group demonstrated almost negative values, the superior group demonstrated positive values, and the temporal group demonstrated small values (0.30 ± 0.30, 0.49 ± 0.18, and 0.00 ± 0.12 µm, respectively). Horizontal coma values in the inferior and superior groups were not large, but the temporal group demonstrated large horizontal coma values (-0.08 ± 0.22, -0.01 ± 0.18, and -0.41 ± 0.08 µm, respectively). We switched the sign of horizontal coma from positive to negative in the left eyes of the temporal group (4 of 11 eyes).

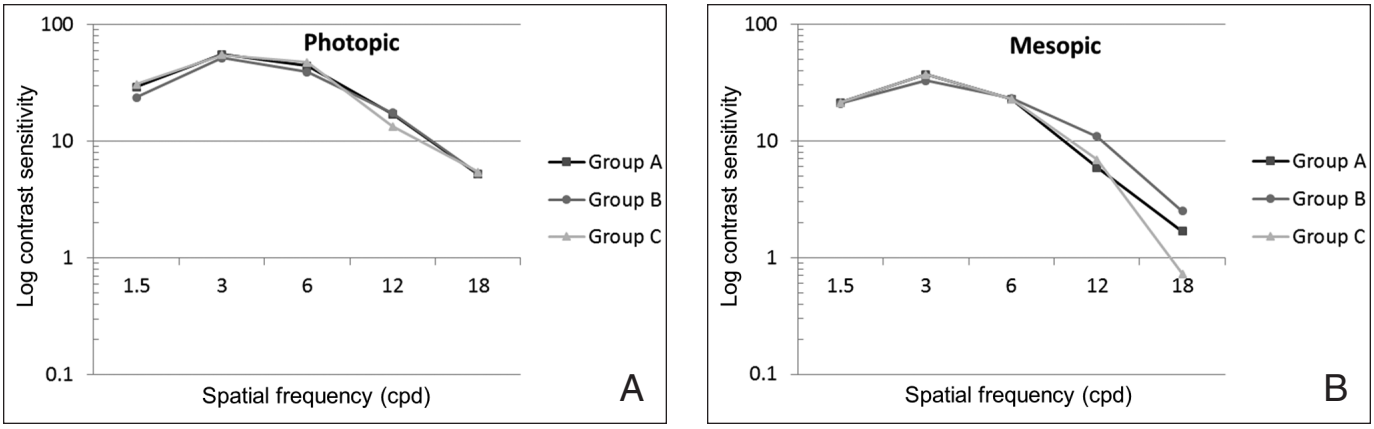

Figure 1. (A) Photopic and (B) mesopic contrast sensitivity in the three groups. No statistically significant differences were found (cpd = cycles per degree). Group A = inferior near segment; Group B = superior near segment; Group C = temporal near segment

TABLE 3
Postoperative Ocular HOAs

Aberration	Inferior Group	Superior Group	Temporal Group	*P*[a]
Total HOA (μm)	0.70 ± 0.15	0.66 ± 0.22	0.56 ± 0.07	.086
Spherical aberration (μm)	0.25 ± 0.11	0.24 ± 0.12	0.20 ± 0.06	.623
Vertical coma (μm)	-0.30 ± 0.30	0.49 ± 0.18	0.00 ± 0.12	< .001
Horizontal coma (μm)	-0.08 ± 0.22	-0.01 ± 0.18	-0.41 ± 0.08[b]	.001

HOA = higher order aberration
[a]*Kruskal–Wallis test.*
[b]*Horizontal coma switched from positive to negative in left eyes.*

Four of 25 patients in the inferior group did not answer the questionnaire. Three of 21 patients (14.3%) in the inferior group, 1 of 9 patients (11.1%) in the superior group, and 0 of 9 patients in the temporal group reported severe halo. Three patients (14.3%) in the inferior group, 1 patient (11.1%) in the superior group, and 5 patients (45.5%) in the temporal group reported moderate halo. However, there were no statistically significant differences between groups ($P = .264$; Fisher exact test). Two patients (9.5%) in the inferior group, 0 patients in the superior group, and 2 patients (18.2%) in the temporal group reported severe glare. Eight patients (38.1%) in the inferior group, 4 patients (44.4%) in the superior group, and 3 patients (27.3%) in the temporal group reported moderate glare. However, there were no statistically significant differences between groups ($P = .821$; Fisher exact test) (**Figure 2**).

Two of 21 patients (9.5%) in the inferior group always required reading glasses in comparison with 0 patients in the superior and temporal groups. Nine patients (42.9%) in the inferior group, 2 patients (22.2%) in the superior group, and 3 patients (27.3%) in the temporal group sometimes required reading glasses. However, there were no statistically significant differences between the three groups ($P = .508$; Fisher exact test). Five of 21 patients (23.8%) in the inferior group reported that they were moderately satisfied with their IOLs. The rest (76.2%) of the patients in the inferior group and all patients in the superior and temporal groups reported that they were very satisfied with their IOLs. Also, there were no statistically significant differences between the three groups ($P = .110$; Fisher exact test) (**Figure 3**). All patients in the inferior, superior, and temporal groups reported that they would recommend the procedure to another person.

DISCUSSION

The Lentis Mplus multifocal IOL demonstrates good visual outcomes with minimal optical side effects.[1-3,5-8,14-16] Theoretically, the design of a refractive, rotationally asymmetric, surface-embedded near segment makes the IOL independent of pupil size and demonstrates minimal energy loss.[1,2,6] Light hitting the transition area of the embedded sector is reflected away from the optical axis to prevent superposition of interference or diffraction.[1,3] The refractive rotationally asymmetric IOL has two refractive zones (one for far vision and one for near vision) and both are on the optical axis of the lens. Light in the near vision-specific zone is refracted to the near focus, and light in the rest

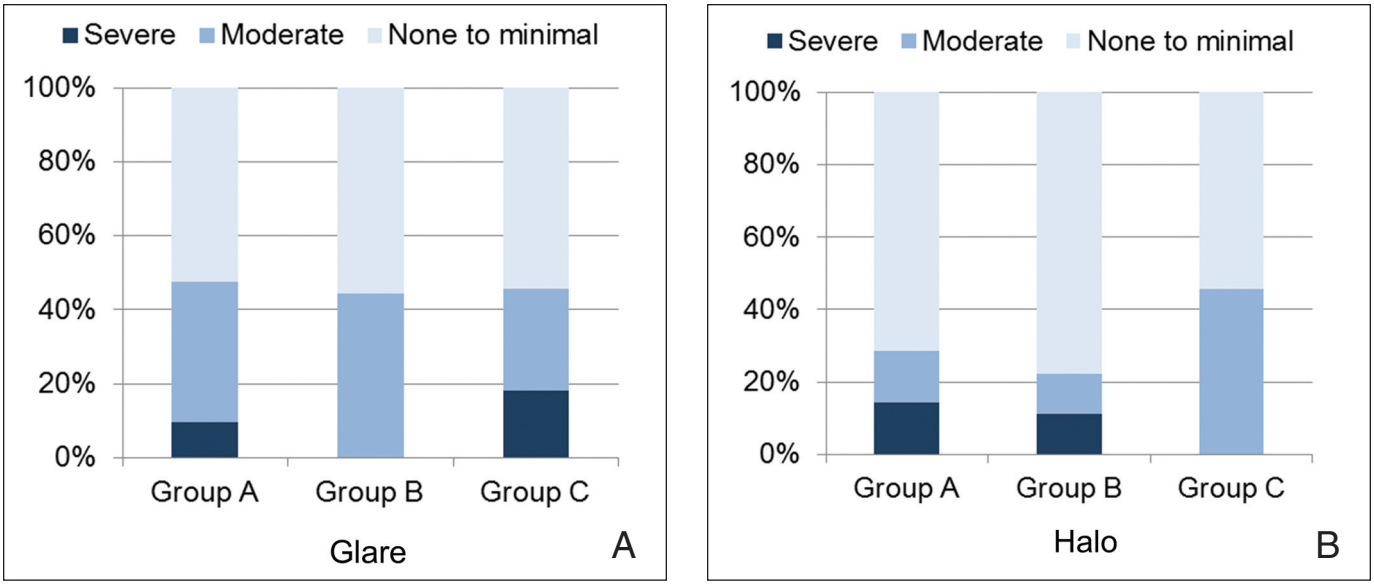

Figure 2. Subjective experience of (A) glare and (B) halo during daily life activities. Group A = inferior near segment; Group B = superior near segment; Group C = temporal near segment

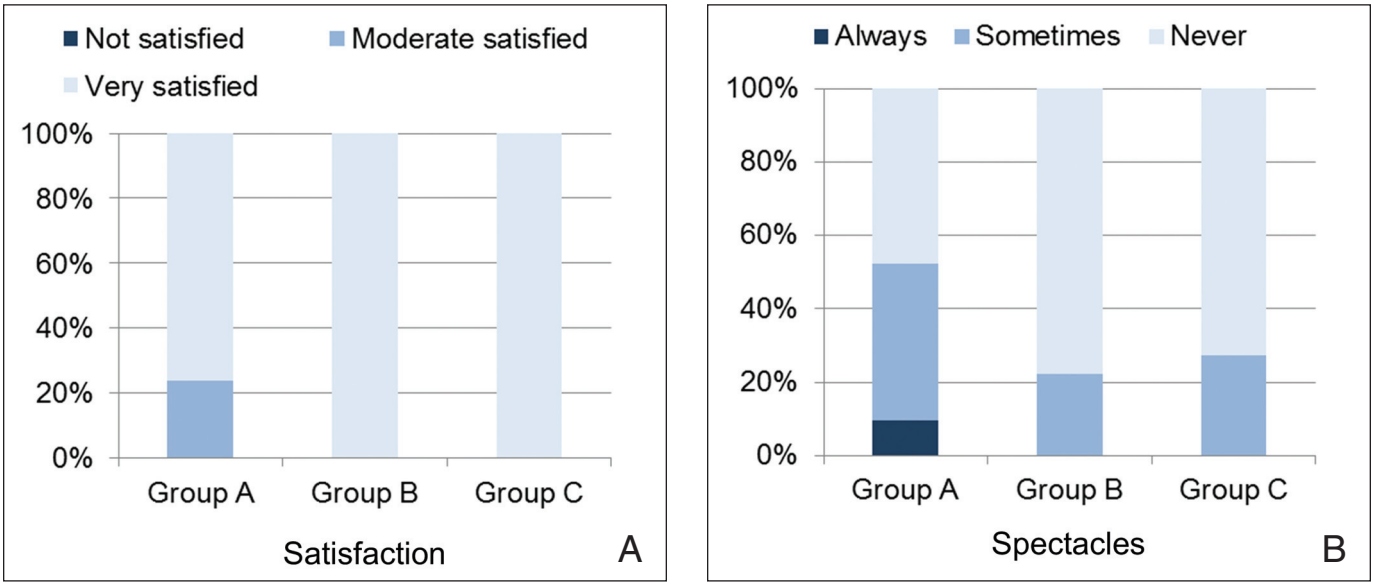

Figure 3. Patient (A) satisfaction and (B) dependency on spectacles for reading. Group A = inferior near segment; Group B = superior near segment; Group C = temporal near segment

of the lens is refracted to the far focus.[1,2] Therefore, incoming light rays are distributed to two principal focal points. We believed that by properly centering the IOL within the pupillary area, any direction of the near segment could result in the same focusing onto the fovea at far and near focal points. We also placed the IOL in the capsular bag with good centration.

The Lentis Mplus is a bifocal lens. In the case of bifocal lenses in the spectacle plane, the near segment is placed inferiorly to gaze downward for near work. However, the IOL is placed in the lens plane of the eye (ie, the position of the near segment in this IOL could be independent of gaze for near work). The inferior positioning of the near segment of this IOL has mostly been recommended.[2-5,15,16] However, a downward gaze for near work would not necessarily require an inferiorly placed near segment. In the current study, no statistically significant differences were found in terms of distance, intermediate, and near visual acuities, contrast sensitivity, or questionnaire results between the three groups after surgery.

We speculate that the results of our study might depend on the patient's cornea. One case report that showed better results after superior rotation of the near segment in the eye with small inferior corneal scar sug-

gests that the optimal positioning of near segment could be dependent on the cornea's status.[17] In the current study, we excluded the eyes with irregular corneas using preoperative topography and only included the eyes that had normal corneas without much irregularity. Hence, comparable effects on visual outcomes could be found regardless of the direction of the near segment.

We also evaluated ocular HOAs in each group and found that the vertical and horizontal coma values were significantly different between the three groups. Considering the additive power of +3.00 D in the near segment of this IOL, such differences were reasonable. One could assume that the inferior and superior position of the near segment would induce negative and positive vertical coma, respectively, and the temporal position of the near segment would have little influence on vertical coma (-0.30 ± 0.30, 0.49 ± 0.18, and 0.00 ± 0.12 μm, respectively). As is the case for horizontal coma, one could assume that the inferior and superior position of the near segment would have little influence on horizontal coma and the temporal position of the near segment would induce negative horizontal coma in the right eye (0.08 ± 0.22, -0.01 ± 0.18, and -0.41 ± 0.08 μm, respectively). If the near segment was placed nasally in the right eye, horizontal coma would be induced by a large positive degree.

The current study was limited by its retrospective nature and the sample size was small and unequivalent between the superior (9 eyes), temporal (11 eyes), and inferior (25 eyes) groups. The questionnaire used in this study was not widely accepted to assess subjective symptoms following multifocal IOL implantation and some caution might be needed to interpret the subjective outcome. The relatively short postoperative period might not draw a firm conclusion. Future large-scale prospective studies with longer follow-up periods are required to confirm the current findings.

The position of the near segment in eyes with rotationally asymmetric multifocal IOLs has no significant effect on visual performance. This seems to be the case when focusing on two focal points at far and near distances, regardless of the direction of the near segment, if two optic zones of different powers are well centered within the pupillary area.

AUTHOR CONTRIBUTIONS

Conception and design (ISS, HT); data collection (ISS, SYY); analysis and interpretation of data (ISS, JYK, MJK, HT); writing the manuscript (ISS); critical revision of the manuscript (ISS, SYY, JYK, MJK, HT); supervision (HT)

REFERENCES

1. Alió JL, Piñero DP, Plaza-Puche AB, Chan MJ. Visual outcomes and optical performance of a monofocal intraocular lens and a new-generation multifocal intraocular lens. *J Cataract Refract Surg.* 2011;37:241-250.
2. Muñoz G, Albarrán-Diego C, Ferrer-Blasco T, Sakla HF, García-Lázaro S. Visual function after bilateral implantation of a new zonal refractive aspheric multifocal intraocular lens. *J Cataract Refract Surg.* 2011;37:2043-2052.
3. Alió JL, Plaza-Puche AB, Javaloy J, Ayala MJ, Moreno LJ, Piñero DP. Comparison of a new refractive multifocal intraocular lens with an inferior segmental near add and a diffractive multifocal intraocular lens. *Ophthalmology.* 2012;119:555-563.
4. Muñoz G, Albarrán-Diego C, Javaloy J, Sakla HF, Cerviño A. Combining zonal refractive and diffractive aspheric multifocal intraocular lenses. *J Refract Surg.* 2012;28:174-181.
5. Alió JL, Plaza-Puche AB, Montalban R, Javaloy J. Visual outcomes with a single-optic accommodating intraocular lens and a low-addition-power rotational asymmetric multifocal intraocular lens. *J Cataract Refract Surg.* 2012;38:978-985.
6. McAlinden C, Moore JE. Multifocal intraocular lens with a surface-embedded near section: short-term clinical outcomes. *J Cataract Refract Surg.* 2011;37:441-445.
7. Alfonso JF, Fernández-Vega L, Blázquez JI, Montés-Micó R. Visual function comparison of 2 aspheric multifocal intraocular lenses. *J Cataract Refract Surg.* 2012;38:242-248.
8. Alió JL, Plaza-Puche AB, Javaloy J, Ayala MJ. Comparison of the visual and intraocular optical performance of a refractive multifocal IOL with rotational asymmetry and an apodized diffractive multifocal IOL. *J Refract Surg.* 2012;28:100-105.
9. Alió JL, Plaza-Puche AB, Javaloy J, Ayala MJ, Vega-Estrada A. Clinical and optical intraocular performance of rotationally asymmetric multifocal IOL plate-haptic design versus C-loop haptic design. *J Refract Surg.* 2013;29:252-259.
10. Alió JL, Plaza-Puche AB, Piñero DP. Rotationally asymmetric multifocal IOL implantation with and without capsular tension ring: refractive and visual outcomes and intraocular optical performance. *J Refract Surg.* 2012;28:253-258.
11. Alió JL, Plaza-Puche AB, Piñero DP, Javaloy J, Ayala MJ. Comparative analysis of the clinical outcomes with 2 multifocal intraocular lens models with rotational asymmetry. *J Cataract Refract Surg.* 2011;37:1605-1614.
12. Ramón ML, Piñero DP, Pérez-Cambrodí RJ. Correlation of visual performance with quality of life and intraocular aberrometric profile in patients implanted with rotationally asymmetric multifocal IOLs. *J Refract Surg.* 2012;28:93-99.
13. van der Linden JW, van Velthoven M, van der Meulen I, Nieuwendaal C, Mourits M, Lapid-Gortzak R. Comparison of a new-generation sectorial addition multifocal intraocular lens and a diffractive apodized multifocal intraocular lens. *J Cataract Refract Surg.* 2012;38:68-73.
14. Venter JA, Pelouskova M, Collins BM, Schallhorn SC, Hannan SJ. Visual outcomes and patient satisfaction in 9366 eyes using a refractive segmented multifocal intraocular lens. *J Cataract Refract Surg.* 2013;39:1477-1484.
15. Rosa AM, Loureiro Silva MF, Lobo C, et al. Comparison of visual function after bilateral implantation of inferior sector-shaped near-addition and diffractive-refractive multifocal IOLs. *J Cataract Refract Surg.* 2013;39:1653-1659.
16. Venter JA, Pelouskova M, Bull CE, Schallhorn SC, Hannan SJ. Visual outcomes and patient satisfaction with a rotational asymmetric refractive intraocular lens for emmetropic presbyopia. *J Cataract Refract Surg.* 2015;41:585-593.
17. Bala C, Meades K. Improvement in vision with inverted placement of an asymmetric refractive multifocal intraocular lens. *J Cataract Refract Surg.* 2014;40:833-835.

Question
1. How satisfied are you with the outcome of your procedure? **1) Very satisfied 2) Moderately satisfied 3) Unsatisfied** **2. How much difficulty do you now have with your vision at night because of glare from bight light?** **1) None to minimal 2) Moderate 3) Severe** **3. How much difficulty do you now have with your vision at night because of starburst or halos around bright light?** **1) None to minimal 2) Moderate 3) Severe** **4. Do you need reading glasses after surgery?** **1) No, almost not 2) Well, sometimes 3) Yes, nearly always** **5. Would you recommend the procedure to your friends or relatives?** **1) Yes 2) No**

Figure A. Subjective patient questionnaire.