Original Article

Clinical Outcomes of Enhanced Monofocal (Mono-EDOF) Intraocular Lenses with the Mini-Monovision Technique versus Trifocal Intraocular Lenses: A Comparative Study

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Abstract

Objectives: It was aimed to compare the clinical results of the mini-monovision technique (MMV) with enhanced monofocal intraocular lens (IOL) and trifocal IOL applications and to evaluate the intereye differences in the MMV group.

Materials and Methods: This retrospective observational study evaluated the results of cataract surgeries performed on 48 eyes of 24 patients. Surgeries in Group I were performed for MMV using the RayOne EMV IOL targeting emmetropia in dominant eyes (Group IA) and -0.70 diopter (D) myopia in non-dominant eyes (Group IB), while those in Group II were performed with the AcrySof® IQ PanOptix™ TNFT00 IOL targeting emmetropia. After the surgeries, uncorrected and corrected distance, intermediate, and near distance visual acuities, contrast sensitivity measurements, and defocus curves were determined. Subjective evaluation was made with the National Eye Institute Visual Function Questionnaire (NEI VFQ-25). The groups were compared statistically.

Results: Postoperative refraction mean spherical equivalent was -0.25±0.22 D, -0.67±0.33 D, and -0.16±0.31 D in the three groups, respectively. A statistical difference was identified in favor of Group IA for uncorrected distance vision and in favor of Group IB for near vision ($p<0.05$). There was no difference in bilateral uncorrected visions in Groups I and II ($p>0.05$). While contrast sensitivity was better in Group I at all spatial frequencies ($p<0.05$), better vision was achieved in the defocus curve at distance in Group IA and at near in Group IB. In the binocular evaluation, it was seen that Groups I and II had similar results. In the subjective evaluation, NEI-VFQ-25 scores were 94.1±4.2/100 in Group I and 91.5±3.0/100 in Group II at 6 months ($p>0.05$). Photic complaints were significantly more common in Group II.

Conclusion: With the MMV technique, it was observed that enhanced monofocal lenses provided better visual acuity at all distances and less dysphotopsia than trifocal lenses, whereas trifocal lenses were better at providing independence from glasses.

Keywords: Presbyopia-correcting intraocular lenses, mini-monovision technique, enhanced monofocal IOLs, mono-EDOF IOLs

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Introduction

Today, cataract surgery has become extensively used to treat both cataract and presbyopia. While cataract was initially treated uneventfully in many aspects with monofocal intraocular lenses (IOLs),[1,2] when it came to the treatment of presbyopia, only partial success could be achieved with the monovision technique.[3] As a result, first bifocal and then trifocal IOLs became widely adopted for the treatment of presbyopia. Trifocal IOLs are reported to provide excellent near, intermediate, and distance visual acuities, allowing a very high rate of spectacle independence. However, it has also been observed that because of significant photic complaints and loss of contrast sensitivity, their areas of indication are limited, especially in relation to patients' lifestyles and concomitant ocular diseases.[4,5,6] Later, the "enhanced depth of focus" (EDOF) group of lenses was introduced to treat presbyopia. However, the first of these were hybrid EDOF IOLs, which combined an increased focal depth with multifocal optical properties, and it was determined that they did not offer adequate correction of presbyopia, while also causing the abovementioned problems of trifocal lenses at nearly the same rate.[7,8] Subsequently, another subgroup of focal depth enhancing lens were developed under the name of "monofocal plus" or "monofocal enhanced". As these lenses utilize spherical aberration (SA) to increase the depth of focus, they can also be called pure EDOF (non-diffractive, non-refractive).[9] Although this group was found to largely eliminate problems such as dysphotopsia and loss of contrast sensitivity, they could not

match the excellence of trifocal lenses in near vision.[10] To eliminate this last problem, it was recommended to use this group of lenses with the "mini-monovision" (MMV) technique, which targets emmetropia in the dominant eye and a myopic offset of -0.25 to -1.00 diopter (D) in the non-dominant eye.[11,12]

As a result, two popular IOL groups and approaches seem to predominate in the current treatment of pseudophakic presbyopia: 1) pure EDOF or enhanced monofocal (mono-EDOF) IOL implantation with the MMV approach, and 2) trifocal IOL implantation with a bilateral emmetropia approach. This study endeavored to compare these two groups. The study has two separate aims; the first is to determine and compare the clinical results obtained with both approaches, and the second is to investigate the MMV method in terms of intereye differences in functionality and reliability.

Materials and Methods

Study Design and Patients

This retrospective observational study included bilateral cataract and clear-lens surgical cases performed by two surgeons (İ.C. and H.A.B.) in two different centers.

The study protocol was approved by the Ethics Committee of Yozgat Bozok University (decision no: 2024-GOKA EK241_241_2024.03.27_12, date: 27.03.2024) and was carried out in accordance with the principles of the Declaration of Helsinki. The surgeries were performed with an interval of 7-21 days between fellow eyes.

All patients included in the study were over 50 years of age and had visual impairment due to cataract or had presbyopic complaints and desired spectacle independence. Patients with severe ocular pathology, uncontrolled diabetes and diabetic retinopathy, age-related macular degeneration, other retinal and macular diseases, uveitis, diseases affecting the pupil, severe dry eye, glaucoma, strabismus, amblyopia, or history of any ocular surgery or trauma were not included in the study. In addition, patients with axial length outside the range of 21.5-26.00 mm and corneal astigmatism greater than 0.75 D were excluded from the study. All patients underwent preoperative macular optical coherence tomography examination with an Optovue RTVue (Optovue, Fremont, CA, USA) device and the presence of retinal disease was ruled out. All included patients were informed about the study and a consent form was obtained.

Two separate groups were formed for the study. Patients in the first group (Group I) received the enhanced monofocal RayOne EMV IOL (Rayner Intraocular Lenses Limited, Worthing, United Kingdom) targeting emmetropia in the dominant eye (Group IA) and -0.70 D of myopia in the non-dominant eye (Group IB). Patients in the second group (Group II) received AcrySof® IQ PanOptix™ TNFT00 (Alcon Laboratories Inc., Fort Worth, TX, USA) IOLs with emmetropia targeted in both eyes. Each group included 24 eyes of 12 patients. Before the operations, detailed eye examinations including monocular and binocular corrected and uncorrected visual acuities, manifest refractions, corneal keratometric values, intraocular pressures, and biometric measurements obtained using the Lenstar LS 900 (Haag-Streit, USA) device were performed in all patients. Dominant and non-dominant eyes were determined. Tear functions were evaluated with the Schirmer and tear film break-up tests. The Barrett-II formula was used for IOL power calculations.

The surgeries were performed following a standard pupil dilatation regimen, under topical anesthesia, using a Centurion Vision System (Alcon Inc., Fort Worth, TX, USA) through a 2.2-mm main incision made on the steep keratometry axis or using a temporal approach. The same surgical phacoemulsification protocol was used in all cases, and all IOLs were placed in the capsule. Postoperatively, the patients received topical moxifloxacin (Vigamox ophthalmic solution, Novartis, Basel, Switzerland) for 1 week and prednisolone for 3 weeks.

Intraocular Lenses

The RayOne EMV is a one-piece hydrophilic acrylic lens with 26% water content. It has an optic diameter of 6.0 mm, total diameter of 12.5 mm, and biconvex optic shape. The refractive index is 1.46 and the Abbe number is 56. It has an aspheric anterior surface and closed-loop anti-vaulting haptics. The lens is implanted using a preloaded injector.

The PanOptix TNFT00 is a one-piece hydrophobic acrylic with an optic diameter of 6.0 mm, total diameter of 13.0 mm, and two open-loop modified L haptics. It has a 4.5-mm central non-apodized diffractive region with 15 diffractive rings and a peripheral refractive region between 4.5 and 6.0 mm. The refractive index is 1.55 and the Abbe number is 37. The lens has negative asphericity of -0.10 µm.

Postoperative Evaluation

The patients were operated between November 2021 and May 2023 and followed up for at least 6 months (mean 12±4.8 months) postoperatively. Examinations were performed at postoperative 1 day, 1 week, and 1, 3, and 6 months. At each examination, manifest refractions were recorded, followed by monocular and binocular corrected and uncorrected distance (4 m), intermediate (66 cm), and near (40 cm) visual acuity measurements made in photopic environment using the Early Treatment Diabetic Retinopathy Study (ETDRS) chart for distance, the Colenbrander mixed contrast card set (Precision Vision, IL, USA) for intermediate, and the Jaeger chart for near. As the charts were designed for use at distances of 35 cm and 63 cm, the logarithm of the minimum angle of resolution (logMAR) values were corrected according to the distances of 40 cm and 66 cm used in this study.[13]

Defocus curves were determined at postoperative 6 months. The procedure was performed under photopic conditions, separately for the dominant and non-dominant eyes and binocularly for patients in Group I and binocularly in Group II, between +2.0 and -4.0 D at a distance of 4 m by adding -0.50 D lenses.

Contrast sensitivity tests were also performed at postoperative 6 months. Measurements were performed under photopic conditions (85 cd/m^2) with and without glare using the CSV-1000 (Vector Vision Co, Ohio, USA) device. Results were obtained at spatial frequencies of 3, 6, 12, and 18 cycles per degree (cpd) and translated to logCS using the table provided by Vector Vision.[14]

Subjective Assessment and Evaluation of Side Effects

The patients' satisfaction with their surgical outcomes was assessed by administering the National Eye Institute Visual Function Questionnaire (NEI VFQ-25) twice, at postoperative 3 and 6 months.[15] This scale consists of questions in 12 domains: general vision, near vision, distance vision, driving, peripheral vision, color vision, ocular pain, general health and vision, role limitations, dependency, social functioning, and mental health. The highest score is 100 and represents an optimal functional state. In this study, patients were asked additional questions about halo (rings around lights), glare (trouble seeing street signs due to bright lights or oncoming headlights), double vision and ghosting, and color vision at 3 and 6 months after their second eye surgery. The patients were shown standard photographs showing examples of photic phenomena. If they answered yes, the type of symptom was noted and patients were asked to rate the extent to which these symptoms affected their daily lives. The act of driving at night was specifically questioned, and patients were also asked about their spectacle independence at near, intermediate, and distance and whether they would recommend the same IOL to family and friends. In addition, patients in the MMV group were asked whether they noticed a difference in vision between eyes in normal daily binocular viewing conditions. Responses to these additional questions were assessed independently of the NEI VFQ-25 questionnaire.

Statistical Analysis

All data were analyzed using SPSS software (version 22.0, IBM Corp., Armonk, NY, USA). Wilcoxon paired-samples test, chi-square test, and Mann-Whitney U tests were used for comparisons between the groups. Results were evaluated with a 95% confidence interval and a p value of <0.05 was considered statistically significant. Affirmative responses to the additional questions in the questionnaire were evaluated by percentage.

Results

A total of 48 eyes of 24 patients with complete follow-up were included in the study. The mean age of the 12 patients in Group I was 65.75 (±9.98) years and that of Group II was 63.25 (±7.46) years. Demographic characteristics and preoperative data of the groups are given in Table 1. There was no statistical difference between the groups.

All operations were performed without complications. The cumulative dissipated energy was 4.20±2.41 seconds in Group I and 4.95±3.05 seconds in Group II, while the mean power of the implanted lenses was 21.2±2.49 D in Group I and 21.1±2.04 D in Group II. There was no difference between the groups in terms of surgical parameters.

Visual Outcomes

Vision and refraction results obtained at postoperative 3 and 6 months were recorded and the most recent values obtained at month 6 were used in the study. Mean spherical equivalent (SE) values were -0.25±0.22 D in Group IA, -0.67±0.33 D in Group IB, and -0.16±0.31 D in Group II. In Group I, comparison of SE values between dominant and non-dominant eyes with the Wilcoxon paired-samples test revealed a statistically significant difference (p=0.022), whereas no significant difference was found between Group IA and Group II (p=0.101). In Group I, only one patient had a myopic outcome of -1.0 D in the non-dominant eye. The mean final visual acuities measured at postoperative 6 months are given in Table 2. Statistical evaluations were performed in the RayOne EMV group between dominant and non-dominant eyes monocularly and between the RayOne EMV group and PanOptix groups binocularly. In Group I, there was a difference between dominant and non-dominant eyes in favor of dominant eyes for uncorrected distance visual acuity and in favor of non-dominant eyes for uncorrected near visual acuity. When refractive errors were corrected in the non-dominant eyes, there was no significant difference between the groups (Table 2).

There were also no differences in any binocular uncorrected visual acuity measurements between the RayOne EMV MMV approach and the binocular PanOptix group measurements (p>0.05).

Comparison of defocus curves in Group I showed that dominant eyes provided better visual acuity between +2.00 and 0.00 D (corresponding to distance vision), while non-dominant eyes had better results between -1.50 and -4.0 D (corresponding to near vision). In binocular measurements, there was marked

Table 1. Demographic characteristics and preoperative and operative data of the patients

Parameter	RayOne EMV group	PanOptix group	p value
Mean age (years)	65.75±9.98	63.25±7.46	0.246*
Sex (female/male)	6/6	6/6	1.000**
Dominant eyes (right/left)	4/8	6/6	0.670**
Mean corrected distance visual acuity (logMAR)	0.12±0.22	0.16±0.31	0.567*
Mean corneal toricity (D)	0.48±0.23	0.43±0.29	0.212*
Mean kappa angle (mm)	0.20±0.22	0.22±0.19	0.809*
Mean axial length (mm)	23.53±1.10	23.22±1.99	0.555*
Mean cumulative dissipated energy (seconds)	4.20±2.41	4.95±3.05	0.460*
Mean implanted IOL power (D)	21.2±2.49	21.1±2.04	0.784*

*Mann-Whitney U test, **Chi-square test, logMAR: Logarithm of the minimum angle of resolution, D: Diopter, IOL: Intraocular lens

improvement in the areas where both subgroups were inadequate (Figure 1A). Although the RayOne EMV and PanOptix had very similar binocular defocus curves, it was noted that results for distance vision were slightly better in the RayOne EMV MMV group, while there was no difference for near and intermediate vision (Figure 1B).

The results of contrast sensitivity measurements are shown in Table 3. There was a significant difference in favor of the RayOne EMV MMV group in both glare and no-glare conditions ($p<0.05$).

Subjective Assessment, Dysphotopsia, and Spectacle Independence

Scores on the VFQ-25 used for subjective assessment were 94.1±4.2 out of 100 in Group I at 6 months (with no difference between 3 and 6 months). In Group II, the scores were 89.9±5.6 at 3 months and 91.5±3.0 at 6 months, which was not a significant difference ($p=0.234$). In addition, when problems such as halo, glare, starburst, and ghosting were described and shown as pictures to the patients, one patient in the RayOne EMV group reported glare in one eye (non-dominant) at 3 and 6 months (4.1%). In the PanOptix group, dysphotopsia was reported in both eyes by 5 patients (41.6%), including halo in 2 patients (16.6%), glare in 2 patients (16.6%), and starburst in 1 patient (8.3%). The patients stated that the severity of these symptoms decreased between 3 and 6 months. When asked whether they would recommend this surgery to their relatives, 100% of patients in both groups answered affirmatively. In terms of spectacle independence, a patient in Group I whose non-dominant eye had -1.0 D myopia expressed noticing an intereye difference in distant vision, especially while watching television. The patient was initially given distance glasses, then underwent corneal refractive surgery at postoperative 4 months, after which the myopia was reduced to -0.50 D and the problem was solved. Another patient with good near vision (J1 level) requested near glasses to read very small writing, and the problem was solved by providing +0.50 D reading glasses. As a result, 2 of the 12 patients were prescribed glasses (one for distant and one for near) and the spectacle independence rate was 83.3%. Group II had 100% spectacle independence.

At the patients' postoperative 6-month follow-up examination, no problems such as IOL tilt and decentration, posterior capsule opacity, or other concomitant ocular problems were encountered in either group.

Table 2. Postoperative visual acuity results (logMAR)

Visual acuities	Group I (RayOne EMV MMV) Monocular			Group I (RayOne EMV MMV) binocular	Group II (PanOptix) binocular	p value**
	Group IA Dominant eyes	Group IB Non-dominant eyes	p value*			
UDVA	0.00±0.03	0.05±0.08	**0.019**	0.00±0.03	0.01±0.10	0.789
UIVA	0.03±0.06	0.01±0.04	0.231	0.00±0.02	0.00±0.11	0.504
UNVA	0.04±0.06	0.01±0.04	**0.045**	0.01±0.02	0.02±0.05	0.231
CDVA	-0.01±0.02	-0.01±0.03	0.713	-0.01±0.03	0.02±0.13	0.546
DCIVA	0.02±0.04	0.01±0.04	0.812	0.00±0.01	0.01±0.11	0.812
DCNVA	0.05±0.06	0.04±0.07	0.433	0.00±0.03	0.00±0.15	0.909

*Comparison of dominant and non-dominant eye VA in the RayOne EMV group; Wilcoxon paired-samples test, **Comparison of binocular VA in RayOne EMV MMV and PanOptix groups; Mann-Whitney U test. logMAR: Logarithm of the minimum angle of resolution, MMV: Mini-monovision, UDVA: Uncorrected distance visual acuity, UIVA: Uncorrected intermediate distance visual acuity, UNVA: Uncorrected near visual acuity, CDVA: Corrected distance visual acuity, DCIVA: Distance-corrected intermediate distance visual acuity, DCNVA: Distance-corrected near visual acuity. Results given as mean and standard deviation. Significant differences are shown in bold

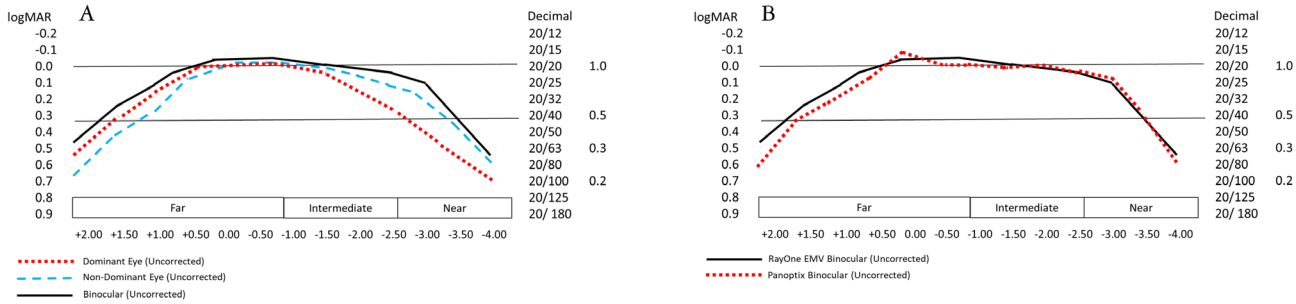

Figure 1. (A) RayOne EMV mini-monovision group: dominant eyes, non-dominant eyes, and binocular average defocus curves. (B) Average binocular defocus curves of the RayOne EMV and PanOptix groups. logMAR: Logarithm of the minimum angle of resolution

Table 3. Contrast sensitivity measurements (logCS)				
Spatial frequencies		**RayOne EMV MMV group**	**PanOptix group**	**p value***
No-glare condition	3 cpd	1.96±0.16	1.77±0.11	**0.045**
	6 cpd	1.99±0.23	1.71±0.56	**0.031**
	12 cpd	1.59±0.15	1.39±0.23	**0.009**
	18 cpd	1.21±0.19	1.01±0.09	**0.013**
Glare condition	3 cpd	1.81±0.15	1.55±0.17	**0.022**
	6 cpd	1.84±0.23	1.59±0.28	**0.017**
	12 cpd	1.41±0.07	1.25±0.19	**0.044**
	18 cpd	1.15±0.20	1.00±0.24	**0.034**
*Mann-Whitney U test, cpd: Cycles per degree. Results given as mean and standard deviation. Significant differences are shown in bold				

Discussion

This study sought to investigate two main issues. The first was to compare the visual outcomes obtained with enhanced monofocal lenses used with the MMV approach with those obtained with trifocal lenses and also determine to what extent enhanced monofocal group lenses provide solutions to common adverse effects of trifocal lenses. The second was to investigate the visual objective and subjective results of the intereye refractive difference created with MMV approach.

Numerous publications and meta-analyses in the literature have shown that trifocal lenses provide uncorrected visual acuities that can be considered perfect for near, intermediate, and far distances.[4,5,16,17] These publications report a mean binocular uncorrected distance visual acuity between -0.02 and 0.00 logMAR, binocular uncorrected intermediate distance visual acuity (80 cm) between 0.00 and 0.11, and binocular uncorrected near visual acuity (40 cm) between 0.00 and 0.18, and although different results were reported for spectacle independence, the results were close to 100%. However, we also see that dysphotopsia rates are reported at very high rates in the same studies. For example, in a study by Kohnen et al.[4] with PanOptix trifocal lenses, dysphotopsia was reported in 93% of the cases (89% halo, 11% glare, 7% double vision, 4% ghosting, and 4% distorted vision). In a meta-analysis published by Mencucci et al.[5], a high prevalence of halo (70%) and glare (50%) was seen with trifocal lenses. Loss of contrast sensitivity is another important problem with trifocal lenses. Rosen et al.[18] determined that significant contrast reduction with multifocal lenses was reported in two-thirds of the 195 studies examined in their meta-analysis. Again, Mencucci's et al.[5] study with two separate trifocal lenses reports a significant decrease from normal values, more prominently at higher spatial frequencies (18 cpd).

When the causes of dissatisfaction with multifocal lenses were investigated, dysphotopsia was identified as the second most important cause after blurred vision.[19,20] In addition, dysphotopsia was found to be the second most important cause after loss of contrast sensitivity among the reasons for surgical IOL exchange.[21] These two important adverse effects, as well as the limited indication areas in major ocular comorbidities, have led to research beyond trifocal lenses despite their excellent visual results. The first alternative developed was EDOF group lenses that combined refractive or diffractive optical properties and would later be called hybrid EDOF,[9] but these lenses were found to cause dysphotopsia and contrast loss to almost the same degree as trifocal lenses and yet could not match their performance for near vision.[7,22,23] Following the emergence of many lenses claiming to be EDOF in the market, the American Academy Task Force Consensus reports proposed four standard criteria delineating the definition of EDOF.[24,25] Thus, although the aim was to differentiate EDOF lenses from monofocal lenses, meeting the American National Standard Institute (ANSI)-III criterion in particular (median distance corrected monocular intermediate distance [66 cm] visual acuity should be at least 0.2 logMAR) is not possible without a very large comparative study. Therefore, many lenses that provide a substantial focal depth do not qualify as EDOF and are classified as enhanced monofocal or monofocal plus. New approaches have been proposed in response to this insufficiency and confusion, leading to the separate classification of hybrid EDOF lenses (refractive or diffractive EDOF lenses) and pure EDOF lenses (pinhole or SA-based). Here, according to the definitions of Kanclerz et al.[9], if the lens uses chromatic aberration, has diffractive physical properties, or is refractive and uses additional dioptric power to increase near vision, it is not pure EDOF. In a new classification published later, we see that non-diffractive lenses that increase the depth of focus through modifications to the central zone that provide a change from center to periphery are collected in the same group (type 5 in the publication), and depth of focus is mainly achieved with the addition of SA in this group.[26]

Although these lenses were classified as enhanced monofocal after the ANSI criteria, we think it would be appropriate to call them "non-diffractive/non-refractive EDOF", considering that the group does not contain multifocal optical properties and provides significant focal depth, and the ANSI criteria should be revised to define the enhanced monofocal groups. It would at least be more accurate to classify the enhanced monofocal group as a subgroup under EDOF lenses, because the current nomenclature ignores the increase in focal depth provided by this group of lenses. In many publications we also see the use of the term "mono-EDOF" for this group of lenses.[27,28]

In our opinion, the Ray-One EMV lens, which meets three of the four ANSI criteria, can also be referred to as non-diffractive EDOF until the ANSI standards are reconsidered or standard definitions are introduced for the enhanced monofocal lens group, as the monocular focal depth of the lens is reported as 1.49 D and 2.25 D in MMV (with -1.0 D offset in the non-dominant eye).[27,28,29] Nevertheless, in the present study, the Ray-One EMV lens is referred to as enhanced monofocal or mono-EDOF.

The RayOne EMV IOL, as a non-diffractive, positive SA-based lens, is considered as a solution to the known problems of trifocal lenses along with other predominantly negative SA IOLs in the same group, such as Eyehance, Vivity, and LuxSmart.

In studies targeting emmetropia in both eyes, excellent results were obtained in the range of -0.01 to 0.00 logMAR at distance and intermediate distance with the enhanced monofocal or mono-EDOF lenses Eyehance, Vivity, and RayOne EMV. Additionally, near vision that can be considered successful and satisfactory at the level of 0.1 logMAR at -2.0 D on the defocus curve was achieved with Vivity and RayOne EMV lenses, whereas this value was unsatisfactory with the Eyehance lens (0.4 logMAR).[10] However, in Kohnen's et al.[4] PanOptix studies, near vision (40 cm) was excellent at 0.00 logMAR at -2.0 D. In short, although enhanced monofocal lenses provide very good and satisfactory results in near vision, they do not achieve the same level of excellence as trifocal lenses. In the same study, it was noted that the proportion of cases without halo or glare was 95%-100% in the enhanced monofocal non-diffractive lens groups, while the contrast sensitivity results were nearly the same as in the monofocal lens group.

Hovanesian et al.[8] reported that 69% of the patients in the PanOptix group and 85% in the Vivity group reported no or minimal halo and glare, and this difference was significant. In the same study, the rate of complete spectacle independence was 83% in the PanOptix group but only 33% in the Vivity group, which was a highly significant statistical difference ($p<0.0001$). There was also a significant difference in patient satisfaction results, with 85% of patients in the PanOptix group and 57% in the Vivity group stating they were very satisfied.

In a study conducted by Asena et al.[30] targeting bilateral emmetropia, the visual difference in the PanOptix /Vivity comparison was in favor of mono-EDOF at distance and the trifocal lens at near. In that study, better near vision in the trifocal lens group despite postoperative SE results of -0.60 D in the Vivity group and -0.09 D in the PanOptix group indicates the superiority of the trifocal lens in this area, while to the contrary, the better distance vision in the mono-EDOF group may be a result of the superior contrast provided by non-diffractive lenses. In this context, the MMV approach emerges as a solution by targeting -0.25 to -1.00 D myopia to the non-dominant eye to ensure excellent outcomes despite the residual near visual acuity problem with enhanced monofocal lenses.

In our study, evaluation of the binocular uncorrected visual outcomes obtained using the RayOne EMV IOL with MMV targeting -0.70 D in the non-dominant eye shows that the results obtained (0.00±0.03 logMAR at distance, 0.00±0.02 logMAR at intermediate, and 0.01±0.02 logMAR at near) did not differ statistically from the visual results achieved in the PanOptix trifocal group ($p>0.05$). In addition, we observed that 95.9% of patients in the MMV group did not experience dysphotopsia, and contrast sensitivity results in glare and no-glare conditions were significantly better than in the PanOptix group (Table 3).

It is seen that the MMV approach provides a significant benefit, especially in the enhanced monofocal groups that we refer to as non-diffractive mono-EDOF. For example, Park et al.[11] investigated the differences between emmetropia and MMV groups using the Eyehance IOL, with -0.75 D targeted for non-dominant eyes in the MMV group, and reported that binocular UCVA increased from 0.33±0.13 logMAR to 0.06±0.06 logMAR, spectacle dependence for near vision decreased from 80% to 20%, and there was no difference between the groups in terms of dysphotopsia. In another study, Solomon et al.[12] compared emmetropia and MMV groups using the Vivity lens and reported a postoperative mean SE of -0.45 D in the MMV group and 0.01 D in the emmetropia group. Near visual acuity was 0.39 logMAR in the emmetropia group and 0.21 logMAR in the MMV group. The difference was significant ($p<0.001$). There was again no difference in dysphotopsia between the groups.

Our study corroborates previous studies in the literature conducted with other monofocal plus or mono-EDOF lenses, and to our knowledge, there is no other publication in the literature on the MMV method with RayOne EMV lenses.

At the same time, our study shows that spectacle independence reached 83.3% with the MMV approach. This is still below the 100% figure achieved with PanOptix. As a result, in the comparison of trifocal lenses and MMV using enhanced monofocal lenses, which was one of the two main objectives of our study, we can say that trifocal lenses are still superior in functional areas such as spectacle independence, whereas the use of mono-EDOF lenses with the MMV approach is superior in terms of avoiding adverse effects, providing patient satisfaction, and preventing possible unhappiness.

The second important issue is the problems that may be encountered with MMV. For example, there is a case report in the literature in which lens exchange was required due to patient intolerance after implementing MMV with Vivity lenses despite having only -0.50 D myopia in the non-dominant eye.[31] This is one of the reasons why dominant and non-dominant eyes were examined separately and compared in our study. Accordingly, uncorrected visual acuities in the dominant and non-dominant eyes respectively were 0.00±0.03 and 0.05±0.08 logMAR for distance ($p<0.05$), 0.03±0.06 and 0.01±0.04 logMAR for intermediate ($p>0.05$), and 0.04±0.06 and 0.01±0.04 logMAR for near ($p<0.05$). Thus, there was a significant difference in favor of the dominant eye for distance and the non-dominant eye for near vision. The mean SE obtained in the non-dominant eyes of our patients was -0.67±0.33 D. When the patients were asked whether they noticed an intereye difference in the postoperative questionnaire, only 1 of the 12 patients (who had postoperative refraction of -1.00 D in the non-dominant eye) said they noticed

a difference between the eyes and was uncomfortable. One of the important considerations when applying the MMV method is how much myopia should be targeted in the non-dominant eye. For example, a study conducted by van Amelsfort et al.[32] using Vivity lenses showed that when -0.25 D was targeted in the non-dominant eye and a postoperative mean SE of -0.13 D was obtained, binocular near vision remained at the level of 0.23 logMAR. As a result, we can say that setting a myopic target of at least -0.50 D for the non-dominant eye is effective in improving binocular near vision, and we found that the intereye difference was not perceived by patients, did not cause subjective complaints, and did not require glasses unless it exceeded -1.00 D.

Study Limitations

The limiting aspects of our study can be considered the small number of patients and its basis on subjective questionnaires for dysphotopsia assessment instead of more quantitative methods such as a halometer.

Conclusion

Enhanced monofocal (mono-EDOF) lenses implanted using the MMV approach largely eliminated dysphotopsia and severe contrast sensitivity reduction, which are important potential problems of trifocal lenses, and the MMV method provides a solution to the issue of these lenses being less effective than trifocals in near vision when emmetropia is targeted.

Ethics

Ethics Committee Approval: The study protocol was approved by the Ethics Committee of Yozgat Bozok University (decision no: 2024-GOKAEK241_241_2024.03.27_12, date: 27.03.2024) and was carried out in accordance with the principles of the Declaration of Helsinki.

Informed Consent: Obtained.

Authorship Contributions

Surgical and Medical Practices: İ.C., H.A.B., Concept: İ.C., H.A.B., Design: İ.C., H.A.B., Data Collection or Processing: İ.C., H.A.B., Analysis or Interpretation: İ.C., H.A.B., Literature Search: İ.C., H.A.B., Writing: İ.C., H.A.B.

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