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VISUAL OUTCOMES FOLLOWING PHACOEMULSIFICATION WITH LUCIDIS EXTENDED DEPTH OF FOCUS INTRAOCULAR LENS IMPLANTATION

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ABSTRACT

Purpose: To evaluate the visual performance and contrast vision outcomes after implantation of Lucidis extended depth-of-focus (EDOF) intraocular lens (IOL) following cataract surgery.

Materials and methods:

This prospective, single-center study included 66 eyes from 52 patients undergoing cataract surgery with implantation of the Lucidis IOL (SAV-IOL SA, Switzerland). Uncorrected and corrected visual acuity at distance (5 m), intermediate (67 cm), and near (40 cm) were assessed at 1 week, 1 month, 3 months, and 6 months postoperatively. Contrast sensitivity, photic phenomena (halos and glare), and patient-reported outcomes were evaluated at 3 and 6 months.

Statistical analysis was performed using SPSS version 20, with significance set at $p < 0.05$.

Results: At 6 months after surgery, uncorrected distance vision was 0,07 ± 0,09 logMAR, intermediate vision was 0,18 ± 0,08 logMAR and near vision was 0,14 ± 0,1 logMAR. Post-corrected distance vision was 0,03 ± 0,06 logMAR, intermediate vision was 0,06 ± 0,09 logMAR and near vision was 0,05 ± 0,08 logMAR. A total of 95.5% of eyes showed a reduction of ≤3 lines in contrast sensitivity at 10%. Most patients achieved spectacle independence for distance and intermediate vision, while 15% required spectacles for near tasks. No halos were reported at 6 months, and glare was minimal and transient.

Conclusion: The Lucidis EDOF IOL provides excellent visual outcomes across all distances, maintains contrast sensitivity, and minimizes photic phenomena, resulting in high patient satisfaction following cataract surgery.

Keywords: Intraocular lens; IOL; Extended depth of focus; EDOF; Cataract surgery.

1. INTRODUCTION

In the last decades, as the economy has developed and the quality of life has improved, there is an increasing demand among the elderly for clear vision at all distances with spectacle independence. Multifocal IOLs (MF IOLs) have been widely used to provide functional vision at multiple distances; however, they are often associated with reduced contrast sensitivity and photic phenomena such as halos and glare [1]. The need to address these concerns led to the development of new technologies capable of creating a single elongated focal point with an extended depth-of-focus (EDOF). This technology provides a significantly broader range of vision compared to monofocal IOLs while minimizing visual disturbances. Nevertheless, conventional EDOF IOLs typically provide limited near vision due to restricted focal extension [2].

The Lucidis IOL (Swiss Advanced Vision, Switzerland) is a hybrid refractive/aspheric EDOF lens designed to address the near-vision limitations of standard EDOF lenses. By providing a continuous range of focus from far to near, it aims to offer patients a smooth visual experience at all distances [3]. To date, however, the clinical use of Lucidis is not yet widespread, and there is a lack of comprehensive studies analyzing its clinical outcomes. Therefore, we conducted this study with the objective: "To evaluate visual outcomes at various distances, contrast sensitivity, and nocturnal photic phenomena in patients implanted with the Lucidis EDOF IOL following phacoemulsification."

2. SUBJECTS AND METHODS

2.1. Study Design

This is a prospective, single-center study conducted from January 2023 to December 2023 at the Japan International Eye Hospital (Hanoi), utilizing the Lucidis EDOF IOL The Lucidis is a single-piece foldable multi-zone refractive/aspheric IOL designed for capsular bag implantation. All patients were provided with comprehensive information regarding the study and were thoroughly explained the potential benefits and risks associated with the Lucidis IOL implantation. The study adhered to the tenets of the Declaration of Helsinki, and informed consent was obtained from all participants.

- Inclusion Criteria

Patients aged over 40 years with unilateral or bilateral cataracts requiring surgery, indicated for surgery and a desire for postoperative spectacle independence were included. Eligible participants were required to have regular preoperative corneal astigmatism of less than 1.00 Dioptrie and an angle Kappa of less than 0.5 mm.

- Exclusion Criteria

Exclusion criteria included any coexisting ocular pathologies or a history of previous ocular surgery.

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Cases with dense cataracts that precluded accurate axial length measurements or macular scans using the IOL Master 700 were also excluded. Furthermore, patients who experienced intraoperative or postoperative complications, or those who failed to complete the 6-month follow-up period, were removed from the final analysis.

2.2. Study Procedure

All surgeries were performed by a single experienced surgeon. Phacoemulsification was conducted through a 2.2 mm incision on the steep corneal axis. The Lucidis IOL was implanted in the capsular bag. Postoperative medication followed the standardized protocols of the Ministry of Health. Clinical outcomes were evaluated at 1 day, 1 week, 1 month, 3 months, and 6 months postoperatively.

Assessments included visual acuity (UCVA, BCVA), refraction, contrast sensitivity, photic phenomena and patient satisfaction

2.3. Statistical Analysis

Data were managed using Microsoft Excel and analyzed using SPSS software (version 20.0). Quantitative and qualitative variables are described using the mean and standard deviation (SD). An independent T-test was used to compare mean values between two groups, and the Wilcoxon signed-rank test was employed for the comparison of continuous data. A p-value of less than 0.05 was considered statistically significant.

3. RESULTS

From January 2023 to December 2023, we enrolled 66 eyes of 52 eligible patients in the study. The cohort included 19 males (36.5%) and 33 females (63.5%). The mean age was 70.33 ± 8.6 years (range: 44–88 years).

3.1. Preoperative Ocular Characteristics

Preoperative characteristics are summarized in Table 1. The mean preoperative best-corrected visual acuity (BCVA) was 0.66 ± 0.53 logMAR, indicating relatively poor baseline vision. Notably, the mean angle kappa was 0.30 ± 0.12 mm, which falls within the acceptable range for premium IOL implantation.

Table 1. Preoperative Clinical and Biometric Characteristics

Parameter	Mean	Min	Max
Visual Acuity (logMAR)	0.66 ± 0.53	0.2	1.6
Intraocular Pressure (mmHg)	15.5 ± 2.4	13	20
Astigmatism (D)	0.58 ± 0.37	0	1.0
Angle Kappa	0.3 ± 0.12	0	0.5
Axial Length (mm)	22.89 ± 1.1	22.2	26.8
Nuclear Hardness (LOCS III)	2.8 ± 1.05	1	4

3.2. Postoperative Refractive Outcomes

The rate of achieving the target refraction postoperatively was highly favorable (Table 2). The majority of eyes achieved emmetropia or mild myopia, which is consistent with the goal of EDOF lenses to optimize near-vision performance.

Table 2. Distribution of Postoperative Residual Refractive Error

Refractive Status	Power (D)	Number of Eyes	Percentage (%)
Emmetropia	-0.5 to +0.5	54	81.8
Myopia	-0.75 to -1.0	8	12.1
Hyperopia	+0.75 to +1.0	4	6.1

3.3. Uncorrected Visual Acuity (UCVA) Outcomes

Postoperatively, uncorrected visual acuity (UCVA) showed statistically significant improvement at all distances compared to baseline ($p < 0.0001$) (Table 3). At 6 months, uncorrected distance visual acuity (UDVA) achieved excellent results, with 80.3% of eyes reaching 0.8 decimal acuity or better. Notably, the mean uncorrected near visual acuity (UNVA) was 0.14 ± 0.1 logMAR. These findings demonstrate excellent functional vision across all distances, particularly strong performance in near vision compared with conventional EDOF lenses.

Table 3. Uncorrected visual acuity results at various distances

Distances			
Mean (logMAR)	**p**	**Visual acuity ≥ 0.8 [n(%)]**	**Visual acuity < 0.8 [n(%)]**
Preoperative CDVA			
0.68 ± 0.24		0 (0%)	66 (100%)
UDVA			
0.07 ± 0.09	< 0.0001	53 (80.3%)	13 (19.7%)
UIVA			
0.18 ± 0.08		20 (30.3%)	46 (69.7%)
UNVA			
0.14 ± 0.1		31 (47%)	35 (53%)

CDVA corrected distance visual acuity; UDVA Uncorrected distance visual acuity; UIVA Uncorrected intermediate visual acuity; UNVA Uncorrected near visual acuity

3.4. Postoperative Corrected Distance Visual Acuity (CDVA) Outcomes

With optimal distance correction, the majority of eyes achieved excellent visual acuity (Table 4). Notably, 100% of the eyes reached a distance visual acuity of 0.8 or better. These results confirm the optical quality of the Lucidis lens, which enables patients to attain their maximum visual potential when required.

Table 4. Postoperative corrected distance visual acuity results

Distances			
Mean (logMAR)	**p**	**Visual acuity ≥ 0.8 [n(%)]**	**Visual acuity < 0.8 [n(%)]**
Preoperative corrected distance visual acuity			
0.68 ± 0.24		0 (0%)	66 (100%)
UDVA			
0.03 ± 0.06	< 0.0001	66 (100%)	0 (0%)
Uncorrected intermediate visual acuity			
0.06 ± 0.09		61 (92.4%)	5 (7.6%)
Uncorrected near visual acuity			
0.05 ± 0.08		63 (95.4%)	3 (4.6%)

3.5. Postoperative Contrast Sensitivity Outcomes

Contrast sensitivity is an essential metric for evaluating the image quality of intraocular lenses (IOLs). The results presented in Table 5 indicate that the majority of patients maintained stable low-contrast (10%) visual acuity. A decline exceeding three lines was observed in only a small percentage of cases (4.5%). These findings confirm the superior ability of hybrid EDOF technology to preserve contrast sensitivity, enabling patients to maintain functional vision even under complex lighting conditions.

Table 5. Postoperative low-contrast (10%) visual acuity results

Low-contrast (10%) visual acuity parameters	Number of Eyes	Percentage (%)
Decline ≤ 3 lines	63	95.5
Decline > 3 lines	3	4.5
Total	66	100.0

3.6. Postoperative Visual Disturbances

Photic phenomena, such as halos and glare, are common adverse effects associated with the implantation of MF IOLs. Our assessment of postoperative visual disturbances yielded highly favorable outcomes. No cases of halos were reported at any of the follow-up intervals. Regarding glare, only one case (1.5%) was recorded at the 1-month visit; however, this symptom resolved spontaneously by the 3-month mark. Notably, 100% of patients reported no difficulty with night driving, suggesting excellent neuroadaptation to this IOL.

4. DISCUSSION

Extended depth-of-focus technology was introduced with the expectation of achieving spectacle independence following cataract surgery, providing patients with the ability to attain clear vision across various distances without the need for correction. EDOF lenses were designed to overcome the inherent limitations of MF-IOLs, specifically photic phenomena such as halos and glare, which are particularly problematic during night driving. However, traditional EDOF models are generally effective for distance and intermediate vision but often provide inadequate near visual performance. According to a study by Tran D.B. et al. (2021) comparing EDOF (Symfony) and Trifocal (Panoptix) lenses, the trifocal IOL provided significantly better near vision (by 1.5 lines) but slightly lower distance vision (by 0.5 lines) compared to the EDOF model [4]. Similarly, Thao N.T.P. et al. (2024) evaluated the efficacy of other EDOF-IOLs labeled, such as Eyhance and Isopure, reporting a distance visual acuity of 0.18 ± 0.11 logMAR (~20/30) and an intermediate visual acuity of 0.21 ± 0.11 logMAR (~20/33), while near vision only reached 0.47 ± 0.12 logMAR (~20/55) [5]. These findings are entirely consistent with the assessments of many authors regarding the near-vision limitations of previous EDOF designs. This is largely due to the constraints of pure EDOF technology, which typically allows for a focal extension of only approximately +1.50 D, equivalent to the range from distance to intermediate, and lacks the additional +1.50 D required to support a near focal point.

4.1. Evaluation of Visual Outcomes at Various Distances

The Lucidis EDOF intraocular lens (IOL) features a unique design based on hybrid technology, combining a refractive bifocal lens with non-diffractive beam-shaping technology. This combination provides a continuous range of focus from 0.00 D to +3.00 D, creating two primary focal zones: the distance focal point of the base lens and an EDOF range spanning from intermediate to near distances. This design effectively addresses near-vision requirements while maintaining the superior characteristics of the EDOF category, such as producing fewer visual disturbances compared to diffraction MF-IOLs. This enhances overall visual quality and successfully supports daily activities at any distance [6].

In our study, visual outcomes following Lucidis IOL implantation were highly favorable across all distances. Specifically, the uncorrected distance visual acuity (UDVA) reached 0.07 ± 0.09 logMAR (~20/23), uncorrected intermediate visual acuity (UIVA) was 0.18 ± 0.08 logMAR (~20/30), and the mean uncorrected near visual acuity (UNVA) was 0.14 ± 0.1 logMAR (~20/28). These figures confirm the lens's ability to maintain stable image resolution over a broad focal range, enabling patients to perform tasks ranging from driving and viewing television to using electronic devices and reading.

Our results align with international reports. A study by Rabinovich M. et al. (2022) involving 181 eyes demonstrated impressive visual outcomes; at 3 months, the mean binocular UDVA was 0.038 ± 0.05 logMAR, UIVA was 0.09 ± 0.1 logMAR, and UNVA was 0.16 ± 0.14 logMAR [6].

Similarly, Mermoud A. et al. (2019) emphasized in their study of 158 eyes that while monocular UDVA (0.2 logMAR) may be slightly lower than some other EDOF models, the Lucidis lens excelled at intermediate (0.07 logMAR) and near (0.15 logMAR) distances [7].

Notably, both our study and international studies confirm that the Lucidis IOL maintains near-normal contrast sensitivity, comparable to monofocal lenses. This is of significant clinical importance, as it ensures sharp image quality even in low-light conditions. The high rate of spectacle independence in daily activities reported by Mermoud et al. has contributed to a significant improvement in patient's postoperative quality of life.

4.2. Comparison of Lucidis with Other EDOF IOL Models

4.2.1. Defocus Curve and Visual Range Analysis

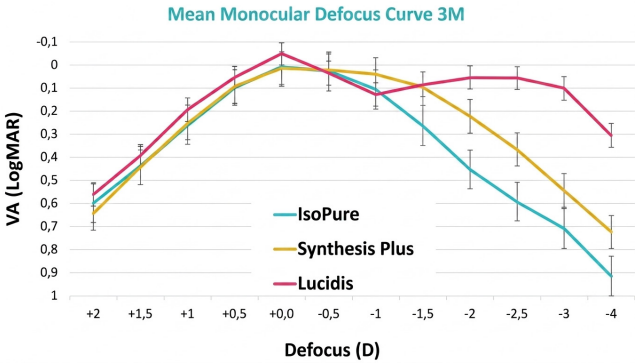


Figure 1. Monocular defocus curves of EDOF IOL (IsoPure, Synthesis+, and Lucidis) ranging from +2 D to −4 D with best distance correction (logMAR = logarithm of the minimum angle of resolution)[8].

Lucidis's defocus curve reflects its ability to provide continuous and stable vision across a wide focal range with superior near vision compared to other EDOF intraocular lenses.

The superior performance of Lucidis can be attributed to its hybrid refractive/EDOF optical design, combining a bifocal refractive configuration with pseudo non-diffracting beam technology. This design enables a continuous focal range from 0.00 D to +3.00 D, with two primary zones of focus, distance focus and extended intermediate-to-near focus. As a result, Lucidis overcomes the “near vision gap” commonly seen in traditional EDOF IOLs while maintaining low dysphotopsia rates.

4.2.2. Comparison with diffractive MF IOLs

When compared with diffractive MF IOLs, the Lucidis lens demonstrates comparable performance with the added advantage of faster recovery. A study by Ozulken (2020) indicated that distance, intermediate, and near visual acuities were equivalent between the Lucidis and AT-Lisa Tri groups at 3 months; however, the Lucidis group tended to achieve visual stability earlier, as early as the first postoperative month [9]. This is significant for enhancing early patient satisfaction following surgery.

4.2.3. Contrast Sensitivity and Image Quality

Contrast sensitivity is considered the gold standard for evaluating sharp image quality, particularly under mesopic conditions. In this study, 95.5% of cases showed low-contrast (10%) visual acuity decline of no more than 3 lines, confirming that Lucidis maintains image quality comparable to monofocal lenses.

This performance is superior to diffractive MF IOLs, which often suffer from light energy loss due to the use of discrete focal points. In comparison with the findings of Toygar et al [10]. The advantage of Lucidis lies in its EDOF technology, which creates a continuous elongated focal point, optimizing light energy utilization and providing more realistic images than difractive MF IOLs models.

4.2.4. Management of Nocturnal Visual Disturbances

Photic phenomena, such as halos and glare, are often the primary barriers to patient satisfaction with MF IOLs. In our study, no patients reported the occurrence of halos during the 6-month follow-up.

Theoretically, the aberration-neutral design of the Lucidis lens minimizes image distortion. Compared to MF lenses, which also reported minimal visual disturbances , Lucidis and its hybrid technology offer a distinct advantage by providing a smooth transition of focus. Eliminating "focal jumps" facilitates faster neuroadaptation and reduces functional visual disturbances, especially during night driving.

5. CONCLUSION

The Lucidis EDOF IOL provides excellent visual outcomes across all distances, maintains contrast sensitivity, minimizes photic phenomena and achieving spectacle independence resulting in high patient satisfaction following cataract surgery.

DISCLOSURE

The authors report no conflicts of interest in this work.

LIMITATIONS

This study has several limitations:

- single-center design
- relatively small sample size
- absence of a control group

Future randomized controlled studies comparing Lucidis with other premium IOLs are warranted.

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