Original Article

Enhancing Visual Outcomes and Patient Satisfaction: A Case Series of Mix-and-Match Approach for Unhappy Presbyopic Patients Post-Cataract Surgery

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Abstract

This case series explored the mix-and-match approach of implanting an extended depth of focus (EDOF) intraocular lens (IOL) in the fellow eye to improve visual outcomes, reduce spectacle dependence, and enhance satisfaction in presbyopic patients dissatisfied with monofocal IOL outcomes, highlighting personalised refractive solutions for suboptimal results post-cataract surgery. Seven patients dissatisfied with post-operative presbyopia following monofocal IOL in first eye received EDOF IOL in the second eye (mix-and-match approach). Visual outcomes were assessed using a logMAR chart for near (40 cm), intermediate (60 cm and 80 cm) and distance (6 m) visual acuity (VA). Contrast sensitivity was measured using the Pelli-Robson chart, and halos and glare were evaluated with the Zeiss Halo and Glare Stimulator. Patient satisfaction was measured using the CATQUEST-9SF 2011 questionnaire before and after EDOF IOL implantation in the second eyes. Results showed statistically significant improvement in uncorrected near VA at 40cm and intermediate VA at 60cm in eyes with EDOF IOL (0.26 ± 0.18 and 0.11 ± 0.15 respectively) compared to eyes with monofocal IOL (0.64 ± 0.28 and 0.39 ± 0.26 respectively), while maintaining good uncorrected distance VA. Only one patient reported halos with the EDOF IOL, not affecting night driving. Contrast sensitivity showed no significant difference between monofocal IOL (1.60 ± 0.14) and EDOF IOL (1.60 ± 0.17) eyes. All patients were satisfied, experiencing improvements in recognised faces, walking on uneven surfaces, reading newspapers and TV subtitles, engaging in hobbies and seeing price tags. This mix-and-match approach demonstrated efficacy in enhancing near and intermediate vision while maintaining good distance vision, offering a personalised solution to reduce spectacle dependence without compromising contrast sensitivity or causing significant halos and glare.

Keywords: Contrast sensitivity; extended-depth of focus; intraocular lens; intermediate vision; mix-and-match; presbyopia

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Introduction

Cataract surgery is one of the most commonly performed surgical procedures, and intraocular lens (IOL) implantation plays a critical role in determining post-operative patients' satisfaction. It is often necessary to prevent vision-threatening complications, as untreated cataracts are a leading cause of lens-induced glaucoma, which can result in permanent optic nerve damage (1). Monofocal IOL remains a popular choice due to its excellent optical clarity and affordability. However, it provides a focused vision at a single distance, leaving patients dependent on spectacles for near tasks. For some patients, the unmet expectation of functional vision at multiple distances often happened due to inadequate preoperative counselling leading to dissatisfaction, particularly with presbyopia correction.

Various approaches are employed to address presbyopia correction, typically through the insertion of premium IOLs. Among these, presbyopia-targeted cataract surgery stands out, offering contemporary options such as multifocal IOLs, extended depth of focus (EDOF) IOLs, and monovision techniques (2-6). These approaches are pivotal in managing presbyopia by providing patients with tailored solutions to meet their visual needs at varying distances (2-6). However, multifocal IOLs, which split light to create multiple focal points, may lead to optical disturbances such as glare, halos and reduced contrast sensitivity (7). Furthermore, patients with ocular comorbidities such as glaucoma, diabetic retinopathy, or age-related macular degeneration are unsuitable candidates for multifocal IOLs due to potential reductions in visual function and quality (4).

EDOF IOLs represent a contemporary advancement in lens technology, enhancing intermediate visual acuity, particularly beneficial for tasks such as computer work-while maintaining high-quality distance vision. These lenses bridge the gap between monofocal and multifocal IOLs, offering fewer undesired optical effects, such as halos and glare, and improving contrast sensitivity (2,3). EDOF IOLs function by generating a single elongated focal point, allowing patients to experience a smoother visual transition across varying distances. Unlike multifocal IOLs, which split light into multiple foci, EDOF lenses create a continuous and elongated focal plane, reducing the risk of overlapping images and optical disturbances (8).

Presbyopia post-cataract surgery with monofocal IOL implantation in the first eyes may lead to dissatisfaction particularly among myopic patients, can be addressed through several strategies. These include monovision techniques or IOL exchange procedures to multifocal or EDOF lenses, although the latter carries surgical risks, such as posterior capsule rupture and retinal detachment (9-12). An alternative approach involves a mix-and-match approach with an EDOF lens implanted in the fellow eye. This method can enhance patients' satisfaction by preserving excellent distance vision, reducing dependence on spectacles, and facilitating a smoother adaptation process. While EDOF lenses such as TECNIS Synergy, AT LARA (Zeiss), Lentis Comfort and AcrySof IQ Vivity (Alcon) are designed to minimise halos and glare, they may still pose a higher risk of these visual disturbances than the monofocals (13,14); mixing monofocal with multifocal IOLs is generally not recommended, as the disparity in optical design can cause reduced binocular visual quality and patient dissatisfaction (13).

This case series aimed to illustrate the outcomes of a mix-and-match approach in patients who were dissatisfied with the loss of accommodation following uneventful cataract surgery with monofocal IOL implantation in their first eye. The analysis focuses on post-operative near, intermediate, and distance visual acuity, contrast sensitivity, patients' satisfaction, and incidence of halos and glare.

Materials and Methods

This prospective case series consists of seven patients who were unsatisfied with their near vision following an uneventful cataract surgery on their first eye with monofocal IOL implantation. The patients were not adequately counselled prior to the initial surgery regarding the limitations of monofocal IOLs. One month postoperatively, they expressed dissatisfaction with the visual outcome of the first eye. After consultation and discussion with the patients, they agreed to receive an EDOF IOL for their fellow eye. The type of EDOF IOL was selected randomly, and the procedure was performed by a single surgeon to minimise differences in surgically induced aberrations.

Each patient was required to complete the CATQUEST-9SF 2011 questionnaire before and after the EDOF IOL implantation in the fellow eye. The purpose of administering the CATQUEST-9SF 2011 questionnaire before and after EDOF IOL implantation was to assess visual function, satisfaction with vision in daily activities, and changes in quality of life resulting from the implantation. It included two global assessment components and seven questions focusing on specific daily activities affected by vision. This questionnaire is a validated questionnaire, which is available in three languages including English, Malay and Mandarin language (15). Post-operatively, visual acuity was recorded for distance vision at 6 m, intermediate vision at 60 cm and 80 cm, and near vision at 40 cm using the logarithm of minimum angle of resolution (logMAR) chart monocularly and binocularly. The logMAR chart was used in this study for visual acuity assessment, as it is more accurate and reliable than traditional Snellen chart. It uses a logarithmic scale to ensure uniform letter size and spacing across lines. Lower values indicate better vision (e.g., 0.0 equals 6/6 or 20/20 vision), while higher values indicate poorer vision, allowing for more precise tracking of visual performance. Additionally, contrast sensitivity of each eye was evaluated using the Pelli-Robson chart (Precision Vision, Inc., Illinois, USA) to assess the quality of vision beyond standard visual acuity measurements. Contrast sensitivity provides valuable complementary information to visual acuity when comparing different IOL designs, highlighting its importance in evaluating overall visual outcomes following cataract surgery (16). Halos and glare were assessed by using Halo & Glare simulator (Carl Zeiss Meditec, Germany). The Halo and Glare simulator allows patients to choose from different types of halos such as concentric rings, starbursts, or irregular shapes around light sources, and the size and intensity of the halos or glare can be adjusted to simulate the range of size and intensity reported by patients. All visual acuity, contrast sensitivity, and halo and glare assessments were part of routine pre- and postoperative clinical care and were non-invasive. All patients provided informed consent prior to enrolment in the study.

Statistical analysis

Data was collected and analysed using IBM Statistical Package for the Social Sciences (SPSS) statistic 27.0 (IBM Corp). An independent t-test was conducted to compare mean visual acuity (in logMAR) at various distances between eyes implanted with monofocal IOLs and the fellow eyes implanted with EDOF IOLs following the mix-and-match approach. A paired t-test was used to evaluate differences in contrast sensitivity between the monofocal eyes and their respective fellow eyes with EDOF IOLs. Statistical significance was defined as a p-value less than 0.05. Responses to the CATQUEST-9SF 2011 questionnaire, collected before and after implantation in the fellow eye, were analysed using descriptive statistics and presented in bar charts. The Pearson chi-square test was applied to each questionnaire item to identify significant differences, with a p-value <0.05 considered statistically significant.

Results

Our case series presented a comprehensive analysis of visual acuity at different distances, contrast sensitivity, and the presence of halos or glare after surgery for seven patients. These individuals underwent implantation of different types of intraocular lenses, with a monofocal lens in one eye and an EDOF lens in the fellow eye, as detailed in Table 1.

TABLE 1: Post-operative monocular and binocular visual acuity at various distances, contrast sensitivity and presence of glare and halos in patients who had mix-and-match intraocular lens implantations

		Visual acuity (logMAR)				Contrast sensitivity (logCS)	Glare	Halos
		UNVA 40 cm	UIVA 60 cm	UIVA 80 cm	UDVA 6 m			
Patient 1	1st eye: NIDEK SZ-1, NIDEK CO., LTD., Gamagori, Japan	0.70	0.30	0.20	0.02	1.65	×	×
	2nd eye: LENTIS® Comfort LS-313 MF15, Teleon Surgical B.V., Spankeren, The Netherlands	0.20	0.00	0.00	0.10	1.80	×	×
	Binocular	0.20	0.00	0.00	0.00	1.95		
Patient 2	1st eye: ZEISS AT TORBI 709MP, Carl Zeiss Meditec AG, Jena, Germany	0.30	0.20	0.10	0.10	1.80	×	×
	2nd eye: ZEISS AT LARA 929MP, Carl Zeiss Meditec AG, Jena, Germany	0.20	0.00	0.00	0.10	1.80	×	√
	Binocular	0.20	0.00	0.00	0.00	1.95		
Patient 3	1st eye: TECNIS Eyhance™ ICB00, Johnson & Johnson Surgical Vision, Inc., Santa Ana, CA, USA	0.70	0.30	0.20	0.10	1.65	×	×
	2nd eye: TECNIS Synergy™, Johnson & Johnson Surgical Vision, Inc., Santa Ana, CA, USA	0.20	0.20	0.20	0.00	1.65	×	×
	Binocular	0.20	0.00	0.10	0.00	1.80		
Patient 4	1st eye: ZEISS AT TORBI 709MP, Carl Zeiss Meditec AG, Jena, Germany	0.90	0.70	0.70	0.20	1.35	×	×
	2nd eye: ZEISS AT LARA 929MP, Carl Zeiss Meditec AG, Jena, Germany	0.60	0.40	0.40	0.14	1.50	√	×
	Binocular	0.50	0.40	0.30	0.00	1.65		

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Patient 5	1st eye: TECNIS™ ZCB00, Johnson & Johnson Surgical Vision, Inc., Santa Ana, CA, USA	0.50	0.10	0.14	0.10	1.65	×	×
	2nd eye: TECNIS Synergy™, Johnson & Johnson Surgical Vision, Inc., Santa Ana, CA, USA	0.10	0.20	0.14	0.02	1.35	×	×
	Binocular	0.10	0.00	0.12	0.00	1.80		
Patient 6	1st eye: HOYA Vivinex™ XC-1, HOYA Surgical Optics GmbH, Singapore / Japan	0.80	0.50	0.30	0.00	1.50	×	×
	2nd eye: LENTIS® Comfort LS-313 MF15, Teleon Surgical B.V., Spankeren, The Netherlands	0.40	0.00	0.10	0.10	1.50	×	×
	Binocular	0.20	0.00	0.00	0.00	1.80		
Patient 7	1st eye: HOYA Vivinex™ XC-1, HOYA Surgical Optics GmbH, Singapore / Japan	0.90	0.60	0.60	0.00	1.60	×	×
	2nd eye: ZEISS AT LARA 829MP, Carl Zeiss Meditec AG, Jena, Germany	0.10	0.00	0.00	0.20	1.62	×	×
	Binocular	0.00	0.00	0.00	0.00	1.90		

UNVA: Uncorrected near visual acuity; UIVA: Uncorrected intermediate visual acuity; UDVA: Uncorrected distance visual acuity; cm: centimeter; m: meter.
×: No or absence; √: yes or presence

Meanwhile, Table 2 summarised the mean visual acuity in logMAR at various distances for both eyes. There were statistically significant differences found in uncorrected near visual acuity (UNVA) at 40 cm and uncorrected intermediate visual acuity (UIVA) at 60 cm between the eyes receiving monofocal IOLs and EDOF IOLs which were 0.64 (0.28) vs 0.26 (0.18) and 0.39 (0.22) vs 0.11 (0.15), respectively.

Binocular visual acuity was also analysed for our patients. Mean binocular UNVA at 40 cm, UIVA at 60 cm, 80 cm, and UDVA at 6 m were found to be 0.20 (0.15), 0.06 (0.15), 0.07 (0.11), and 0.06 (0.07), respectively. The binocular visual acuity was found to have a synergetic improvement from the monocular visual acuity achieved by the eyes implanted with EDOF IOLs in all distances. For contrast sensitivity, we found that there was no statistically significant difference between the eyes which were implanted with monofocal IOLs [1.60 (0.14)] and EDOF IOLs [1.60 (0.17)] with p-value of 0.97.

CATQUEST-9SF 2011 questionnaire was used to investigate patients' satisfaction before and after EDOF IOL implantation. Our results showed a significant improvement in the two global assessment questions regarding patients' general difficulty and satisfaction before and after mix-and-match approach as shown in Fig.1 and Fig. 2, with p-values of 0.027 and 0.019 respectively.

TABLE 2: Mean visual acuity in logMAR at various distances for eyes receiving monofocal and extended depth of focus intraocular lenses

Visual acuity (logMAR)	**Mean (SD)**		**p-value**
	Monofocal IOL N= 7 eyes	**EDOF IOL N= 7 eyes**	
UNVA at 40 cm	0.64 (0.28)	0.26 (0.18)	0.010
UIVA at 60 cm	0.39 (0.22)	0.11 (0.15)	0.021
UIVA at 80 cm	0.32 (0.24)	0.12 (0.15)	0.081
UDVA at 6 m	0.07 (0.07)	0.09 (0.07)	0.605

UNVA: Uncorrected near visual acuity; UIVA: Uncorrected intermediate visual acuity; UDVA: Uncorrected distance visual acuity; SD: standard deviation; EDOF: extended depth of focus; IOL: intraocular lens; cm: centimeter; m: meter; N: total number of patients. Independent t-test. Significant p-value<0.05

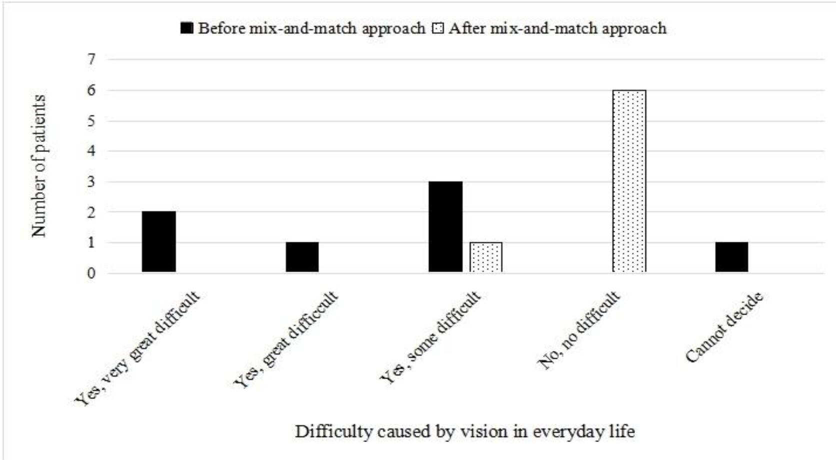

FIGURE 1: The bar chart showed the number of patients who experienced difficulty in everyday life due to their vision, both before and after the mix-and-match approach

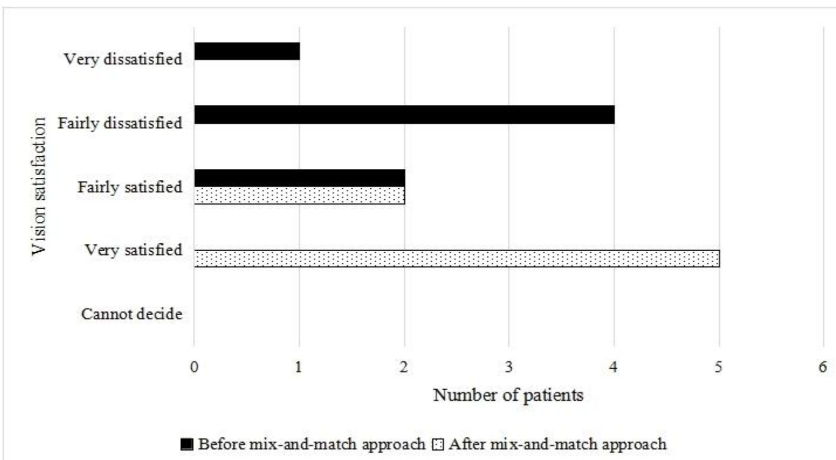

FIGURE 2: The bar chart illustrateed vision satisfaction before and after the mix-and-match approach

Generally, there were improvements in terms of difficulty in performing certain tasks, especially for reading text in newspaper after mix-and-match approach with a p-value of 0.025. These results were summarised in Fig. 3.

Using the Halo & Glare Stimulator, only one experienced concentric ring halos with a size of 25% and intensity of 30%, while another patient reported glare with a size of 30% and intensity of 32% after the implantation of EDOF lenses, though these findings were not statistically significant. Both patients adapted to the side effects well without any difficulty while driving at night. In overall, all patients were satisfied with mix-and match approach, they were experiencing improvements in recognised faces, walking on uneven surfaces, reading newspapers and TV subtitles, engaging in hobbies, and seeing price tags.

Discussion

This study evaluated the clinical outcomes of a mix-and-match approach using monofocal and EDOF IOLs in patients who were dissatisfied with the results of monofocal implantation in their first eye. The results demonstrated statistically significant improvements in UNVA and UIVA in eyes implanted with EDOF IOLs compared to those with monofocal IOLs. Binocular vision showed synergistic enhancement at all distances-near, intermediate, and far following the mix-and-match approach. Contrast sensitivity remained comparable between both groups, with no statistically significant difference. Patient-reported outcomes, measured using the CATQUEST-9SF 2011 questionnaire, revealed significant improvements in satisfaction and visual function, particularly in tasks such as reading newspapers and recognising faces.

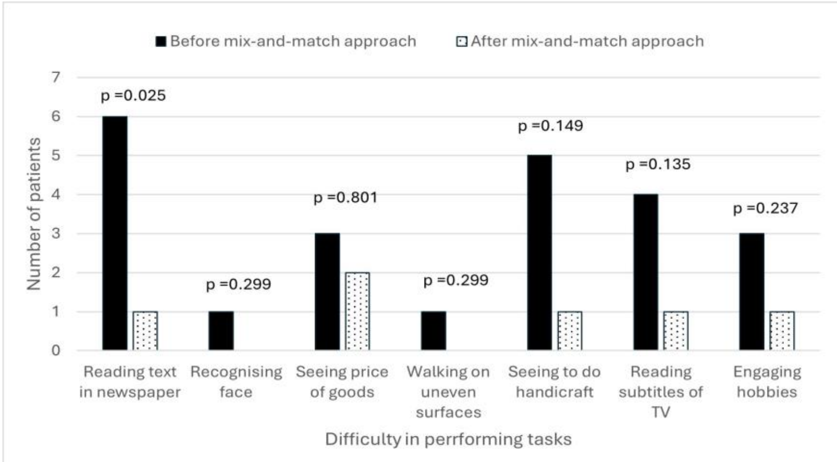

FIGURE 3: The bar chart demonstrated the difficulty in performing tasks before and after the mix-and-match approach

Visual disturbances such as halos and glare were minimal and well tolerated, with all patients reporting overall satisfaction after the procedure.

The outcomes of our study demonstrated statistically significant visual improvement in eyes implanted with EDOF IOLs compared to monofocal IOLs, particularly in uncorrected near and intermediate visual acuity. Mean UNVA at 40 cm was 0.26 (0.18) in the EDOF group versus 0.64 (0.28) in the monofocal group, and UIVA at 60 cm was 0.11 (0.15) versus 0.39 (0.22), respectively. This aligns with Rodov et al. (2019), who reported significantly better intermediate and near visual acuities with EDOF IOLs compared to monofocal IOLs: their EDOF group achieved a mean UNVA of 0.23 and UIVA of 0.14, while the monofocal group showed 0.51 and 0.42, respectively (11). Our binocular visual acuity outcomes further reinforced this improvement: binocular UNVA at 40 cm was 0.20 (0.15), UIVA at 60 cm was 0.06 (0.15), UIVA at 80 cm was 0.07 (0.11), and UDVA at 6 m was 0.06 (0.07). These results compare favourably with Song et al. (2020), where a mix-and-match group using bifocal and EDOF IOLs achieved binocular UNVA of 0.19, UIVA of 0.14, and UDVA of 0.03 (17). Moreover, our findings are supported by Van Amelsfort et al. (2022), who reported that targeting a non-diffractive EDOF IOL for mini-monovision resulted in mean binocular UNVA of 0.26 and UIVA of 0.12 at 3 months (18). Our mix-and-match results provided comparable or superior visual outcomes, particularly in intermediate vision, underscoring the efficacy of the mix-and-match approach using monofocal and EDOF IOLs to enhance the visual range. In contrast, Zeilinger et al. (2024) investigated bilateral implantation of the AcrySof IQ Vivity (a non-diffractive EDOF lens) and found mean binocular UNVA of 0.36 (0.14), UIVA of 0.10 (0.09), and UDVA of 0.06 (0.07) at 3 months (19). Compared to our results, our mix-and-match approach offered superior near vision (0.20 vs. 0.36), similar intermediate vision (0.06 vs. 0.10), and equivalent distance vision (0.06 vs. 0.06), highlighting the additional benefit of this approach in enhancing functional vision. In terms of contrast sensitivity, our study revealed no statistically significant difference between EDOF [1.60 (0.17)] and monofocal [1.60 (0.14)] IOLs (p = 0.97). This finding is consistent with Pieh et al. (1998), who reported similar contrast sensitivity under both photopic and mesopic conditions between refractive and diffractive multifocal IOLs (20). Likewise, Alice et al. (2020) observed no significant difference among aspheric monofocal lenses (16). Patient satisfaction, assessed via CATQUEST-9SF, showed significant improvement postoperatively. General difficulty improved with a p-value of 0.027, and overall satisfaction improved with a p-value of 0.019. Specific task difficulty, such as reading newspapers, also improved significantly (p = 0.025). Tarib et al. (2019) similarly noted improved Catquest scores postoperatively in their mix-and-match cohort, with high scores in reading, driving, and facial recognition tasks (21). Regarding photic phenomena, only two patients in our study reported mild symptoms: one with concentric halos (25% size, 30% intensity), and one with glare (30% size, 32% intensity). Both adapted well, with no driving impairment. This low incidence echoes findings by Tomagova et al. (2023), who reported that 90% of patients experienced minimal or no halos or glare with a non-diffractive EDOF lens targeted for mini-monovision (22).

Notably, both of our patients with symptoms had the Zeiss AT LARA toric 929MP lens implanted in the fellow eye. This is not unexpected, as diffractive lenses are known to have a higher incidence of halos and glare compared to refractive designs (11,20).

While our study demonstrated significant improvements in near, intermediate, and binocular visual acuity with the mix-and-match approach using monofocal and EDOF IOLs, several factors may explain differences between our findings and those reported in other studies. First, the specific IOL models and designs used in our study may contribute to the observed variations. We included both non-diffractive and diffractive EDOF lenses, with five patients receiving non-diffractive designs and two receiving diffractive EDOF IOLs. Non-diffractive EDOF IOLs are generally associated with better visual quality and fewer photic phenomena compared to diffractive or bifocal IOLs used in other studies (11,17). Rodov et al. (2019) utilised diffractive EDOF lenses, which are known to produce more pronounced halos and glare compared to non-diffractive designs (11). This difference in optical technology may partially explain the higher levels of patient satisfaction and lower incidence of photic disturbances observed in our study. However, it is important to note that even among the two patients in our cohort who received diffractive EDOF IOLs, the reported halos and glare were mild and did not impact night driving or overall satisfaction. This suggests that, with appropriate patient selection and lens matching, both types of EDOF lenses can contribute positively within a mix-and-match strategy.

Additionally, our patient cohort may have unique characteristics that influence visual outcomes. For instance, our study included patients who underwent a mix-and-match approach, optimising the benefits of both IOL types for near and intermediate vision. This strategy may enhance binocular visual acuity more than the standard bilateral EDOF or monofocal approaches used in some comparative studies (20,21). Lastly, differences in study methodologies, such as the timing of postoperative assessments, may also explain some variations in results. Our study assessed patient satisfaction using the CATQUEST-9SF questionnaire, which may include more nuanced questions regarding daily activities and specific visual tasks compared to other studies that employed less comprehensive measures (15,21). However, our patient-reported outcomes were collected at 1 month postoperatively, a relatively early time point that may not fully capture the extent of neural adaptation or long-term satisfaction with the IOLs. In contrast, other studies may have evaluated outcomes at later intervals, such as 3 or 6 months post-op (18,19), when visual acuity and subjective satisfaction could be more stable. These methodological differences include timing of assessment, IOL design, and questionnaire choice-highlight the importance of considering multiple variables when comparing results across studies, and may help explain the differences observed in patient outcomes. This study contributes significantly to the current body of knowledge regarding the efficacy and patient satisfaction of the mix-and-match approach using monofocal and EDOF IOLs in cataract surgery. Unlike previous studies that primarily focused on bilateral implantation of either monofocal or multifocal IOLs, our research provides valuable insight into the advantages of combining IOLs of different designs to address the visual needs of patients across multiple distances (11,13,17). Our findings suggest that the mix-and-match approach can effectively improve UNVA and UIVA, as well as binocular visual acuity, which is an important consideration for enhancing quality of life post-surgery. The significant improvement in patient satisfaction as measured by the CATQUEST-9SF questionnaire further supports the benefits of this approach, emphasising its potential to address specific visual tasks such as reading newspapers and TV subtitles. Moreover, the study adds to the growing body of evidence on the role of non-diffractive EDOF IOLs in achieving a wider range of functional vision with fewer side effects such as halos and glare, which are often associated with diffractive IOLs (20). By using a newer non-diffractive EDOF lens design, this study demonstrates that advanced IOL technology can mitigate the drawbacks of previous multifocal IOLs, making the mix-and-match approach a viable alternative for patients seeking spectacle independence without compromising visual quality. Our results also offer important clinical implications, suggesting that surgeons may consider a mix-and-match approach particularly for patients who are dissatisfied with the outcome of monofocal IOL implantation in the first eye or who have specific visual needs to achieve better outcomes than those seen with traditional monofocal or multifocal IOLs alone.

Despite the promising outcomes observed, this study has several limitations that warrant consideration. Firstly, the relatively small sample size restricts the generalisability of the results to broader patient populations. A larger cohort would enable more robust statistical analysis and enhance the reliability of the findings. Secondly, the study did not account for ocular dominance, a critical factor in the success of monovision and mini-monovision strategies, where the dominant eye is typically corrected for distance. The omission of this variable may have influenced patient satisfaction and visual performance outcomes. Moreover, the use of different brands and models of IOLs introduces variability, which could confound the results. Standardising the IOL types in future studies would reduce this variability and strengthen the evidence. Additionally, the relatively short follow-up period may not adequately reflect long-term visual outcomes or late-onset complications such as photic phenomena. Extended follow-up is essential to evaluate the durability and safety of the mix-and-match approach over time.

Conclusion

The mix-and-match implantation of a monofocal IOL in the dominant eye and an EDOF IOL in the fellow eye offers an effective strategy for improving near and intermediate visual acuity while maintaining satisfactory distance vision and contrast sensitivity. This approach yielded high levels of patient satisfaction, with minimal photic disturbances, making it a viable option for patients dissatisfied with initial monofocal implantation. The results underscore the importance of individualised IOL selection to enhance visual performance and quality of life following cataract surgery. Further prospective studies with larger cohorts and longer follow-up durations are warranted to validate these findings and refine patient selection criteria for the mix-and-match strategy

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