Study on low contrast visual acuity among presbyopes using multifocal contact lens in photopic and mesopic condition

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Abstract Aim:

This study investigates the effect of multifocal contact lenses (MFCLs) on low contrast visual acuity (LCVA) among presbyopic subjects under photopic (bright) and mesopic (dim) lighting conditions.

Methods:

A prospective, single-masked, randomized study was conducted on 20 eyes of presbyopic participants aged 40–50 years. Subjects underwent prefitting evaluations followed by LCVA measurements using the Freiburg Visual Acuity and Contrast Test (FrACT) under both lighting conditions before and immediately after MFCL insertion. Pupil size was also measured. Statistical analyses were performed using SPSS version 20.

Results:

Post-MFCL insertion, LCVA declined under both lighting conditions. In photopic conditions, median LCVA decreased from 1.22 logCS to 1.07 logCS; under mesopic conditions, it dropped from 0.88 logCS to 0.61 logCS. Pupil size constricted significantly post-insertion in both conditions (photopic: from 3.34 mm to 3.05 mm, mesopic: from 5.62 mm to 5.30 mm; $p < 0.001$). Statistical analyses confirmed significant variability in LCVA and pupil size pre- and post-MFCL use.

Conclusion:

Multifocal contact lens wear resulted in reduced low contrast visual performance, more pronounced under mesopic conditions. The observed pupil constriction post-insertion may contribute to altered contrast perception. These findings emphasize the importance of considering lighting conditions and optical design during MFCL prescription.

Keywords: Presbyopia, Multifocal contact lens, Low contrast visual acuity, Photopic, Mesopic, FrACT, Pupil size

1. INTRODUCTION

Presbyopia is an age-related refractive condition that typically becomes clinically evident after the age of 40, characterized by a progressive decline in accommodative amplitude and near visual function. Multifocal contact lenses (MFCLs) have become a widely adopted modality for presbyopia management, offering simultaneous correction for distance, intermediate, and near vision within a single lens.

LCVA is crucial for everyday visual tasks such as night driving, face recognition, or reading faded or low-contrast text. These tasks become particularly challenging under varying illumination levels, such as photopic (bright) and mesopic (dim) lighting conditions, both of which have a significant impact on contrast sensitivity. Given the complex optical profile of MFCLs—especially in simultaneous vision designs—there is a need to understand how these lenses interact with the visual system under such lighting variations.

2. METHODS

A prospective, single-masked, randomized experimental study was conducted over 18 months at the Department of Optometry, SRM Institute of Science and Technology, to investigate the effects of multifocal contact lenses (MFCLs) on low contrast visual acuity (LCVA) under varying illumination conditions in early presbyopic subjects.

Twenty presbyopic individuals aged between 40 and 50 years were enrolled based on specific inclusion and exclusion criteria. Inclusion criteria comprised subjects with early symptoms of presbyopia, near vision difficulty, and an add requirement, while individuals with ocular pathologies, surgery history, or dry eye symptoms were excluded.

All participants underwent a complete eye examination including slit lamp biomicroscopy, visual acuity testing, subjective and objective refraction, keratometry, and pupil size measurement. Each subject was fitted with a Bausch & Lomb PureVision2 MFCL (Balafilcon A, 36% water content, base curve 8.6 mm, diameter 14 mm). Lens performance was assessed based on corneal coverage, centration, movement, comfort, and visual quality.

Low contrast visual acuity was measured using the Freiburg Visual Acuity and Contrast Test (FrACT), a computerized vision testing application. Measurements were conducted under photopic (100 cd/m²) and mesopic (10 cd/m²) conditions using a calibrated monitor. Each participant's LCVA was measured before and immediately after MFCL insertion. Pupil size was measured under the same lighting conditions using a millimeter scale and direct illumination. Randomization was applied to determine which eye was assessed. Data were analyzed using SPSS v20, and paired t- tests and ANOVA were used to assess statistical significance.

3. RESULTS

A total of 40 eyes were screened. Based on the randomization, inclusion and exclusion criteria, only 20 eyes of presbyopic adults with mean age of 45 ± 5 years (range: 40-50 years) participated in our study, and all participants completed the study.

In our study, participants are between 40 and 50 years old, with the largest group (5 people) being 40 years old, typically marking the beginning of presbyopia. A small number of participants are 41, 43, 44, and 47 years old, and they likely fall into the early to middle stages of presbyopia. Two individuals are aged 45 and 46, which suggests they are in the middle stages of presbyopia. The 48- year-old participant, along with four 50-year-olds, are likely experiencing more advanced forms of presbyopia, a condition that often becomes more noticeable as one ages.

The gender ratio of the participants was 40% (n = 8) male and 60% (n = 12) female. The mean spherical and near refractive error of the participants is given in Table 1.

Table 1 Age and Refractive profile of the participants

Demograhics	Mean ± standard deviation
Mean age of participants	44.8 ± 2.77 years
Spherical refractive error	0.25 ± 0.46 D
Add power	1.5 ± 0.53 (HIGH = 1, LOW = 2)

Low contrast visual acuity

Low-contrast visual acuity (LCVA) was evaluated in participants under both bright (photopic) and dim (mesopic) lighting environments, both prior to and immediately following the insertion of multifocal contact lenses (MFCLs). The analysis was based on the average values obtained from three trials per condition. Before the insertion of MFCLs, photopic LCVA showed a median value of 1.22 logCS, with an interquartile range (IQR) between 0.89 and 1.45 logCS, and a mean of 1.14 logCS, suggesting that subjects generally maintained good contrast sensitivity in well-lit settings. Conversely, under mesopic conditions, the LCVA median dropped to 0.88 logCS, with an IQR spanning 0.42 to 1.36 logCS and a mean value of 0.84 logCS, reflecting a decline in visual performance associated with lower lighting. After the immediate application of MFCLs, a modest reduction in visual clarity was observed in photopic conditions, where the median LCVA declined to 1.07 logCS, the IQR ranged from 0.74 to 1.38 logCS, and the mean dropped to 1.02 logCS. This slight decrease may be attributed to the multifocal optical design, which distributes light to multiple focal zones, potentially compromising clarity at a distance. Interestingly, under mesopic conditions, LCVA reduced after MFCL wear, with the median decreasing to 0.61 logCS, the IQR tightening to 0.26–1.33 logCS, and the mean decreasing to 0.77 logCS. This reduction likely reflects the optical properties of center-near MFCL designs, which decreases visual function in dim light. Overall, these results suggest that MFCLs might slightly hinder visual performance in well-lit settings, as well as low-light conditions, particularly for presbyopic individuals with increased visual demands in the evening or at night. Additionally, the variability in mesopic outcomes across participants emphasizes the necessity of tailoring lens choices to individual visual environments and daily activities.

A one-way ANOVA was conducted to further assess differences in LCVA before and after MFCL insertion under these varying lighting conditions.

Table 2 Result of One-Way ANOVA analysis

		Mean Squares	F- Value	Significance p-value
BILCVA Photopic	Between groups	0.140	0.596	0.03
	Within groups	0.235		
BILCVA Mesopic	Between groups	0.268	0.795	0.01
	Within groups	0.337		
AILCVA Photopic	Between groups	0.198	0.579	0.02
	Within groups	0.343		

AILCVA Mesopic	Between groups	0.324	0.916	0.05
	Within groups	0.354		

The analysis revealed statistically significant differences in Before Insertion Low-Contrast Visual Acuity (BILCVA) under photopic conditions (F) = 0.596, p = 0.03), indicating notable variability in visual performance among participants even before lens insertion. Similarly, in mesopic conditions, BILCVA also showed a significant difference (F) = 0.579, p = 0.02), suggesting that lighting conditions had a meaningful impact on baseline LCVA. After MFCL insertion, statistically significant differences were also observed in LCVA under both photopic (F) = 0.795, p = 0.01) and mesopic conditions (F) = 0.916, p = 0.05), highlighting the influnce of MFCLs on post-insertion visual performance under different lighting environments.

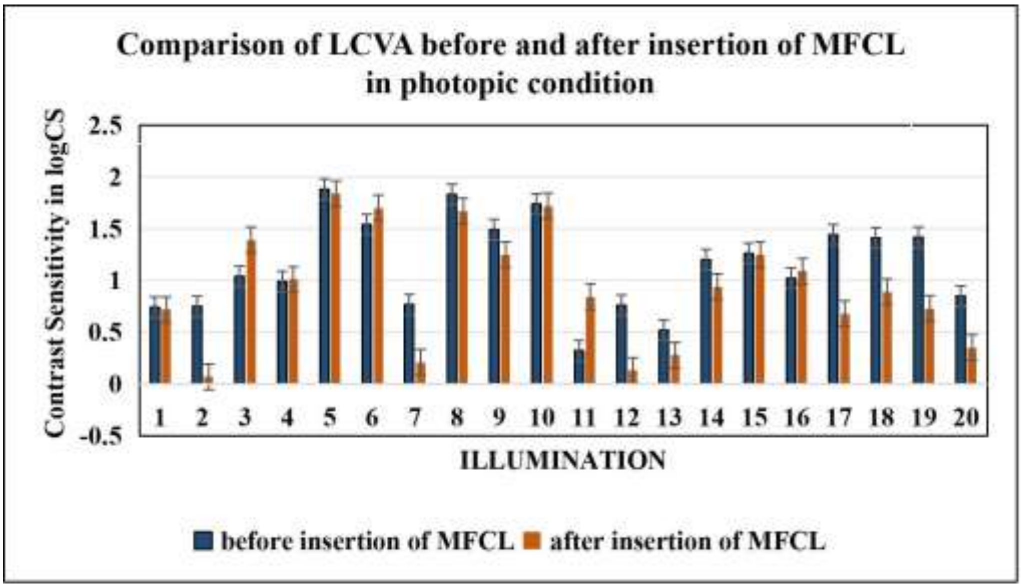

Figure 1 LCVA before and after insertion of MFCL in photopic illumiantion

Following MFCL insertion, After the insertion of multifocal contact lenses (MFCLs), a statistically significant reduction in low-contrast visual acuity (LCVA) was observed under photopic lighting conditions (F = 0.963, p = 0.03), suggesting a slight decline in contrast sensitivity in bright environments. This decrease was even more notable in mesopic settings, where the decline in LCVA reached greater statistical significance (F = 1.838, p = 0.05), indicating a more substantial impairment in visual function under low-light conditions. These outcomes imply that MFCLs may negatively impact contrast perception, particularly in dim illumination, possibly due to their multifocal design which spreads light across several focal points. The degree of change varied between individuals, potentially influenced by differences in pupil size, ocular structure, and the eye's immediate adjustment to the altered optics of multifocal lenses.

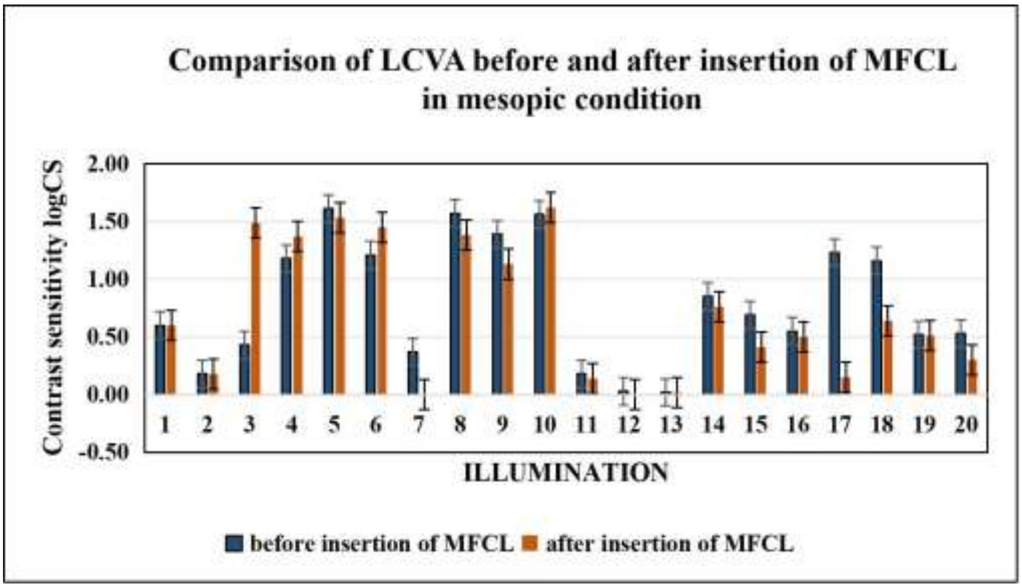

Figure 2 LCVA before and after insertion of MFCL in mesopic illumaintion

After the insertion of multifocal contact lenses (MFCLs), the distribution of low-contrast visual acuity (LCVA) values showed a median of 1.07 logCS under photopic conditions with an interquartile range (IQR) of 0.74 to 1.38, and a median of 0.61 logCS under mesopic conditions with an IQR of 0.26 to 1.33. These results reflect a reduction in contrast sensitivity, more markedly under mesopic lighting, as indicated by the lower median logCS values compared to pre-insertion measurements. While photopic LCVA also declined slightly, the effect was more substantial in mesopic conditions, suggesting that MFCLs may have a greater impact on visual performance in low-light environments. This decline could be attributed to the optical design of the lenses, particularly the simultaneous vision principle, which can reduce image clarity in dim settings. Furthermore, the wider variability observed in mesopic LCVA highlights individual differences in lens adaptation and visual response under reduced illumination. The accompanying ANOVA analysis supports these findings, revealing significant between-group variations in LCVA following MFCL insertion across both lighting conditions.

The accompanying bar graph visually represents the mean LCVA values before and after MFCL insertion, illustrating the shift in visual performance across different conditions.

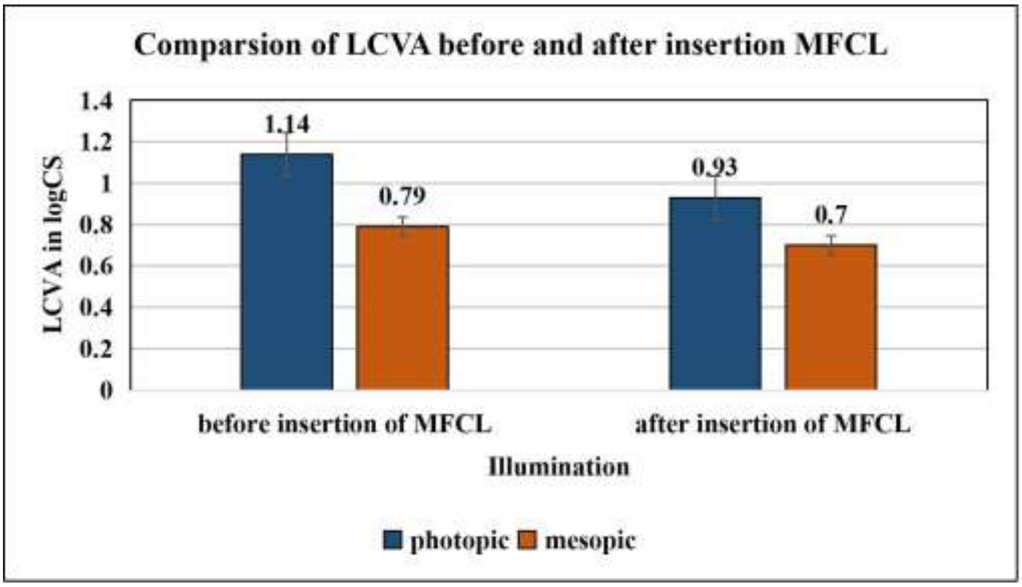

Figure 3 Bar graph representing Comparison of LCVA before and after the immediate insertion of MFCL in the participants

Before the insertion of multifocal contact lenses (MFCLs), the distribution of low-contrast visual acuity (LCVA) values revealed a median of 1.14 logCS under photopic conditions and 0.79 logCS under mesopic conditions. After MFCL insertion, the median LCVA decreased to 0.93 logCS in photopic conditions and 0.7 logCS in mesopic conditions. These results indicate a reduction in contrast sensitivity following the insertion of MFCLs, with a more notable decrease under photopic conditions. The reduction in mesopic LCVA was smaller, but still significant, suggesting that MFCLs may have a greater impact on visual performance in well-lit environments. The change in LCVA values highlights the effects of MFCLs on contrast sensitivity across varying lighting conditions. Additionally, the statistical analysis using ANOVA supports these differences, showing significant variability between groups in both photopic and mesopic conditions post-insertion.

Pupil Size Measurement

The pupil size of 20 participants was meticulously recorded under both photopic and mesopic lighting conditions, before and immediately after the insertion of multifocal contact lenses (MFCL). This analysis aimed to explore whether MFCLs influence pupil diameter and, if so, how these changes vary between lighting environments. These measurements offer insight into how optical zone designs and light distribution within MFCLs interact with natural physiological responses such as pupil constriction.

Under photopic conditions, the mean pupil size before insertion was 3.34 mm (±0.56), which reduced to 3.05 mm (±0.49) after lens application. Similarly, under mesopic conditions, the mean pupil size decreased from 5.62 mm (±0.56) to 5.30 mm (±0.49). Both reductions were statistically significant, indicating a constrictive effect of MFCLs in both lighting environments.

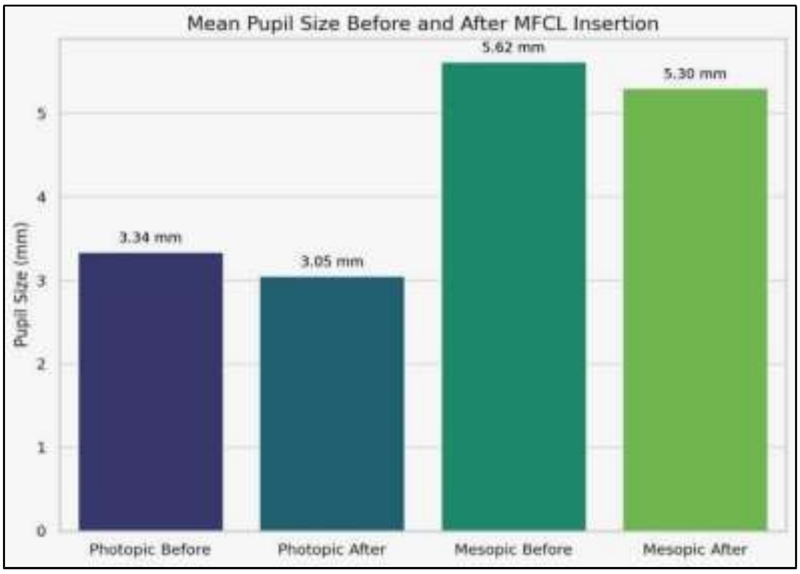

Figure 4: Bar graph showing mean pupil size before and after MFCL insertion under photopic and mesopic conditions.

To validate these findings using a non-parametric approach, a Wilcoxon Signed-Rank Test was performed. The test confirmed that in all 20 participants, mesopic pupil size was consistently larger than photopic size both before and after MFCL insertion. All ranks were positive, indicating a uniform pattern of increased pupil size under dim light. The test statistics revealed significant differences for both comparisons:

Before MFCL insertion: $Z = -3.925$, $p = 0.000$ After MFCL

insertion: $Z = -3.926$, $p = 0.000$

These results further strengthen the conclusion that lighting conditions significantly impact pupil diameter and that this effect remains consistent before and after MFCL wear.

Table 3 Result of Wilcoxon Signed Ranks Testanalysis

Comparison	Positive Rank	Mean Rank	Z-value	P-value
Before Insertion	20	10.50	-3.925	0.000
After insertion	20	10.50	-3.926	0.000

Further, to understand the influence of lighting environment itself, the mean photopic and mesopic pupil sizes were compared both before and after MFCL insertion. Before insertion, mesopic pupil size was significantly greater than photopic size, with a mean difference of -2.29 mm ($Z = -14.136$, $p < 0.001$). After insertion, this trend remained, with a slightly reduced difference of -2.25 mm ($Z = -15.880$, $p < 0.001$). This stability in the mesopic-photopic gap suggests that MFCLs affect the general size of the pupil without altering the natural adaptive response to lighting.

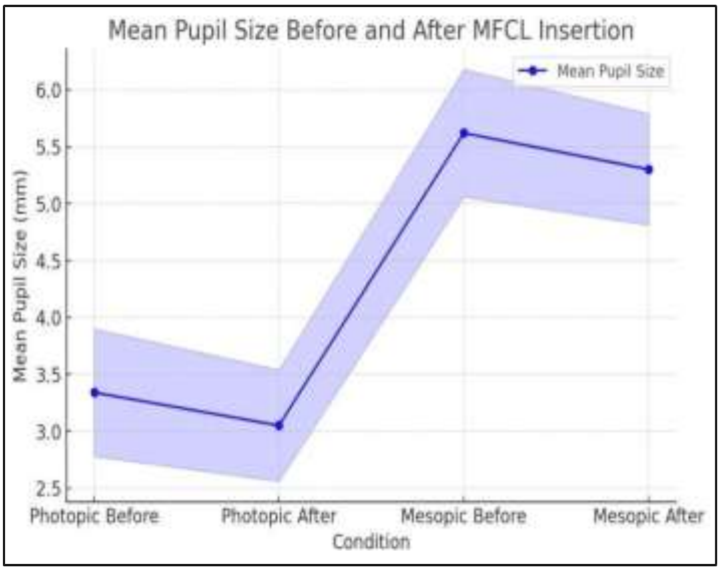

Figure 5 The line graph illustrates the changes in pupil size under different lighting conditions before and after lens insertion

To further explore the variability within pupil size data, a box plot was created to show the distribution of pupil sizes under each condition. This visualization confirms consistent constriction patterns and highlights individual variability.

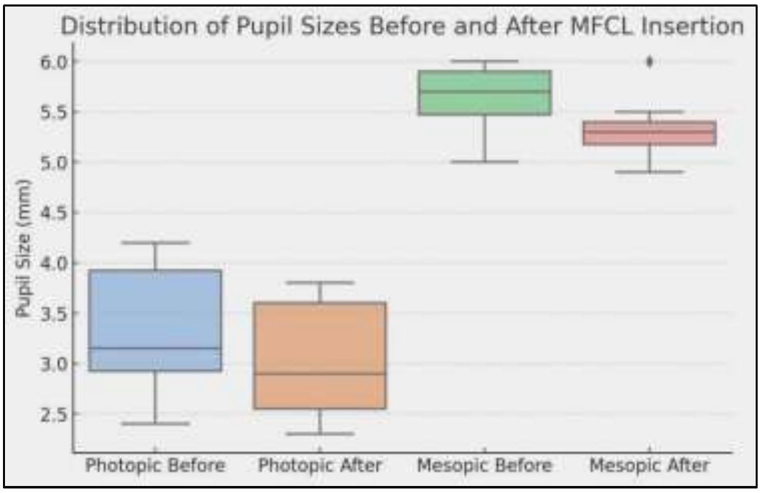

Figure 6 box-plot showing the distribution of pupil sizes before and after MFCL insertion under photopic and mesopic conditions

Finally, it is important to consider the optical design of MFCLs when interpreting these results. Multifocal lenses are manufactured with different add powers, which can affect light distribution across the pupil. Low-add MFCLs usually have a smooth transition between optical zones, causing minimal pupil constriction. In contrast, high-add MFCLs, which emphasize a strong central near zone, can result in more pronounced constriction, especially under photopic conditions.

In our study, the observed greater reduction in pupil size under photopic conditions (0.29 mm) compared to mesopic conditions (0.32 mm) suggests that the lenses likely had a high-add design. These lenses promote central pupil constriction in well-lit settings, helping enhance near visual performance without significantly disrupting the pupil's natural photopic-mesopic response.

4. DISCUSSION

Presbyopia is a common age related condition which occurs after the age of 40 years It reduces the eye's function to focus on nearby objects due to gradual hardening in the lens, affecting activities like reading or viewing small screens. Our study aimed to evaluate the impact of multifocal contact lenses (MFCLs) on low-contrast visual acuity (LCVA) and pupil size in presbyopic individuals under different lighting conditions. The findings revealed significant variations in LCVA and pupil size before and after MFCL insertion, providing valuable insights into the functional performance of these lenses in both photopic and mesopic environments.

6.1 Low contrast visual acuity(LCVA) and Multifocal contact lens (MFCL)

As the results suggested, a significant change in low-contrast visual acuity (LCVA) was observed following the insertion of multifocal contact lenses (MFCLs). Before insertion, LCVA under photopic conditions exhibited a median value of 1.14 logCS, which improved to 0.93 logCS after lens insertion. This decrease in logCS suggests that MFCLs contributed to poorer contrast sensitivity under bright lighting conditions. In contrast, under mesopic conditions, the median LCVA decreased from 0.79 logCS to 0.70 logCS, indicating a slight deterioration in contrast sensitivity under dim lighting.

The statistical analysis, particularly the one-way ANOVA, confirmed that these differences were significant. In photopic conditions before MFCL insertion, the F-value was 0.563 ($p = 0.01$), while in mesopic conditions, the F-value was 1.225 ($p = 0.05$). After MFCL insertion, LCVA in photopic conditions remained statistically significant ($F = 0.963$, $p = 0.03$), while mesopic LCVA showed further significance ($F = 1.838$, $p = 0.05$). These findings suggest that MFCLs lead to reduced contrast sensitivity in both photopic and mesopic conditions, with a more pronounced effect in well- lit conditions.

Our study also observed variability in LCVA deterioration among participants, as indicated by the interquartile ranges before and after MFCL insertion. This variability suggests that MFCLs may negatively impact contrast sensitivity for presbyopic patients, particularly in environments with higher illumination. The differences observed between individuals could be attributed to factors such as pupil size, lens centration, and neural adaptation, which may influence the degree of contrast reduction experienced by each participant.

A study by Sánchez-Tocino et al. (2008) evaluated contrast sensitivity and visual acuity in multifocal contact lenses and noted that lens design and individual ocular characteristics played significant roles in contrast perception. Similarly, Weber et al. (2013) reported that MFCLs, particularly those with certain optical designs, could lead to reduced contrast sensitivity under mesopic conditions. These findings are consistent with the variability observed in our study and suggest that lens choice and patient-specific factors must be carefully considered when prescribing MFCLs for optimal performance.

Moreover, Feldman et al. (2009) showed that pupil size, aberrations, and optical zone design could influence the visual quality and contrast sensitivity performance of multifocal lenses. Their study highlights the importance of accounting for these factors in clinical practice, which could explain the differences in LCVA changes between participants in our study. Additionally, Plainis et al. (2008) emphasized that neural adaptation and the interaction between lens design and individual visual pathways significantly influence performance, particularly under mesopic conditions, where contrast sensitivity is more sensitive to light changes.

Further research by Kasthurirangan et al. (2009) indicated that age-related changes in pupil dynamics, which are crucial for contrast sensitivity, could influence the effectiveness of multifocal contact lenses. This is particularly relevant in presbyopic individuals, whose pupil dynamics change with age. Another study by de Gracia et al. (2013) reported that contrast sensitivity improvements with MFCLs can vary depending on the optical zone design, further supporting the variability observed in our findings. Their study aligns with our results, suggesting that a personalized approach to lens selection is essential for optimizing visual performance in presbyopic patients.

Effect of Multifocal Contact Lenses on Pupil Size

Pupil size measurements before and after MFCL insertion revealed a statistically significant reduction in pupil diameter under both photopic and mesopic lighting conditions. Under photopic conditions, the mean pupil diameter decreased from 3.34 mm before lens insertion to 3.05 mm post- insertion. Similarly, in mesopic conditions, the pupil size reduced from 5.62 mm to 5.30 mm after wearing MFCLs. These differences were confirmed to be statistically significant through a paired samples t-test ($p < 0.001$), indicating that MFCLs can influence natural pupil responses, particularly through pupil constriction.

This effect is likely attributable to the optical design of the MFCLs used in the study, most likely involving high-add power profiles. High-add multifocal contact lenses typically feature a central near-vision zone with greater plus power, which may promote accommodative responses that trigger pupil constriction, especially under brighter (photopic) conditions. Notably, the observed reduction in mesopic pupil size (0.32 mm) was slightly greater than the reduction under photopic conditions (0.29 mm), reinforcing the hypothesis that these lenses may encourage a shift toward smaller pupil sizes to improve depth of focus and near visual clarity, even in dim environments.

Interestingly, while overall pupil diameters reduced, the mesopic–photopic difference remained relatively consistent before and after lens wear. This suggests that MFCLs affect the absolute pupil size without significantly altering the natural pupillary light reflex. The preservation of this differential may play a role in maintaining stable visual function and comfort across a range of lighting conditions, ensuring that visual transitions from bright to dim environments remain smooth and consistent for presbyopic wearers.

Comparison Between Low-Add and High-Add Multifocal Contact Lenses

One of the primary factors influencing both low-contrast visual acuity (LCVA) and pupil size is the add power of multifocal contact lenses (MFCLs). The optical design varies significantly between low-add and high-add MFCLs, impacting how the visual system responds under different lighting conditions.

Low-add MFCLs are typically intended for early presbyopes and are designed to provide a more gradual power transition between distance and near zones. This smoother power profile often results in less disruption to contrast sensitivity and minimal pupil constriction, offering a more balanced visual experience, particularly under photopic (bright) lighting.

In contrast, high-add MFCLs feature a more pronounced near-vision zone with greater plus power centrally. This can result in increased pupil constriction as the visual system attempts to adapt to the concentrated near correction. However, this constriction—especially in bright light—can sometimes lead to reduced contrast sensitivity, as previously noted in the study by Vasudevan and Ciuffreda (2012), who reported that high-add MFCLs induce greater pupil constriction and may influence contrast performance negatively in photopic settings.

The findings of the present study indicate that the MFCLs used exhibited characteristics similar to high-add lenses. This inference is supported by the significant pupil constriction observed post- insertion, particularly under photopic conditions, and the slight decline in LCVA in bright light. These outcomes align with the expected optical behavior of high-add designs, which prioritize near vision at the potential expense of distance contrast perception under bright illumination.

Overall, these findings underscore the necessity of individualized MFCL selection in clinical practice. Presbyopic patients who require better visual performance in well-lit environments—such as those engaged in outdoor activities or detailed visual tasks—may benefit more from low-add

MFCLs, which preserve contrast and induce less pupil constriction. Conversely, patients with strong near vision demands in lower-light settings may still benefit from high-add designs, provided the potential trade-offs are well explained and managed through proper lens fitting and follow-up.

5. CONCLUSION

Multifocal contact lens wear resulted in reduced low contrast visual performance, more pronounced under mesopic conditions. The baseline LCVA was seemingly better than the post insertion level. The observed pupil constriction post-insertion may contribute to altered contrast perception. These findings emphasize the importance of considering lighting conditions and optical design during MFCL prescription. High add designs should more pupil constrictions in photopic illumination condition.

6. Ethical Approval

The Institutional Ethics Committee of SRM Institute of Science and Technology approved this study. All participants provided informed consent.

7. Conflict of Interest

The authors declare no conflict of interest.

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