· Clinical Research ·

Rainbow halos occur less following implantation of extended range of vision one-piece intraocular lenses *vs* diffractive bifocal intraocular lenses

Jae-hyung Kim[1], Youngsub Eom[2], Seo Yeon Park[2], Soo Youn Choi[2,3], Ho Sik Hwang[4], Jun-Heon Kim[5], Jong Suk Song[2], Hyo Myung Kim[2]

[1]Seoul Daabom Eye Center, Cheongju 28568, Republic of Korea
[2]Department of Ophthalmology, Ansan Hospital, Korea University College of Medicine, Seoul 15355, Republic of Korea
[3]BGN World Tower Eye Clinic, Seoul 05551, Republic of Korea
[4]Department of Ophthalmology, Yeouido St. Mary's Hospital, College of Medicine, the Catholic University of Korea, Seoul 07345, Republic of Korea
[5]Joeunnun Vision Clinic, Seoul 06134, Republic of Korea
Correspondence to: Youngsub Eom. Department of Ophthalmology, Ansan Hospital, Korea University College of Medicine, 123, Jeokgeum-ro, Danwon-gu, Ansan-si, Gyeonggi-do 15355, Republic of Korea. hippotate@hanmail.net
Received: 2019-04-24 Accepted: 2020-01-17

Abstract

● **AIM:** To evaluate clinical outcomes following implantation of an extended range of vision intraocular lens (IOL), the ZXR00, and a diffractive multifocal IOL with +2.75 diopters (D) add power, the ZKB00.

● **METHODS:** Totally 30 patients who underwent either bilateral implantation of the ZXR00 IOL with intended emmetropia (ZXR00 emmetropia group: 20 eyes) and intended micromonovision (ZXR00 monovision group: 20 eyes), or bilateral implantation of the ZKB00 IOL with intended emmetropia (ZKB00 group: 20 eyes) were included in this study. Visual acuity at 4 m, 80, and 40 cm; and the types of halos (misty, fine, and rainbow) were analyzed at one and three months after surgery.

● **RESULTS:** There were no significant differences in distance visual acuity among the three groups. The mean uncorrected intermediate visual acuity was better in the ZXR00 emmetropia and monovision groups (0.02 logMAR and 0.02 logMAR, respectively) than in the ZKB00 group (0.14 logMAR). The mean uncorrected near visual acuity was worse in the ZXR00 emmetropia group (0.26 logMAR) than in the ZXR00 monovision and ZKB00 groups (0.12 logMAR and 0.10 logMAR, respectively). There was an increased incidence of rainbow halos in the ZKB00 group *vs* in either ZXR00 group (*P*=0.033).

● **CONCLUSION:** Implantation of the ZXR00 IOL with intended micromonovision provide superior visual acuity than implantation of the ZXR00 IOL with intended emmetropia. The ZXR00 IOLs tend to show a lower incidence of rainbow halos than did the ZKB00 IOL.

● **KEYWORDS:** halos; intraocular lens; diffractive bifocal; multifocal; rainbow halos
DOI:10.18240/ijo.2020.06.09

Citation: Kim J, Eom Y, Park SY, Choi SY, Hwang HS, Kim JH, Song JS, Kim HM. Rainbow halos occur less following implantation of extended range of vision one-piece intraocular lenses *vs* diffractive bifocal intraocular lenses. *Int J Ophthalmol* 2020;13(6):913-919

INTRODUCTION

Multifocal intraocular lenses (IOLs) are specifically designed to have two or more optimum foci and provide better near and/or intermediate vision and similar distance vision in comparison with monofocal IOLs[1-3]. Multifocal IOLs actually improve patient performance of near-vision tasks with better distance corrected and uncorrected near visual acuity (DCNVA and UNVA)[4]. Thus, multifocal IOLs could become one of the best options for correcting presbyopia after cataract surgery[5]. However, it has been reported that glare or halos are more common in cataract patients who received multifocal IOLs than in those who received monofocal IOLs[4,6]. Photic phenomena, such as glare and halos, are one of the reasons for patient dissatisfaction[7-9]. The most common reasons for multifocal IOL explantation were reduced contrast sensitivity and photic phenomena[9].

A new type of multifocal IOL that provides an extended range of the focal point of the lens has been introduced. The TECNIS Symfony® ZXR00 (Johnson & Johnson Vision, Jacksonville, FL, USA) IOL is one example of an extended range of vision IOL that provides continuous focus from distance to intermediate[10-11]. Thus, it is expected that the ZXR00 IOL provides a reduced incidence of visual disturbance and dysphotopsia and enhanced contrast sensitivity when compared with previous diffractive multifocal IOLs. Reduced incidence of visual disturbance and enhanced contrast sensitivity could increase patient satisfaction. In addition, the ZXR00 has relatively farther reading distance with lower add power as compared with previous diffractive multifocal IOLs. The size of halos might decrease as the add power of a multifocal IOL decreases, because the size of an out-of-focus image on the retina is produced by the distance or near focus from the add power of the multifocal IOL[12-13]. A diffractive multifocal IOL with a +2.75 diopters (D) add power (ZKB00; Johnson & Johnson Vision) showed better overall postoperative satisfaction than did a +4.00 D add multifocal IOL in a previous study[14]. Multifocal IOLs with lower add powers have weaker near vision[14]. Thus, pseudophakic monovision might be needed in patients who underwent implantation of the ZXR00 to obtain a shorter reading distance according to the characteristics of a farther reading distance of the ZXR00.

This study was conducted to evaluate the clinical outcomes following implantation of the ZXR00 and ZKB00 IOLs in terms of visual function and patient satisfaction. We evaluated visual acuity, postoperative patient satisfaction, the incidence of photic phenomena (*e.g.*, glare, starbursts, and halos), and types of halos (*i.e.*, misty, fine, and rainbow) in patients who underwent implantation of the ZXR00 IOL with micromonovision and those who underwent implantation of the ZXR00 or ZKB00 IOLs with bilateral emmetropic correction.

SUBJECTS AND METHODS

Ethical Approval This study was approved by both the Institutional Review Board of Korea University Ansan Hospital, Gyeonggi, Korea and that of Chungbuk National University College of Medicine, Cheongju, Korea. A prospective Symfony IOL clinical study was registered as a clinical trial at https://cris.nih.go.kr (identification number: KCT0002058). Written informed consent was obtained from all patients who participated in this study, which was conducted in accordance with the tenets of the Declaration of Helsinki.

Forty eyes of 20 patients who underwent bilateral implantation of the ZXR00 IOLs, with either intended emmetropia (ZXR00 emmetropia group: 20 eyes) or intended micromonovision (ZXR00 monovision group: 20 eyes), at the Korea University College of Medicine or Chungbuk National University College of Medicine between July 2016 and July 2017 were prospectively included in this study. Subjects willing to take part in the Symfony IOL clinical trial were randomly allocated into these two groups. Additionally, 20 eyes of 10 patients who underwent bilateral implantation of diffractive ZKB00 multifocal IOLs with +2.75 D of add power at the Korea University College of Medicine between April 2015 and July 2017 were retrospectively included as the ZKB00 group in this study. Patients with best-corrected visual acuity (BCVA) less than 20/25 in the operated eye were excluded from the study[3]. Patients who have traumatic cataracts, history of ocular surgery (*e.g.*, laser vision correction), intraoperative complications, postoperative complications, or other diseases that can affect capsule stability such as pseudoexfoliation syndrome or Marfan syndrome were excluded.

Patient Examination An optical biometer (IOLMaster 500; Carl Zeiss Meditec, Jena, Germany or AL-Scan; Nidek Co., Aichi, Japan) was used to measure the preoperative corneal power, anterior chamber depth (ACD), and axial length (AL). IOL power was calculated using the Haigis formula. In the ZXR00 emmetropia and ZKB00 groups, emmetropic IOL power was selected for both eyes. In the ZXR00 monovision group, emmetropic IOL power was selected for the dominant eye and the IOL power that had a target refraction between -0.75 D and -1.00 D was selected for the non-dominant eye.

Surgical Technique Following topical anesthesia with 0.5% proparacaine hydrochloride, all phacoemulsification and multifocal IOL implantations were performed by one of two experienced surgeons (Eom Y and Kim J). After a 2.2- or 2.75-mm clear corneal incision was made, a continuous curvilinear capsulorrhexis (CCC) slightly smaller than the IOL optic size was created with a cystotome and CCC forceps. A phaco chop technique was used, and remnant cortex was removed with irrigation and aspiration. The ZXR00 or ZKB00 IOL was then inserted into the capsular bag using an injector-cartridge system (DK7796 and 1MTEC30; Johnson & Johnson Vision).

Patient Evaluation Postoperative uncorrected distance visual acuity (UDVA), corrected distance visual acuity (CDVA), uncorrected and distance corrected intermediate visual acuity (UIVA, DCIVA) at 80 cm, UNVA and DCNVA at 40 cm, and manifest refractive error were measured at one month after surgery. Distance corrected defocus curves were measured binocularly at 4 m to determine the visual acuity with each defocus between -4.00 D and +1.00 D in 0.50 D intervals.

Questionnaire Patient perception of photic phenomena, patient satisfaction, and spectacle dependence for near, intermediate, and distance vision were evaluated using a questionnaire given three months postoperatively[15]. The incidence and the degree of bothersomeness of photic phenomena (*e.g.*, glare, starbursts, and halos) and types of halos (*i.e.*, misty, fine, and rainbow) were evaluated using a questionnaire with illustrations[15-16]. The incidence of photic phenomena was graded from 1 to 5: grade 1, never; grade 2, rarely; grade 3, sometimes; grade 4, often; and grade 5, always. The degree of bothersomeness was graded from 1 to 5: grade 1, not at all; grade 2, very little; grade 3, somewhat; grade 4, quite a lot; and grade 5, very. Based on patient statements, we produced illustrations of misty, fine, and rainbow halos

Figure 1 Illustrations of misty, fine, and rainbow halos used in the study questionnaire A: Misty halos; B: Fine halos; C: Rainbow halos.

Table 1 Clinical characteristics of study participants and eyes

Parameters	ZXR00 emmetropia	ZXR00 monovision	ZKB00	*P*
Age, y	62.9±7.5	63.5±8.3	51.0±16.0	0.032[b]
Sex, female (%)	7 (70.0)	8 (80.0)	5 (50.0)	0.350[c]
Corneal power, D	44.48±1.37	43.34±0.90	43.88±1.40	0.041[a]
ACD, mm	3.22±0.55	3.10±0.38	3.32±0.35	0.275[a]
Axial length, mm	23.53±1.50	24.09±1.26	24.10±1.73	0.250[a]
IOL power, D	20.5±5.0	20.4±3.8	20.0±3.8	0.515[a]
Postoperative SE, D				
Emmetropic target	-0.16±0.27	-0.10±0.17	-0.28±0.38	
Myopic target	-	-0.93±0.31	-	

D: Diopters; ACD: Anterior chamber depth; IOL: Intraocular lens; SE: Spherical equivalent. Data are presented as mean±standard deviation, where applicable. [a]Kruskal-Wallis test; [b]One-way ANOVA; [c]Fisher's exact test.

Table 2 Comparison of postoperative binocular visual acuity among the three groups logMAR

Parameters	ZXR00 emmetropia	ZXR00 monovision	ZKB00	*P*[a]
UDVA	0.01±0.05	0.01±0.03	0.02±0.03	0.866
CDVA	-0.06±0.03	-0.04±0.04	-0.04±0.06	0.383
UIVA	0.02±0.06	0.02±0.04	0.14±0.05	<0.001
DCIVA	0.07±0.07	0.07± 0.07	0.15±0.07	0.019
UNVA	0.26±0.12	0.12±0.09	0.10±0.06	0.002
DCNVA	0.33±0.13	0.19±0.07	0.17±0.06	0.009

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.

to assist patients in distinguishing types of halos (Figure 1). Patient satisfaction for overall, near, intermediate, and distance vision was graded from 1 to 5: grade 1, very dissatisfied; grade 2, dissatisfied; grade 3, neither satisfied nor dissatisfied; grade 4, satisfied; and grade 5, very satisfied[14].

Statistical Analysis Statistical analyses were performed with IBM SPSS Statistics Standard 20 (IBM Corp., Armonk, NY, USA). To confirm the normal distribution of the data, the Kolmogorov-Smirnov test was conducted. Statistical analyses were performed using Tukey's Honest Significant Difference post hoc test after one-way ANOVA, the Kruskal-Wallis test with Bonferroni correction, Fisher's exact test, and a Chi-squared linear trend test. A *P*-value less than 0.05 was considered statistically significant.

RESULTS

The mean age (±standard deviation) of the ZXR00 emmetropia group, 62.9±7.5y, and that of the ZXR00 monovision group, 63.5±8.3y, were significantly higher than that of the ZKB00 group, which was 51.0±16.0y (*P*=0.032). Sex, preoperative corneal power, ACD, and AL measured *via* the IOLMaster or AL-Scan, implanted IOL power, and postoperative refractive errors are shown in Table 1.

Table 2 shows postoperative distance (4 m), intermediate (80 cm), and near (40 cm) visual acuities. There were no significant differences in UDVA and CDVA among the three groups. On the other hand, UIVA and DCIVA were better in the ZXR00 emmetropia and monovision groups than in the ZKB00 group (*P*<0.001 and *P*=0.019, respectively). UNVA and DCNVA were better in the ZXR00 monovision and ZKB00 groups than in the ZXR00 emmetropia group (*P*=0.002 and *P*=0.009, respectively).

Figure 2 shows the distance corrected binocular defocus curves. The best visual acuity of -0.06 logMAR to -0.07 logMAR was obtained with a defocus of 0.00 D in all three groups. There was no second peak visual acuity in the ZXR00 emmetropia and monovision groups. On the other hand, the mean second peak visual acuity of 0.01 logMAR was obtained with a defocus of -2.00 D in the ZKB00 group. Between these two peaks of the ZKB00 group (*i.e.*, with defocus levels between -0.50 D and -1.50 D), the visual performance of the ZXR00 emmetropia and monovision groups were better than that of the ZKB00 group. In defocus levels between -2.50 D and -4.00 D, the visual performance of the ZXR00 emmetropia group was the worst of the three groups, but there was no significant difference in the visual performance between the ZXR00 monovision and ZKB00 groups.

There were no significant differences in the incidence and the degree of bothersomeness of photic phenomena (*e.g.*, glare, starbursts, and halos) among the three groups (Table 3). In the comparison of types of halos, there was a tendency for an increase in the incidence of rainbow halos in the ZKB00 group versus in the ZXR00 monovision and emmetropia groups (*P*=0.033, Chi-squared linear trend test; Figure 3). There were no significant differences in patient satisfaction for overall, intermediate, and distance vision among the three groups. Patient satisfaction for near vision was worse in the ZXR00 emmetropia group than in the other groups, but the differences were not statistically significant (*P*=0.067; Table 3).

Figure 4 shows a summary of the questionnaire for spectacle dependence answers collected three months after cataract surgery. There were no significant differences in spectacle dependence for distance and intermediate vision among the three groups. On the other hand, there was a high rate of spectacle dependence for near vision in the ZXR00 emmetropia group (50.0%) as compared with in the other groups (0 in the ZXR00 monovision group and 10.0% in the ZKB00 group; *P*=0.027).

DISCUSSION

This study compared the clinical outcomes following the implantation of TECNIS Symfony® ZXR00 IOLs with intended emmetropia for both eyes or micromonovision and that of diffractive TECNIS® ZKB00 multifocal IOLs with +2.75 D add power. The results demonstrated that patients implanted with the ZXR00 IOLs showed a similar overall satisfaction after cataract surgery when compared with those implanted with ZKB00 IOLs, but experienced a lower incidence of rainbow halos. In clinical situations, sometimes we have heard that patients experience fine halos of various colors, called rainbow halos, following implantation of diffractive multifocal IOLs. In addition, when we see the diffractive IOL through the slit-lamp, there may be some

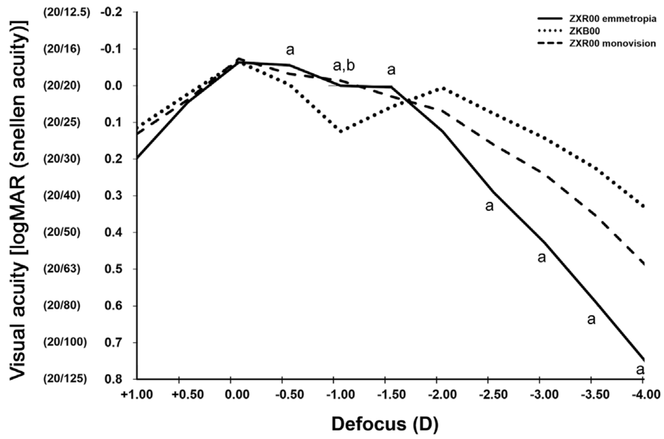

Figure 2 The mean distance corrected binocular defocus curve at one month after surgery of the ZXR00 emmetropia (solid line), ZXR00 monovision (dashed line), and ZKB00 groups (dotted line) [a]Significant difference (*P*<0.05) between the ZXR00 emmetropia and ZKB00 groups; [b]Significant difference (*P*<0.05) between the ZXR00 monovision and ZKB00 groups. All statistical analysis was conducted by the Kruskal-Wallis test with Bonferroni correction.

Table 3 Comparison of incidence and the degree of bothersomeness of photic phenomena (glare, starbursts, and halos), and patient satisfaction for overall, near, intermediate, and distance vision among the three groups mean±SD

Photic phenomena	ZXR00 emmetropia	ZXR00 monovision	ZKB00	*P*[d]
Glare				
Incidence (1-5)[a]	1.8±1.3	2.3±1.5	1.5±0.7	0.526
Bothersome (1-5)[b]	0.6±1.1	1.1±1.3	0.7±1.1	0.607
Starburst				
Incidence (1-5)[a]	1.8±1.3	1.6±1.4	2.1±1.5	0.670
Bothersome (1-5)[b]	0.5±0.9	0.5±1.1	0.6±0.8	0.803
Halos				
Incidence (1-5)[a]	1.4±1.0	2.3±1.8	2.9±1.8	0.137
Bothersome (1-5)[b]	0.5±1.3	0.9±1.3	1.2±1.5	0.407
Satisfaction				
Overall vision (1-5)[c]	4.7±0.7	4.8±0.4	4.4±0.7	0.268
Near vision (1-5)[c]	3.8±0.9	4.7±0.7	4.3±0.8	0.067
Intermediate vision (1-5)[c]	4.9±0.3	4.9±0.3	4.6±0.7	0.361
Distance vision (1-5)[c]	4.9±0.3	4.8±0.4	4.5±0.7	0.252

[a]Incidence of photic phenomena was graded from 1 to 5: grade 1, never; grade 2, rarely; grade 3, sometimes; grade 4, often; and grade 5, always; [b]The degree of bothersomeness was graded from 1 to 5: grade 1, not at all; grade 2, very little; grade 3, somewhat; grade 4, quite a lot; and grade 5, very; [c]Patient satisfaction for overall, near, intermediate, and distance vision was graded from 1 to 5: grade 1, very dissatisfied; grade 2, dissatisfied; grade 3, neither satisfied nor dissatisfied; grade 4, satisfied; and grade 5, very satisfied; [d]Kruskal-Wallis test.

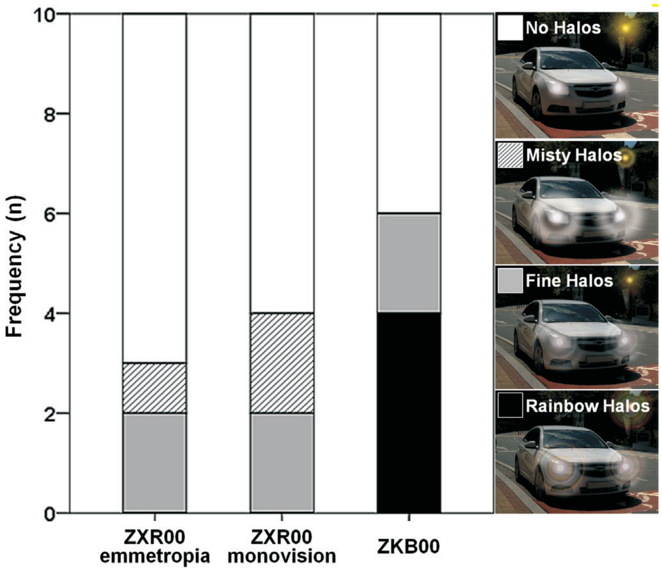

Figure 3 Frequency distribution of the incidence of each type of halo (misty, fine, and rainbow) among the three groups.

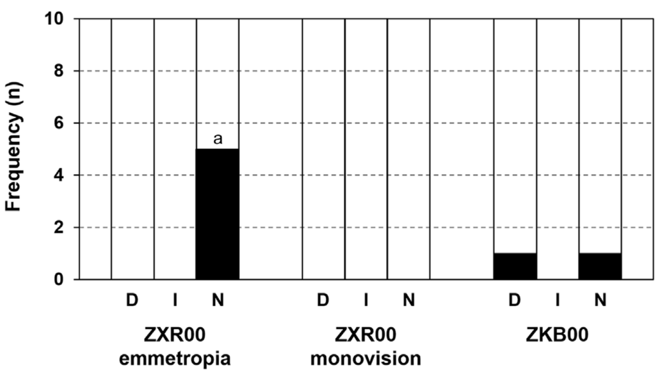

Figure 4 Frequency distribution of the spectacle dependence for distance (D), intermediate (I), and near (N) vision among the three groups [a]$P<0.05$ by the one-way ANOVA.

colorful light refraction and reflection from the eschelets on the IOL surface (Figure 5). It seems that these colorful light refractions and reflections from the IOL surface can cause rainbow halos in eyes with diffractive multifocal IOLs.

A previous study that conducted an optical bench test using diffractive bifocal and trifocal IOLs showed that large background halos were observed in trifocal IOLs versus in bifocal IOLs[13]. In addition, the size of the halos seems to be smaller with IOLs with lower add power[13]. The ZXR00 IOL that provides an extended range of vision has a relatively lower add power as compared with the ZKB00 IOL[17]. Thus, it was expected that the ZXR00 IOL provides lower incidence or a smaller size of halos when compared with previous diffractive multifocal IOLs. Sachdev *et al*[18] showed that patients with ZXR00 IOLs had a high degree of satisfaction and very low photic phenomena experience. Rodov *et al*[19] demonstrated that the ZXR00 IOL had less photic phenomena but higher spectacle dependence when compared with the trifocal IOLs. In this study, the incidence of halos in the Symfony groups tended to

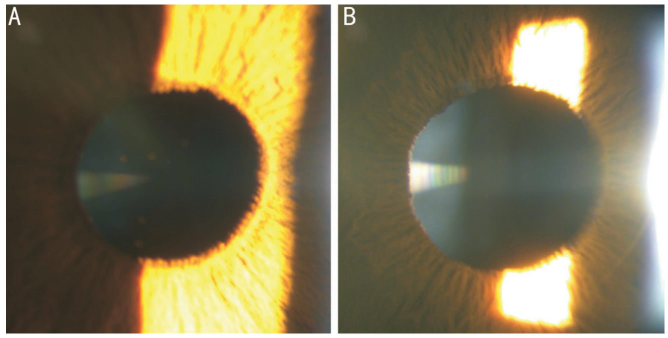

Figure 5 Anterior segment photograph Visible in this image are colorful light refractions and reflections from the eschelets on the IOL surface. A: ZXR00 intraocular lens; B: ZKB00 intraocular lens.

be less, but was not statistically significant. On the other hand, the incidence of rainbow halos in the ZKB00 group was greater than that in both ZXR00 groups. All patients who experienced halos in the ZKB00 group had fine or rainbow halos, but patients in both ZXR00 groups experienced misty or fine halos.

The reason why rainbow halos occurred less in the ZXR00 IOL groups than in ZKB00 IOL group may be because the ZXR00 IOL has achromatic technology as well as low add power. Artal *et al*[20] showed that the ZXR00 IOL provides a sharper focus of light by the combined correction of longitudinal chromatic and spherical aberrations. Millán and Vega[17], who conducted a numerical simulation and optical bench test, demonstrated that the ZXR00 IOL has longitudinal chromatic aberration compensation in both the intermediate and distance foci, whereas there is no chromatic compensation in the distance focus in the ZKB00 IOL. Consistent with the results of the experiment study, it is thought that the incidence of rainbow halos in patients with ZXR00 IOL implants is small due to the achromatic technology and low add power of the ZXR00 IOL. To the best of our knowledge, this is the first clinical study that attempted to distinguish the type of halos and describe the incidence of rainbow halos following the implantation of multifocal IOLs.

The visual performance of multifocal IOLs varies according to the amount of add power in the IOL[21]. Thus, various multifocal IOLs with different add powers have been developed and used. Previous studies have shown that multifocal IOLs with lower add powers provide better intermediate vision but worse near vision than do higher add power multifocal IOLs[22-24]. However, satisfactory outcomes for near vision could be achieved by the implantation of lower add power multifocal IOLs with intended micromonovision[25]. The ZXR00 IOL with a +1.75 D near add power[17] provided better intermediate vision as compared with the ZKB00 IOL with a +2.75 D near add power in this study, which is consistent with the results of previous studies. With respect to near vision, ZXR00 IOLs with intended micromonovision showed similar levels of visual performance to that of the ZKB00 IOL, even though patients with ZKB00 IOL implants had better near vision than did those with ZXR00 IOLs with intended bilateral emmetropia.

Previous studies have shown that the implantation of multifocal IOLs with lower add powers results in better intermediate visual acuity and increased or similar degree of patient satisfaction compared to the multifocal IOLs with higher add power[2,14,22,26]. Kim *et al*[14] demonstrated that patients with multifocal IOLs with a +2.75 D add power had better satisfaction and greater spectacle independence versus patients with multifocal IOLs with either +3.25 D or +4.00 D add powers. Petermeier *et al*[26] showed that the lower add power of multifocal IOLs results in increased patient satisfaction as well as better intermediate visual acuity. In this study, the ZXR00 emmetropia group had the highest rate of spectacle dependence for near vision as compared with the other groups. Nevertheless, patients in the ZXR00 emmetropia and monovision groups showed similar overall satisfaction levels in comparison with patients in the ZKB00 group. Thus, patients who had multifocal IOLs with lower add powers seemed to maintain higher levels of satisfaction even if their spectacle dependency increased somewhat.

There were some limitations to the present study. First, its sample size was relatively small. Second, patients who underwent implantation of ZXR00 IOLs were prospectively included, while the medical records of patients who underwent implantation of ZKB00 IOLs were retrospectively reviewed. Thus, a prospective study with a large number of subjects is needed to further evaluate the incidence and the type of glare following implantation of extended range of vision IOLs and diffractive multifocal IOLs.

In conclusion, it seems that the extended range of vision IOLs with +1.75 D added power that was implanted as intended micromonovision provide better near or intermediate visual acuity without increasing photic phenomena compared to diffractive bifocal IOLs or extended range of vision IOLs with intended emmetropia for both eyes. In addition, diffractive bifocal IOLs tended to have higher incidence of rainbow halos than the extended range of vision IOLs with lower added powers and achromatic technology.

ACKNOWLEDGEMENTS

This work was presented in part at the annual meeting of the Association for Research in Vision and Ophthalmology (ARVO), Honolulu, Hawaii, USA, April 29-May 3, 2018.

Foundations: Supported by the Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science and ICT (No.2018R1C1B6002794); Korea University Grant (No. K1625491; No.K1722121; No.K1811051).

Conflicts of Interest: Kim J, None; **Eom Y,** None; **Park SY,** None; **Choi SY,** None; **Hwang HS,** None; **Kim JH,** None; **Song JS,** None; **Kim HM,** None.

REFERENCES

1 Khandelwal SS, Jun JJ, Mak S, Booth MS, Shekelle PG. Effectiveness of multifocal and monofocal intraocular lenses for cataract surgery and lens replacement: a systematic review and meta-analysis. *Graefes Arch Clin Exp Ophthalmol* 2019;257(5):863-875.

2 Pedrotti E, Carones F, Aiello F, Mastropasqua R, Bruni E, Bonacci E, Talli P, Nucci C, Mariotti C, Marchini G. Comparative analysis of visual outcomes with 4 intraocular lenses: Monofocal, multifocal, and extended range of vision. *J Cataract Refract Surg* 2018;44(2):156-167.

3 Eom Y, Song JS, Kim HM. Spectacle plane add power of multifocal intraocular lenses according to effective lens position. *Can J Ophthalmol* 2017;52(1):54-60.

4 Cao K, Friedman DS, Jin SS, Yusufu M, Zhang JS, Wang JD, Hou SM, Zhu GY, Wang BS, Xiong Y, Li J, Li XX, He HL, Chai LJ, Wan XH. Multifocal versus monofocal intraocular lenses for age-related cataract patients: a system review and meta-analysis based on randomized controlled trials. *Surv Ophthalmol* 2019;64(5):647-658.

5 Nijkamp MD, Dolders MG, de Brabander J, van den Borne B, Hendrikse F, Nuijts RM. Effectiveness of multifocal intraocular lenses to correct presbyopia after cataract surgery: a randomized controlled trial. *Ophthalmology* 2004;111(10):1832-1839.

6 de Silva SR, Evans JR, Kirthi V, Ziaei M, Leyland M. Multifocal versus monofocal intraocular lenses after cataract extraction. *Cochrane Database Syst Rev* 2016;12:CD003169.

7 Greenstein S, Pineda R 2nd. The quest for spectacle independence: a comparison of multifocal intraocular lens implants and pseudophakic monovision for patients with presbyopia. *Semin Ophthalmol* 2017;32(1):111-115.

8 Bartol-Puyal FA, Talavero P, Giménez G, Altemir I, Larrosa JM, Polo V, Pablo LE. Reading and quality of life differences between Tecnis ZCB00 monofocal and Tecnis ZMB00 multifocal intraocular lenses. *Eur J Ophthalmol* 2017;27(4):443-453.

9 Kamiya K, Hayashi K, Shimizu K, Negishi K, Sato M, Bissen-Miyajima H, Survey Working Group of the Japanese Society of Cataract and Refractive Surgery. Multifocal intraocular lens explantation: a case series of 50 eyes. *Am J Ophthalmol* 2014;158(2):215-220.e1.

10 Esteve-Taboada JJ, Domínguez-Vicent A, Del Águila-Carrasco AJ, Ferrer-Blasco T, Montés-Micó R. Effect of large apertures on the optical quality of three multifocal lenses. *J Refract Surg* 2015;31(10):666-676.

11 Pedrotti E, Bruni E, Bonacci E, Badalamenti R, Mastropasqua R, Marchini G. Comparative analysis of the clinical outcomes with a monofocal and an extended range of vision intraocular lens. *J Refract Surg* 2016;32(7):436-442.

12 Pieh S, Lackner B, Hanselmayer G, Zöhrer R, Sticker M, Weghaupt H, Fercher A, Skorpik C. Halo size under distance and near conditions in refractive multifocal intraocular lenses. *Br J Ophthalmol* 2001;85(7):816-821.

13 Carson D, Hill WE, Hong X, Karakelle M. Optical bench performance of AcrySof(®) IQ ReSTOR(®), AT LISA(®) tri, and FineVision(®) intraocular lenses. *Clin Ophthalmol* 2014;8:2105-2113.

14 Kim JS, Jung JW, Lee JM, Seo KY, Kim EK, Kim TI. Clinical outcomes following implantation of diffractive multifocal intraocular lenses with varying add powers. *Am J Ophthalmol* 2015;160(4):702-709.e1.

15 Eom Y, Kim DW, Ryu D, Kim JH, Yang SK, Song JS, Kim SW, Kim HM. Ring-shaped dysphotopsia associated with posterior chamber phakic implantable collamer lenses with a central hole. *Acta Ophthalmol* 2017;95(3):e170-e178.

16 McAlinden C, Pesudovs K, Moore JE. The development of an instrument to measure quality of vision: the Quality of Vision (QoV) questionnaire. *Invest Ophthalmol Vis Sci* 2010;51(11):5537-5545.

17 Millán MS, Vega F. Extended depth of focus intraocular lens: chromatic performance. *Biomed Opt Express* 2017;8(9):4294-4309.

18 Sachdev GS, Ramamurthy S, Sharma U, Dandapani R. Visual outcomes of patients bilaterally implanted with the extended range of vision intraocular lens: a prospective study. *Indian J Ophthalmol* 2018;66(3):407-410.

19 Rodov L, Reitblat O, Levy A, Assia EI, Kleinmann G. Visual outcomes and patient satisfaction for trifocal, extended depth of focus and monofocal intraocular lenses. *J Refract Surg* 2019;35(7):434-440.

20 Artal P, Manzanera S, Piers P, Weeber H. Visual effect of the combined correction of spherical and longitudinal chromatic aberrations. *Opt Express* 2010;18(2):1637-1648.

21 Bissen-Miyajima H, Ota Y, Nakamura K, Hirasawa M, Minami K. Binocular visual function with staged implantation of diffractive multifocal intraocular lenses with three add powers. *Am J Ophthalmol* 2019;199:223-229.

22 Maxwell WA, Cionni RJ, Lehmann RP, Modi SS. Functional outcomes after bilateral implantation of apodized diffractive aspheric acrylic intraocular lenses with a +3.0 or +4.0 diopter addition power randomized multicenter clinical study. *J Cataract Refract Surg* 2009;35(12):2054-2061.

23 Jiang YF, Bu SC, Tian F, Liang JL, Wang TC, Xing XL, Zhang H, Zhang XM. Long-term clinical outcomes after mix and match implantation of two multifocal intraocular lenses with different adds. *J Ophthalmol* 2019;2019:6789263.

24 Yoo A, Kwag JY, Song IS, Kim MJ, Jeong H, Kim JY, Tchah H. Comparison of visual function after implantation of inferior sector-shaped intraocular lenses: low-add +1.5 D vs +3.0 D. *Eur J Ophthalmol* 2016;26(6):607-611.

25 Ganesh S, Brar S, Pawar A, Relekar KJ. Visual and refractive outcomes following bilateral implantation of extended range of vision intraocular lens with micromonovision. *J Ophthalmol* 2018;2018:7321794.

26 Petermeier K, Messias A, Gekeler F, Szurman P. Effect of +3.00 diopter and +4.00 diopter additions in multifocal intraocular lenses on defocus profiles, patient satisfaction, and contrast sensitivity. *J Cataract Refract Surg* 2011;37(4):720-726.