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IMPACT OF INTRAOCULAR LENS DESIGN ON VISUAL QUALITY AND PATIENT SATISFACTION AFTER CATARACT SURGERY

Dr Chidire Sathish Kumar[1*], Dr suman Choudhary[2], Dr Manchirevula Sharanya[3]

[1*]Assistant professor, Maheshwara medical College, satish.chidire@gmail.com
[2]Assistant professor, Maheshwara medical College, drsumanchoudhary999@gmail.com
[3]Post graduate, Maheshwara medical College, drsharanya1403@gmail.com

Abstract
Cataract surgery had evolved into a refractive procedure aimed at improving patient satisfaction and postoperative visual quality. Advances in intraocular lens (IOL) design had expanded visual outcomes beyond distance vision to include intermediate and near vision, while also influencing visual disturbances and spectacle dependence. This study aimed to compare the impact of different IOL designs on postoperative visual quality and patient satisfaction following cataract surgery. This retrospective observational study included 120 patients who underwent uncomplicated cataract surgery with implantation of a single type of IOL. Patients were equally assigned to four groups: monofocal, enhanced monofocal, multifocal/trifocal, and extended depth-of-focus (EDOF) lenses. Postoperative outcomes included visual acuity, visual disturbances, patient satisfaction, and spectacle dependence. Statistical analysis involved descriptive statistics, chi-square tests, correlation analysis, and multivariate regression. Postoperative distance visual acuity was favorable across all IOL groups. Enhanced monofocal, multifocal/trifocal, and EDOF lenses demonstrated superior intermediate visual acuity compared with standard monofocal lenses, while multifocal/trifocal lenses achieved the best near visual acuity. Visual disturbances were more frequent in the multifocal/trifocal group, whereas monofocal and enhanced monofocal lenses showed fewer dysphotopsia symptoms. Patient satisfaction was high across all groups, with significantly higher spectacle independence observed in the multifocal/trifocal and EDOF groups. Intraocular lens type and spectacle independence were significant predictors of patient satisfaction. Overall, intraocular lens design played a key role in postoperative visual quality and functional outcomes, highlighting the importance of individualized IOL selection to optimize satisfaction after cataract surgery.

Keywords: Cataract surgery; Intraocular lens design; Visual quality; Patient satisfaction; Spectacle independence

1. Introduction

Cataract remains one of the leading causes of reversible visual impairment globally and continues to represent a major public health challenge, particularly in ageing populations. The growing rate of cataract ageing has led to a significant increase in cataract surgeries in the world, with the new focus on postoperative quality of life as opposed to pure visual acuity.[1] The development of surgical methods and perioperative care has contributed to a great deal of safety and predictability, thus enabling cataract surgery to be a refractive surgery that attempts to provide functional vision. As a result of this paradigm shift, there has been an expansion of the expectations of patients of cataract surgery. Patients are more demanding high quality of vision at various distances, low reliance on

spectacles, and being without visual irritations. Consequently, surgery outcome measures have shifted away to more encompassing measures like visual quality and patient satisfaction, rather than using traditional measures like best-corrected visual acuity.[2] These results are currently accepted as the key parameters of surgical success. In parallel with the changes in the outcome expectations, the intraocular lens (IOL) technology has been developed remarkably. The first-generation monofocal IOLs have been developed to offer the best distance vision, but they fail to deal with presbyopia. In order to overcome this shortcoming, multifocal IOLs were developed, which provided better near and intermediate vision with multiple simultaneous focal points.[3] This idea was further developed with Trifocal IOLs that improved the intermediate vision, which in turn improved the functional performance in daily activities.[4] Besides multifocal technologies, the alternative methodology has been extended to depth-of-focus (EDOF) lenses. These lenses aim to offer a continuous scope of vision with lower photic effects than multifocal designs will offer.[5] More recently, newer monofocal IOLs have been engineered to have a better intermediate vision but retain a comparable level of contrast sensitivity and reduce dysphotopsia as the conventional monofocal and premium presbyopia-correcting lenses.[6] Since optical principles vary in IOL designs, they have multiple impacts on postoperative outcomes than visual acuity. The parameters of patient satisfaction have been identified to be contrast sensitivity, glare, halos and general quality of vision.[7] Some studies have stated that, irrespective of good postoperative acuity, patients can be dissatisfied with the presence of visual disturbances, and thus the need to develop an overall assessment of outcomes.[8] Patient-reported outcome measure (PROM) has thus become part of cataract surgery evaluation. These are tools that capture subjective visual experience, functional limitations, and satisfaction levels that cannot be measured entirely by the use of objective testing only.[9] The inclusion of PROMs in clinical research is in line with patient-centred care and would give a more comprehensive view of postoperative visual outcomes.[10]

There is still a gap in evidence, even though many studies have compared the visual results of the various IOL designs implanted. Multifocal, trifocal and EDOF lenses have been compared, which provides mixed results regarding visual quality, dysphotopsia and patient satisfaction.[11] This heterogeneity is caused by differences in the study population, outcome metrics and the period of follow-up. Numerous studies focus either on objective visual performance or on subjective satisfaction, and few studies have combined both areas of study under the same analytical paradigm. Multicenter research has shown that patient-reported outcomes cannot be solely accounted for by clinical parameters and, therefore, more comprehensive evaluation strategies are necessary.[12] The combination of optical quality measures and PROMs in long-term measurements is still comparatively scarce. Moreover, newer designs of IOLs, such as the improved monofocal and hybrid lenses, have surpassed the supply of comparative real-life data. Statistically significant comparisons of these lenses and already known multifocal, trifocal, and EDOF designs to the routine clinical conditions are still lacking.[13] The results of the postoperative satisfaction would also be hard to interpret due to variability in patient expectations and preoperative counselling.[14]

There is an increasing clinical significance of proper IOL choice due to the rising patient expectations of spectacle independence and high-quality functional vision over range. Surgeons should exhibit caution in the evaluation of the advantages of high IOL designs and their associated risks, like dysphotopsia and compromised contrast sensitivity.[15] The evaluation of the visual quality and patient satisfaction of various IOL designs based on evidence is thus necessary to make individual surgical planning. Concomitant evaluation of objective visual results and patient-reported satisfaction provides a useful clue to the actual postoperative visual experience in the real world. This kind of evidence assists in informed preoperative counselling, managing expectations, and shared decision-making between the surgeons and patients. [16] Knowledge of design-specific advantages and constraints is also a promising factor in long-term visual functionality and quality of life optimisation after the cataract surgery is performed.[17] Comparative assessment in the real clinical setting also increases the applicability of results to practice. The outcome data provided in real-life help clinicians to personalise the IOL choice based on the visual needs of the particular

individual, lifestyle needs, and the tolerance of the optical effects.[18] This practice would eventually promote better patient satisfaction and long-term surgical outcomes.[19]

Research Objectives

1. To evaluate the impact of different intraocular lens designs on postoperative visual quality following cataract surgery.
2. To assess patient satisfaction levels associated with various intraocular lens designs.

2. Methodology

2.1 Study Design and Setting

This study was conducted as a retrospective observational clinical study aimed at evaluating the impact of different intraocular lens (IOL) designs on postoperative visual quality and patient satisfaction following cataract surgery. The study was carried out at a tertiary eye care centre providing routine cataract surgery services. Medical records of patients who underwent cataract surgery during a predefined study period were retrospectively reviewed, and postoperative outcomes were assessed using data documented during routine follow-up visits as per institutional practice.

2.2 Study Population and Sample Size

The study involved 120 patients who met the eligibility criteria in the study. The inclusion criteria were that the patient must be aged 40 years and above, must have had a single type intraocular lens implanted during uncomplicated cataract surgery, and must have full postoperative visual outcome records available to analyse. The sample size was set to be dependent on the accessibility of the qualified and complete medical records at the time of the study.

2.3 Eligibility Criteria

Ocular comorbidities such as glaucoma, diabetic retinopathy, macular pathology or corneal disease that may influence visual outcomes were not included in the study. Patients who had ocular surgery history in the past, were recorded to have intraoperative or postoperative complications affecting their visual recovery or had incomplete medical records, were also not included in the analysis.

2.4 Intraocular Lens Classification

The patients were divided into classes according to the kind of intraocular lens implanted such as monofocal intraocular lens in which the primary aim was to see objects at a distance, enhanced monofocal intraocular lens in which the aim was to improve Intermediate vision and still allow the eyes to view objects at a distance, multifocal and trifocal intraocular lens in which the aim was to see objects at shorter distances, and extended depth-of-focus intraocular lens in which the aim was to see objects at longer distances with less photic phenomena. Each patient belonged to one group of intraocular lenses only in order to ensure consistency in outcome measurement.

2.5 Outcome Measures

Postoperative outcomes were measured using objective clinical parameters and were also recorded based on patient satisfaction parameters. Objective visual results encompassed the uncorrected visual acuity, best-corrected distance visual acuity, intermediate and near visual acuity (where necessary), and contrast sensitivity, which is determined at the regular follow-up appointments. Glare, halos, night vision problems, and other visual disturbances are the visual quality indicators that were evaluated, according to postoperative clinical reports. The satisfaction was measured by the status of patient satisfaction and spectacle dependence or independence recorded at a time when the patient met the doctor during normal follow-up sessions.

2.6 Data Collection and Statistical Analysis

All data were retrospectively collected on a standardised data collection format based on electronic and paper-based medical records. The documented variables were the demographic factors, the type of intraocular lens, the postoperative visual outcome, as well as the documented satisfaction measures. Data were entered into Excel. Continuous variables were displayed using mean and standard deviation, and categorical variables were displayed as frequencies and percentages. Comparative tests were carried out among various intraocular groups of lens groups using chi-square tests, correlation analysis, and multivariate regression in relation to the data distribution, where a p-value below 0.05 was taken to be of the same significance.

2.7 Ethical Considerations

The research was carried out in accordance with the ethical standards of medical research on human beings. Since this was a retrospective study involving anonymised clinical data, informed consent was not required, as per institutional requirements, and patient confidentiality was upheld throughout the study.

3. Results

3.1 Demographic and Clinical Characteristics

A total of 120 patients who underwent uncomplicated cataract surgery with intraocular lens (IOL) implantation were included in the analysis and were evenly distributed across four IOL groups, with 30 patients in each group. The mean age of the study population was 66.4 ± 7.8 years, and male and female patients were equally represented, with 60 males and 60 females. Surgery was performed in the right eye in 64 patients (53.3%) and in the left eye in 56 patients (46.7%). The mean postoperative follow-up duration was 6.2 ± 1.1 months, and follow-up duration remained consistent across the study population, indicating baseline comparability among groups (Table 1).

Table 1. Baseline demographic and clinical characteristics

Category	**Variable**	**Total (n = 120)**
Age	Mean age (years)	66.4 ± 7.8
Gender	Male	60
	Female	60
Eye operated	Right eye	64
	Left eye	56
Follow-up	Duration (months), mean ± SD	6.2 ± 1.1

Each intraocular lens group contained an identical number of patients, ensuring uniform group size for subsequent comparisons of postoperative outcomes.

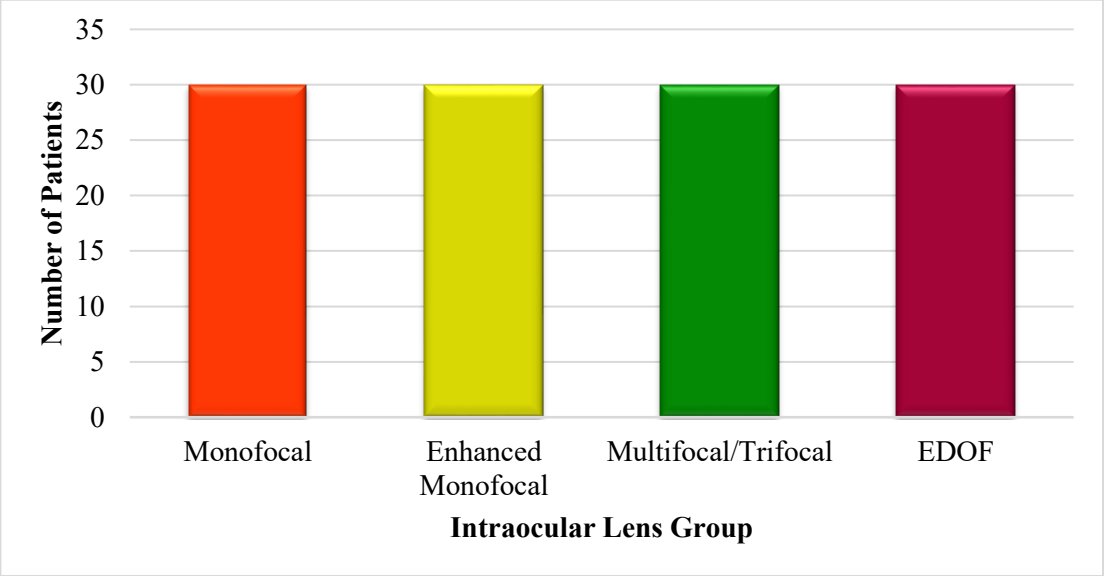

Figure 1. Distribution of patients across intraocular lens groups

As shown in Figure 1, all four intraocular lens groups included 30 patients each, confirming balanced group allocation and supporting consistency in comparisons across visual acuity, visual quality, and satisfaction outcomes.

3.2 Postoperative Visual Acuity Outcomes

All intraocular lens groups demonstrated good postoperative distance visual acuity. Mean uncorrected and best-corrected distance visual acuity were comparable across groups. Enhanced monofocal, multifocal/trifocal, and extended depth-of-focus (EDOF) lenses demonstrated superior intermediate visual acuity compared with standard monofocal lenses. Near visual acuity outcomes were best in the multifocal/trifocal group (Table 2).

Table 2. Postoperative visual acuity outcomes (logMAR, mean ± SD)

Visual outcome	Monofocal	Enhanced Monofocal	Multifocal/Trifocal	EDOF
UDVA	0.06 ± 0.05	0.05 ± 0.04	0.06 ± 0.05	0.05 ± 0.04
CDVA	0.02 ± 0.03	0.02 ± 0.03	0.03 ± 0.03	0.02 ± 0.02
Intermediate VA	0.18 ± 0.07	0.10 ± 0.06	0.09 ± 0.05	0.11 ± 0.06
Near VA	0.32 ± 0.08	0.24 ± 0.07	0.08 ± 0.05	0.18 ± 0.07

3.3 Visual Quality and Dysphotopsia

Postoperative visual disturbances documented during routine follow-up varied across intraocular lens designs. Glare was reported by 3 patients (10.0%) in the monofocal group, 4 patients (13.3%) in the enhanced monofocal group, 11 patients (36.7%) in the multifocal/trifocal group, and 7 patients (23.3%) in the EDOF group. Halos were noted in 2 patients (6.7%), 3 patients (10.0%), 12 patients (40.0%), and 8 patients (26.7%) in the respective groups, as shown in Table 3. Night-vision complaints were recorded in 2 patients (8.3%) in the monofocal group, 4 patients (11.7%) in the enhanced monofocal group, 10 patients (33.3%) in the multifocal/trifocal group, and 6 patients (20.0%) in the EDOF group.

Table 3. Visual disturbances documented during follow-up

Visual disturbance	Monofocal	Enhanced Monofocal	Multifocal/Trifocal	EDOF
Glare	3 (10.0%)	4 (13.3%)	11 (36.7%)	7 (23.3%)
Halos	2 (6.7%)	3 (10.0%)	12 (40.0%)	8 (26.7%)
Night-vision complaints	2 (8.3%)	4 (11.7%)	10 (33.3%)	6 (20.0%)

The distribution of glare, halos, and night-vision complaints across all four intraocular lens designs was examined collectively to assess differences in the frequency of postoperative visual disturbances.

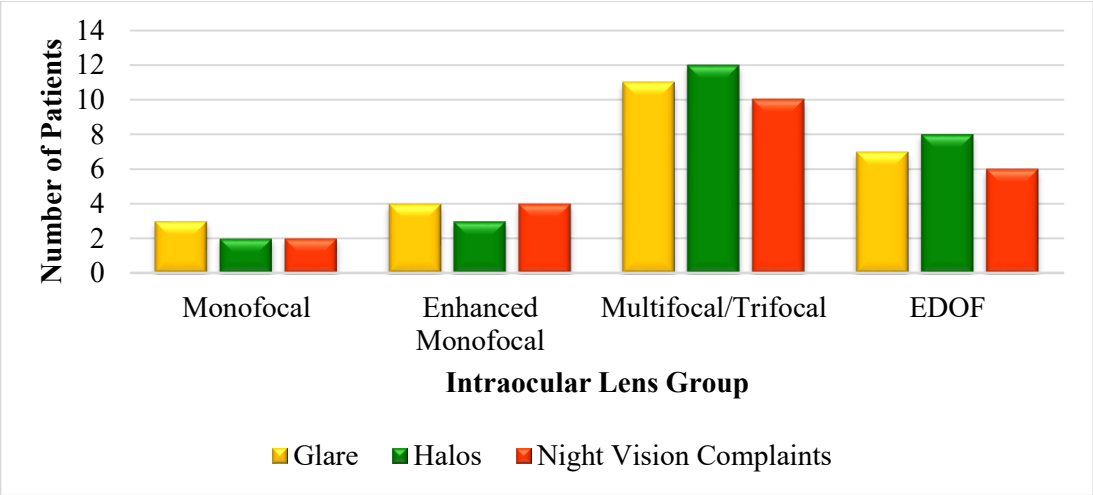

Figure 2. Frequency of visual disturbances across intraocular lens designs

In Figure 2, higher frequencies of glare, halos, and night-vision complaints are observed in the multifocal/trifocal group compared with the monofocal and enhanced monofocal groups, while the EDOF group demonstrates intermediate frequencies of these symptoms.

3.4 Patient Satisfaction and Spectacle Dependence

Patient satisfaction outcomes were consistently high across all intraocular lens groups. Satisfaction was documented in 26 patients (86.7%) in the monofocal group, 27 patients (90.0%) in the enhanced monofocal group, 28 patients (93.3%) in the multifocal/trifocal group, and 27 patients (90.0%) in the EDOF group. Spectacle independence was reported by 9 patients (30.0%) in the monofocal group, 14 patients (46.7%) in the enhanced monofocal group, 25 patients (83.3%) in the multifocal/trifocal group, and 20 patients (66.7%) in the EDOF group (Table 4).

Table 4. Patient satisfaction and spectacle dependence

Outcome	Monofocal	Enhanced Monofocal	Multifocal/Trifocal	EDOF
Satisfied patients	26 (86.7%)	27 (90.0%)	28 (93.3%)	27 (90.0%)
Spectacle independence	9 (30.0%)	14 (46.7%)	25 (83.3%)	20 (66.7%)

Differences in the proportion of patients achieving spectacle independence across intraocular lens designs were further examined across all four lens categories.

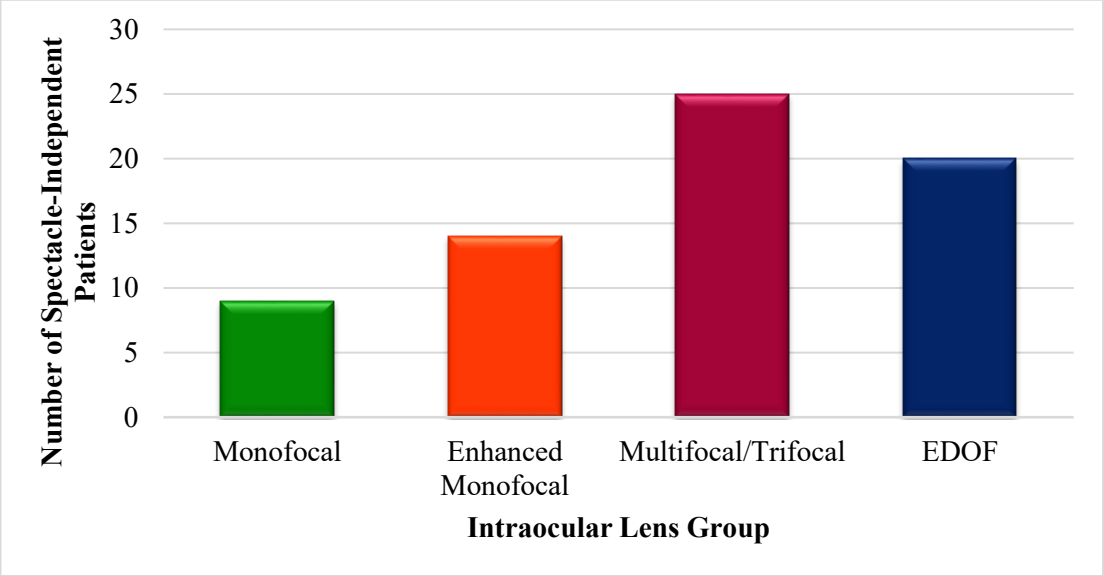

Figure 3. Spectacle independence across intraocular lens groups

As indicated in Figure 3, higher proportions of spectacle independence were observed in patients implanted with multifocal/trifocal and EDOF lenses compared with monofocal and enhanced monofocal lenses.

3.5 Association and Predictive Analysis of Postoperative Outcomes

Statistical analysis identified a significant association between intraocular lens type and spectacle independence ($\chi^2 = 24.86$, $p < 0.001$), as well as between intraocular lens type and the presence of visual disturbances ($\chi^2 = 16.42$, $p = 0.001$), as shown in Table 5. Correlation analysis demonstrated a positive association between intermediate visual acuity and patient satisfaction ($r = 0.52$, $p < 0.001$) and a negative association between visual disturbances and satisfaction ($r = -0.46$, $p < 0.001$). Multivariate regression analysis showed that intraocular lens type and spectacle independence were significant predictors of patient satisfaction ($p < 0.01$).

Table 5. Association and predictive analysis of postoperative outcomes

Outcome assessed	Statistical test	Key statistic	p-value
IOL type vs spectacle independence	Chi-square	$\chi^2 = 24.86$	< 0.001
IOL type vs visual disturbances	Chi-square	$\chi^2 = 16.42$	0.001
Intermediate VA vs satisfaction	Pearson correlation	$r = 0.52$	< 0.001
Visual disturbances vs satisfaction	Pearson correlation	$r = -0.46$	< 0.001
Predictors of satisfaction	Multivariate regression	Significant β	< 0.01

4. Discussion

The present study provides a comparative evaluation of postoperative visual outcomes, visual quality, and patient satisfaction across different intraocular lens (IOL) designs in a real-world clinical setting. The findings indicate that the visual distance acuity of the postoperative period of all types of IOLs was favorable, which confirms the usefulness of modern cataract surgery in terms of restoring the distance vision regardless of the type of the lens design. The finding supports the idea that today cataract surgery has become a predictable refractive procedure with reliably good outcomes of distance. The disparities between IOL designs were brought out more clearly when intermediate and near visual acuity was taken into consideration. Increased monofocal, multifocal/trifocal and extended depth-of-focus (EDOF) lenses demonstrated higher intermediate vision than the monofocal lenses whereas multifocal/trifocal lenses offered the best near visual acuity. These outcomes represent the optical concepts behind any lens design, in which multifocal and trifocal optics focus more on near and intermediate focal points, and EDOF lenses are intended

to increase the scope of continuous vision. The visual quality results showed that there existed a significant trade-off between the functional visual range and visual disturbances. The multifocal /trifocal group showed more glare, halos and night-vision complaints and the monofocal/enhanced monofocal lenses had less symptoms of dysphotopsia. The intermediate visual disturbance frequencies of EDOF lenses indicated a compromise between the visual comfort and the visual range. The satisfaction of the patients was high in all IOL categories and this means that the majority of the patients adapted to their postoperative visual results. Spectacle independence depended, however, on IOL design with multifocal/trifocal and EDOF lenses having a significantly higher rate of spectacle independence than monofocal and enhanced monofocal lenses. The association and regression factors also made it clear that IOL type and spectacle independence were important predictors of patient satisfaction, whereas age and gender were not. These results point at a close relationship between cataract post-surgery satisfaction with functional visual performance and lifestyle outcomes and demographic factors.

The visual performance and satisfaction findings in this paper are aligned with the real world comparisons of the advanced IOL designs recorded in the past. Comparative studies between EDOF and trifocal Lenses have found better near vision and higher spectacle independence in trifocal lenses with a higher rate of dysphotopsia, and EDOF lenses showed more equal visual performance and less photic effects.[20] These findings are in line with the intermediate positioning of EDOF lenses observed in the present study. There have been comparisons of standard monofocal and enhanced monofocal lenses driven by the observation that enhanced monofocal designs have the potential to enhance the intermediate vision and functional visual performance without necessarily raising visual disturbances.[21] The current findings also indicate a better intermediate acuity in the superior monofocal group than the conventional monofocal lenses, with little rise in dysphotopsia. The longitudinal studies of multifocal and accommodating IOLs have noted that patient satisfaction levels are high in spite of visual disturbances that occurred especially where the spectacle independent is attained.[22] This tendency should be noticed in the present study by the fact that in multifocal / trifocal lenses, the spectacle independence was the highest, and more frequently glare and halos were reported, but the overall satisfaction with them was high. Despite the fact that research with pediatric or specialized cataract groups focuses on other clinical issues, the general literature confirms the idea that the choice of IOL can have a significant impact on postoperative functional vision.[23] Also surgical and anatomical variables that affect the effective lens position and refractive outcomes have been depicted to affect the postoperative outcomes, which further supports the essence of thorough preoperative planning.[24] Modern cataract surgery and IOL selection recommendations also focus on custom lens choice according to the needs and tolerance of optical side effects of patients.[25]

The results of this paper have significant clinical decision-making implications in cataract surgery. The findings provide evidence of a personalized approach to the choice of IOL, with the choice of the lens determined by patient lifestyle, visual priorities and tolerance to visual disturbances. Although multifocal and trifocal lenses might be more appropriate in patients who have spectacle independence as their main priority, monofocal and enhanced monofocal lenses could be more applicable in patients who attach importance to visual comfort and contrast sensitivity. The EDOF lenses can provide a trade-off to patients who require a wider visualization range with an intermediate dysphotopsia.

This research has a number of weaknesses that must be recognized. Its retrospective nature makes it impossible to control the possible confounding variables and depends on the correctness of records in clinical practice. The outcome of the patient satisfaction and visual disturbance was evaluated on the basis of routine follow-up records instead of the standardized questionnaires, which can underestimate the subjective visual symptoms. Furthermore, the follow-up period was also short, and it was not possible to determine the long-term adjustment to visual disturbances.

Prospective studies using standardized patient-reported outcome measures should be included in future studies to better measure subjective visual quality and satisfaction. The assessment of neuroadaptation and long-term satisfaction would be possible with the longer periods of follow-up

on the various designs of IOL. More research on individual patient subgroups and lifestyle variables could also help improve the use of personalized IOL selection.

5. Conclusion

This study provides a comparative evaluation of postoperative visual outcomes, visual quality, and patient satisfaction across different intraocular lens (IOL) designs. The results indicate that all types of IOLs yielded positive postoperative distance visual acuity, proving the good performance and predictability of the current cataract surgery to restore distance vision regardless of the lens design used. Intermediate and near visual performance differences were found to be clear between the IOL groups. Upgraded monofocal, multifocal/trifocal and extended depth-of-focus (EDOF) lenses displayed better intermediate optical acuity than the ordinary monofocal ones, whereas multifocal/trifocal ones exhibited the finest near visual acuity. These results were indicative of the desired optical characteristics of superior designs of IOL and their capability to cater presbyopic needs. The balance between visual disturbances and the expanded functional vision was an important point mentioned as a result of visual quality outcomes. The Multifocal and trifocal lenses were found to have more incidences of glare, halos and night-vision complaints, and monofocal and enhanced monofocal lenses had lower incidences of dysphotopsia. Intermediate visual disturbance was observed in EDOF lenses which indicated a trade-off between visual range and visual comfort. There was a high patient satisfaction within all the IOL groups, but spectacle independence showed a lot of difference depending on the lens design. Whilst multifocal and trifocal as well as EDOF lenses had higher spectacle independence rates than monofocal and improved monofocal. IOL type, spectacle independence were identified as significant predictors of patient satisfaction using statistical analysis.

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