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Clinical assessment of brain adaptation following multifocal intraocular lens implantation

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Abstract

Purpose The purpose of this study was to clinically and quantitatively evaluate the speed of brain adaptation following multifocal intraocular lens (IOL) implantation. The speed of brain adaptation is considered to vary among individuals and influence postoperative visual recovery.

Methods At our institution, a total of 24 cases underwent cataract surgery with the implantation of FineVision PodF (BVI/PhysIOL), PanOptix (Alcon), Intensity (Hanita Lenses), Tecnis Synergy (J&J), and Vivity (Alcon). The Mini-Mental State Examination (MMSE) test was performed postoperatively, at least one week after surgery. Patients whose corrected distance visual acuity (LogMAR) was better than 0 and who had no visual disturbance at 1 week postoperatively were classified as Group A ($n=14$). Patients whose corrected distance visual acuity had not reached 0.1 and who still experienced visual disturbance at 1 month postoperatively were classified as Group B ($n=10$). MMSE scores and test completion time for each group were retrospectively investigated as a pilot study.

Results The mean age in Group A was 62 ± 10 years, and in Group B, 76 ± 5.6 years ($p<0.05$). The MMSE test scores were 28.9 ± 1.7 points in Group A and 29.2 ± 0.69 points in Group B, showing no significant difference ($p=0.68$). However, the MMSE test completion time was 256 ± 50 s in Group A and 346 ± 67 s in Group B, with a significant difference ($p<0.05$). The percentage of patients completing the test within 5 min was 93% (13 out of 14) in Group A and 20% (2 out of 10) in Group B.

Conclusion This study suggests that the speed of brain adaptation following multifocal IOL implantation may be reflected in MMSE test completion time. Future research is needed to further quantify brain adaptation speed using different IOL types, conditions, and refined test methods.

Keywords Multifocal intraocular lenses, Brain adaptation, Visual recovery speed, Mini-mental state examination, Test completion time, Postoperative outcomes

Introduction

In cataract surgery, multifocal intraocular lenses (IOLs) have been widely adopted as a treatment for presbyopia, replacing conventional monofocal IOLs. This enables patients to achieve both distance and near vision, significantly improving their postoperative quality of life [1].

However, for patients to adapt to multifocal IOLs, the brain must undergo "brain adaptation" to process new visual information [2, 3]. The speed of brain adaptation varies among individuals, and quantifying this speed is clinically significant.

The Mini-Mental State Examination (MMSE) is a screening test widely used to evaluate cognitive function and detect early dementia [4]. It comprehensively

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assesses orientation to time and place, memory, attention, calculation, language ability, and visuospatial cognition. The MMSE involves tasks such as recalling the current date and location, memorizing and reproducing three words, performing simple calculations, and copying geometric shapes. The test can typically be completed within 10 min, and a score below 23 indicates possible dementia.

This study aimed to retrospectively evaluate the speed of brain adaptation following multifocal IOL implantation using the MMSE test as a clinical tool.

Materials and methods

The ethics committee of Nishi Eye Hospital approved this retrospective study, which followed the tenets of the Declaration of Helsinki.

Subjects

This study included 24 eyes of patients who underwent cataract surgery with multifocal intraocular lens (IOL) implantation. The types of multifocal IOLs and the number of cases are summarized in Table 1. The IOL types included FineVision PodF (BVI/PhysIOL), PanOptix (Alcon), Intensity (Hanita Lenses), Tecnis Synergy (J&J), and Vivity (Alcon).

Grouping

Patients were divided into two groups based on postoperative corrected distance visual acuity (CDVA) and the presence of visual disturbances. Near visual acuity was measured at a distance of 30 cm, ensuring consistency across all participants. Group A comprised 14 eyes of patients with CDVA better than LogMAR 0 and no visual disturbances at one week postoperatively, with a mean age of 62 ± 10 years. Group B included 10 eyes of patients whose CDVA did not reach LogMAR 0.1 and who experienced persistent visual disturbances at one month postoperatively, with a mean age of 76 ± 5.6 years.

Surgical technique

Phacoemulsification cataract surgery was performed by three skillful surgeons, using the Centurion® Vision System (Alcon) under topical anesthesia, supplemented by sub-Tenon's anesthesia using xylocaine (lidocaine). After disinfecting the conjunctival sac and surrounding skin, a 2.8 mm corneal incision was created on-axis at the corneal limbus, accompanied by two side-port incisions. A viscoelastic material was injected, and a continuous curvilinear capsulorhexis (CCC) with a 5.0 mm diameter was created. The nucleus was emulsified and aspirated using the phacoemulsification technique, with the "crack method" employed for nucleus division when necessary. The residual cortex was fully removed using an irrigation/aspiration (I/A) technique. The multifocal IOL was inserted into the capsular bag using a specialized injector system and appropriately positioned. Corneal wounds were closed via hydration. For cases involving FineVision and Intensity IOLs, femtosecond laser assisted cataract surgery (FLACS) was performed using the Catalys® Precision Laser System (J&J), involving a 4.8 mm capsulorhexis and cruciate lens fragmentation prior to proceeding with the standard phacoemulsification and IOL insertion techniques.

Table 1 Types of multifocal intraocular lenses (IOLs) and the number of cases included in the study

IOL types	FineVision	PanOptix	Intensity	Tecnis Synergy	Vivity
Group A	3	9	1	1	0
Group B	1	6	1	1	1

Postoperative management

Postoperatively, all patients were prescribed a regimen of levofloxacin 0.5% eye drops administered three times per day, fluorometholone 0.1% eye drops three times per day, and diclofenac sodium eye drops one to three times per day, depending on the severity of inflammation.

Evaluation criteria

The evaluation included multiple parameters. The MMSE test scores were recorded out of 30 points, and the completion time in seconds was also measured. The MMSE test was conducted postoperatively, at least one week after surgery, to assess cognitive function in a standardized manner. To minimize the influence of visual acuity on MMSE performance, all questions were read aloud by an examiner, and participants responded verbally. The only item requiring visual input was a simple figure-copying task, which had minimal impact on the total test duration. Visual function was assessed by preoperative and postoperative visual acuity, refraction, astigmatism, higher-order aberrations (HOAs), and pupil size. Pupil diameter measurements were performed under mesopic and photopic conditions.

Inclusion criteria

Patients included in this study met the following criteria. Tear break-up time (BUT) was ≥ 10 s with no corneal fluorescein staining. No posterior capsule opacification was present at one month postoperatively. Significant ocular pathologies such as glaucoma or macular disorders were absent. Additionally, patients exhibited a clear cornea and no significant anterior chamber inflammation at one week postoperatively. There were no significant vitreous

opacities, and hearing impairments that could affect MMSE test performance were absent.

Statistical analysis

T-tests were used to compare means between groups, with p-values < 0.05 considered statistically significant.

Results

The comparison of preoperative and postoperative measurement values between the two groups is presented in Table 2.

MMSE test scores averaged 28.9 ± 1.7 points in Group A and 29.2 ± 0.69 points in Group B, with no significant difference between the groups ($p = 0.68$) (Fig. 1). However, the MMSE test completion time was significantly shorter in Group A (256 ± 50 s) compared to Group B (346 ± 67 s) ($p < 0.05$) (Fig. 2). The percentage of patients completing the MMSE test within five minutes was 93% (13 out of 14 patients) in Group A and 20% (2 out of 10 patients) in Group B.

Preoperative visual function assessments revealed that uncorrected distance visual acuity (UDVA) was 0.86 ± 0.60 in Group A and 0.60 ± 0.40 in Group B ($p = 0.33$). Corrected distance visual acuity (CDVA) was 0.23 ± 0.18 in Group A and 0.20 ± 0.15 in Group B ($p = 0.80$). Higher order aberrations (HOAs) were 0.24 ± 0.08 μm in Group A and 0.23 ± 0.05 μm in Group B ($p = 0.57$). Pupil diameter measurements under mesopic conditions were 4.4 ± 0.74 mm in Group A and 4.5 ± 0.67 mm in Group B ($p = 0.73$). Under photopic conditions, pupil diameter was 3.3 ± 0.36 mm in Group A and 3.0 ± 0.10 mm in Group B, with significantly smaller pupil diameters in Group B ($p < 0.05$).

At one week postoperatively, UDVA was 0.05 ± 0.13 in Group A and 0.29 ± 0.20 in Group B ($p < 0.05$). CDVA was −0.04 ± 0.07 in Group A and 0.23 ± 0.12 in Group B ($p < 0.05$). Astigmatism was −0.61 ± 0.59D in Group A and −0.90 ± 0.45D in Group B ($p = 0.19$). The spherical equivalent (SE) was −0.61 ± 0.91D in Group A and −1.1 ± 0.7D in Group B ($p = 0.13$).

At one month postoperatively, UDVA was 0.04 ± 0.12 in Group A and 0.39 ± 0.20 in Group B ($p < 0.05$). CDVA was −0.06 ± 0.08 in Group A and 0.19 ± 0.11 in Group B ($p < 0.05$). Uncorrected near visual acuity (UNVA) was 0.10 ± 0.09 in Group A and 0.45 ± 0.25 in Group B ($p < 0.05$). Corrected near visual acuity (CNVA) was 0.06 ± 0.07 in Group A and 0.31 ± 0.16 in Group B ($p < 0.05$). Astigmatism was −0.66 ± 0.49D in Group A and −0.90 ± 0.44D in Group B ($p = 0.32$). The spherical equivalent (SE) was −0.75 ± 0.93D in Group A and −1.2 ± 0.86D in Group B ($p = 0.19$).

Table 2 Comparison Between Group A and Group B

Parameter	Group A	Group B	*p*-value
Age	62 ± 10 years	76 ± 5.6 years	< 0.05
MMSE score	28.9 ± 1.7	29.2 ± 0.69	0.68
MMSE completion time	256 ± 50 s	346 ± 67 s	< 0.05
Distribution of test completion within 5 min	93% (13/14)	20% (2/10)	-
Preoperative UDVA	0.86 ± 0.60	0.60 ± 0.40	0.33
Preoperative CDVA	0.23 ± 0.18	0.20 ± 0.15	0.80
Preoperative SE	−1.0 ± 1.4D	−1.7 ± 1.1D	0.17
Postoperative UDVA (1 week)	0.05 ± 0.13	0.29 ± 0.20	< 0.05
Postoperative CDVA (1 week)	−0.04 ± 0.07	0.23 ± 0.12	< 0.05
Postoperative UDVA (1 month)	0.04 ± 0.12	0.39 ± 0.20	< 0.05
Postoperative CDVA (1 month)	−0.06 ± 0.08	0.19 ± 0.11	< 0.05
Postoperative UNVA (1 month)	0.10 ± 0.09	0.45 ± 0.25	< 0.05
Postoperative CNVA (1 month)	0.06 ± 0.07	0.31 ± 0.16	< 0.05
Postoperative astigmatism (1 week)	−0.61 ± 0.59D	−0.90 ± 0.45D	0.19
Postoperative astigmatism (1 month)	−0.66 ± 0.49D	−0.90 ± 0.44D	0.32
Postoperative SE (1 week)	−0.61 ± 0.91D	−1.1 ± 0.7D	0.13
Postoperative SE (1 month)	−0.75 ± 0.93D	−1.2 ± 0.86D	0.19
Preoperative HOAs	0.24 ± 0.08 μm	0.23 ± 0.05 μm	0.57
Preoperative pupil diameter (mesopic)	4.4 ± 0.74 mm	4.5 ± 0.67 mm	0.73
Preoperative pupil diameter (photopic)	3.3 ± 0.36 mm	3.0 ± 0.10 mm	< 0.05

Abbreviations: *UDVA* Uncorrected Distance Visual Acuity, *CDVA* Corrected Distance Visual Acuity, *UNVA* Uncorrected Near Visual Acuity, *CNVA* Corrected Near Visual Acuity, *SE* Spherical Equivalent, *HOAs* Higher-Order Aberrations

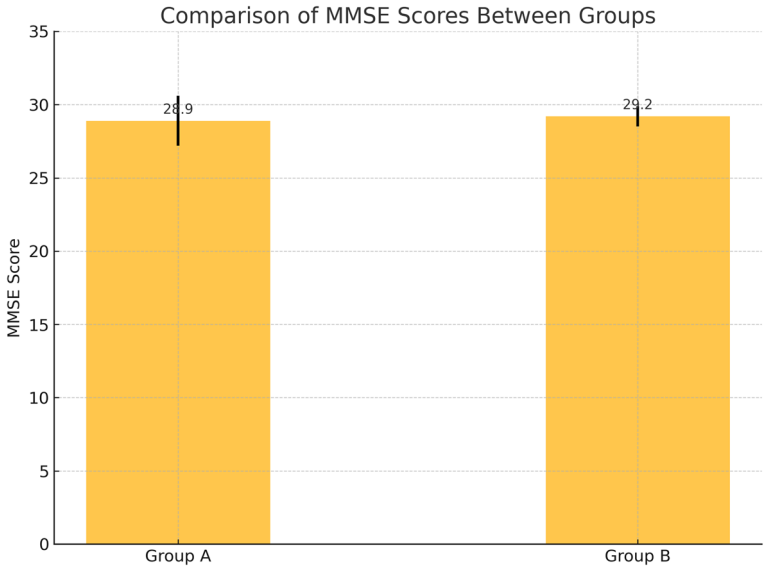

Fig. 1 Comparison of MMSE scores between groups showing no significant differences

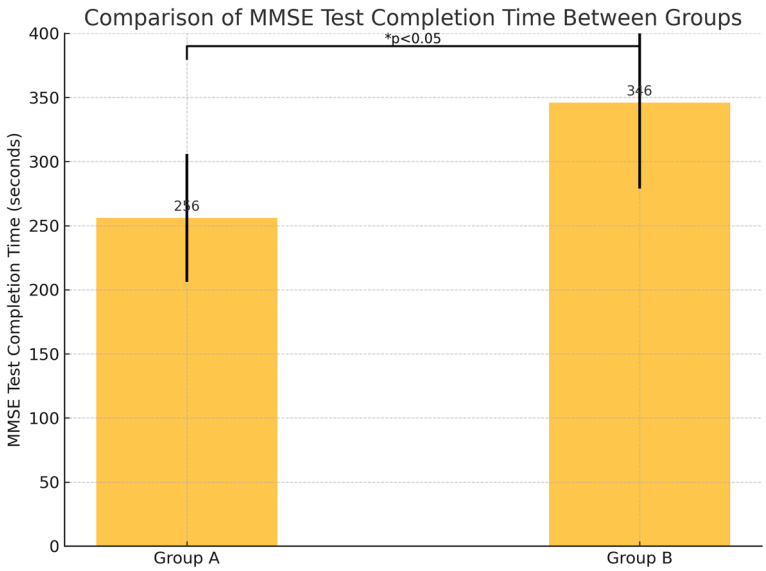

Fig. 2 Comparison of MMSE test completion time between groups showing significant differences

Discussion

First of all, this study aimed to explore whether MMSE completion time could serve as a practical indicator of cognitive processing ability in patients undergoing multifocal IOL implantation. While the relationship between neuroadaptation and cognitive processing ability has been intuitively recognized in clinical practice, no previous study has attempted to evaluate this processing ability using a highly simplified clinical paper-based test. Given that MMSE is widely used and easily applicable in clinical settings, we examined whether its completion time could provide insights into neuroadaptation speed. However, we acknowledge that MMSE completion time does not directly measure neuroadaptation, and its sensitivity may vary based on test environments.

In this study, patients were divided into two groups based on postoperative CDVA and the presence of visual disturbances, regardless of the ages of the patients. No significant differences were found between the two groups in terms of HOAs and no cases had any other clinically significant ocular diseases except cataract that could affect visual acuity. Both uncorrected and

corrected visual acuity, for both distance and near vision, were significantly better in Group A, as a result. This may indicate that Group A, which exhibited more rapid brain adaptation, was also younger and had shorter MMSE test completion times. Conversely, Group B, which exhibited a tendency for slower brain adaptation, was also older and had longer MMSE test completion times.

In other words, this study indicates that the speed of brain adaptation following multifocal intraocular lens (IOL) implantation may be reflected in MMSE test completion time.

Although not statistically significant, postoperative astigmatism exceeding −0.75D in Group B may have influenced the visual outcomes in this group [5–7]. Additionally, while the difference in postoperative refractive values (spherical equivalent) was not significant, Group B showed a more myopic tendency. To minimize the influence of these factors, the groups were specifically defined based on CDVA. The significantly younger age of Group A, which was associated with better visual outcomes, is consistent with previously reported findings [8].

Given that MMSE test scores did not differ significantly between the two groups, it is suggested that this test, originally designed for dementia diagnosis, may not be the best tool for directly assessing the quality of brain adaptation. However, MMSE test completion time likely reflects a certain aspect of processing ability and speed, which could serve as a useful measure for evaluating the speed of brain adaptation which we experience in daily clinical work. Whether patients in Group B would achieve good visual function over a longer postoperative period remains an important question for future investigation.

Although methods such as MRI for evaluating the visual cortex have been explored [2], simple and ethically acceptable tests applicable in routine clinical practice are still needed. This study did not account for the potential influence of IOL types, but the impact of IOL design and the number of focal points on brain adaptation should be further investigated in future studies. It is anticipated that those allowing for easy brain adaptation from the early postoperative period and achieving rapid visual improvement will continue to be highly valued in clinical practice.

Several limitations exist in this study. First, although patients with severe vitreous opacity were excluded, the degree of vitreous opacity was not quantified, making it difficult to rigorously evaluate its influence [9]. Second, the sample size was limited, and the matching of age and pupil size between the two groups was incomplete, which may have affected the results. Furthermore, contrast sensitivity and flare values were not measured, and a more detailed assessment of visual quality is needed [10]. Additionally, although appropriate verbal support was provided during the MMSE test, it cannot be completely ruled out that differences in visual acuity influenced the test completion time. Last but not least, a key limitation of this study is the absence of a monofocal IOL control group, which would allow for a clearer distinction between age-related effects and those specifically related to multifocal IOL neuroadaptation. Future studies should incorporate a monofocal IOL control group to further elucidate the distinct neuroadaptation processes associated with multifocal IOLs.

Future research should address these limitations by including larger sample sizes, quantifying the degree of vitreous opacity, and incorporating more precise evaluations of visual quality, such as contrast sensitivity and glare measurements [10–14]. Although MMSE is a widely available and practical cognitive assessment tool, it may not be the most suitable test for evaluating neuroadaptation. More refined neurocognitive assessments, such as IQ tests, might provide greater precision in measuring cognitive adaptability. However, ethical and practical constraints led us to conclude that incorporating them in this study was not feasible. Future research should explore alternative assessment tools that balance accuracy with clinical applicability. Thus, further investigations employing more precise and clinically relevant assessment methods are necessary to gain deeper insights into the mechanisms of brain adaptation following multifocal IOL implantation [15, 16].

Conclusion

This study suggests that the speed of brain adaptation following multifocal IOL implantation may be reflected in MMSE test completion time. Future research is needed to further quantify brain adaptation speed using different IOL types, conditions, and refined test methods.

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Clinical trial registration

This study is not a registered clinical trial as it is a retrospective pilot study.

Authors' contributions

YN conceived and designed the study, incorporating advice from HN, KN, and ON. YN and ON supervised the study. YN drafted the manuscript based on the collected data. HN, YN, and ON performed the surgeries necessary for data acquisition. MF and MT collected the essential data for the study. YN, HN, ON, and KN analyzed and interpreted the data. ON critically revised the manuscript for important intellectual content. All authors reviewed and approved the final manuscript for submission.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval consent to participate

This retrospective pilot study was approved by the Ethics Committee of Nishi Eye Hospital and was conducted in accordance with the tenets of the Declaration of Helsinki.
Informed consent was obtained from all participants prior to their inclusion in this study.

Consent for publication

Not applicable, as this manuscript does not include any identifiable personal data of participants.

Competing interests

The authors declare no competing interests.

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