Metadata of the article that will be visualized in OnlineFirst

ArticleTitle	Refractive and Visual Outcomes of SmartSight NOVA Refractive Lenticule Extraction for Myopia and Myopic Astigmatism at 3 Months: a Retrospective Case Series	
Article Sub-Title		
Article CopyRight	The Author(s) (This will be the copyright line in the final PDF)	
Journal Name	Ophthalmology and Therapy	
Corresponding Author	FamilyName	**Yoo**
	Particle	
	Given Name	**Tae Keun**
	Suffix	
	Division	
	Organization	Bright St. Mary Eye Clinic
	Address	Cambridge Building, 110, Teheran-ro, Gangnam-gu, Seoul, 06232, South Korea
	Phone	
	Fax	
	Email	eyetaekeunyoo@gmail.com; fawoo2@yonsei.ac.kr
	URL	
	ORCID	http://orcid.org/0000-0003-0890-8614
Author	FamilyName	**Keum**
	Particle	
	Given Name	**Ji Eun**
	Suffix	
	Division	
	Organization	Bright St. Mary Eye Clinic
	Address	Cambridge Building, 110, Teheran-ro, Gangnam-gu, Seoul, 06232, South Korea
	Phone	
	Fax	
	Email	
	URL	
	ORCID	
Author	FamilyName	**Kim**
	Particle	
	Given Name	**Jong-Chan**
	Suffix	
	Division	
	Organization	Bright St. Mary Eye Clinic
	Address	Cambridge Building, 110, Teheran-ro, Gangnam-gu, Seoul, 06232, South Korea
	Phone	
	Fax	
	Email	
	URL	
	ORCID	
Author	FamilyName	**Kim**
	Particle	
	Given Name	**Jun-Hyung**
	Suffix	
	Division	
	Organization	Bright St. Mary Eye Clinic
	Address	Cambridge Building, 110, Teheran-ro, Gangnam-gu, Seoul, 06232, South Korea
	Phone	
	Fax	
	Email	
	URL	
	ORCID	

Schedule	Received	27 Apr 2026
	Revised	
	Accepted	9 Jun 2026

Abstract

Introduction:
SmartSight NOVA using the ATOS platform (SCHWIND eye-tech-solutions GmbH, Kleinostheim, Germany) is a refractive lenticule extraction method with CenTrax-assisted centration. We hypothesized that SmartSight NOVA would provide safe, effective, and predictable 3-month outcomes for myopia and myopic astigmatism while maintaining favorable positional stability relative to the preoperative vertex-centered reference and acceptable higher-order aberration profiles.

Methods:
This retrospective single-center case series included 84 eyes of 42 patients treated with SmartSight NOVA for myopia and myopic astigmatism. Standard refractive surgery outcome analyses were performed at 1 and 3 months, including visual acuity, manifest refraction, and stability. Higher-order aberrations, chord μ subgroup analyses, and postoperative center-coordinate stability relative to the preoperative position were also assessed.

Results:
No clinically significant intraoperative or postoperative complications were observed during the 3-month follow-up. Preoperative manifest spherical equivalent was −3.70 ± 1.21 D. At 3 months, mean postoperative uncorrected distance visual acuity was 0.006 ± 0.020 logarithm of the minimum angle of resolution (logMAR), and postoperative manifest sphere, cylinder, and spherical equivalent were 0.021 ± 0.311 D, −0.327 ± 0.280 D, and −0.143 ± 0.336 D, respectively. Spherical equivalent was within ± 0.50 diopters (D) in 81.0% of eyes at 1 month and 89.3% at 3 months, and within ± 1.00 D in 100.0% of eyes at both visits. Postoperative refractive astigmatism was ≤ 0.50 D in 86% of eyes and ≤ 1.00 D in 100% of eyes at 3 months. No eyes lost two or more lines of corrected distance visual acuity. Induced higher-order aberrations did not differ significantly among preoperative chord μ groups. Mean displacement magnitude was 0.049 ± 0.028 mm, and 92.9% of eyes were within 0.10 mm of the preoperative position.

Conclusions:
SmartSight NOVA showed favorable early clinical outcomes at 3 months, with good visual and refractive performance, low residual astigmatism, limited higher-order aberration induction, and small postoperative displacement relative to the preoperative vertex-centered reference in most eyes.

Keywords (separated by '-') SmartSight NOVA - Refractive lenticule extraction - Myopia - Myopic astigmatism - Centration

Footnote Information The online version contains supplementary material available at https://doi.org/10.1007/s40123-026-01437-7.

Ophthalmol Ther
https://doi.org/10.1007/s40123-026-01437-7

ORIGINAL RESEARCH

Refractive and Visual Outcomes of SmartSight NOVA Refractive Lenticule Extraction for Myopia and Myopic Astigmatism at 3 Months: a Retrospective Case Series

Ji Eun Keum · Tae Keun Yoo · Jong-Chan Kim · Jun-Hyung Kim

Received: April 27, 2026 / Accepted: June 9, 2026

ABSTRACT

Introduction: SmartSight NOVA using the ATOS platform (SCHWIND eye-tech-solutions GmbH, Kleinostheim, Germany) is a refractive lenticule extraction method with CenTrax-assisted centration. We hypothesized that SmartSight NOVA would provide safe, effective, and predictable 3-month outcomes for myopia and myopic astigmatism while maintaining favorable positional stability relative to the preoperative vertex-centered reference and acceptable higher-order aberration profiles.

Methods: This retrospective single-center case series included 84 eyes of 42 patients treated with SmartSight NOVA for myopia and myopic astigmatism. Standard refractive surgery outcome analyses were performed at 1 and 3 months, including visual acuity, manifest refraction, and stability. Higher-order aberrations, chord μ subgroup analyses, and postoperative center-coordinate stability relative to the preoperative position were also assessed.

Results: No clinically significant intraoperative or postoperative complications were observed during the 3-month follow-up. Preoperative manifest spherical equivalent was -3.70 ± 1.21 D. At 3 months, mean postoperative uncorrected distance visual acuity was 0.006 ± 0.020 logarithm of the minimum angle of resolution (logMAR), and postoperative manifest sphere, cylinder, and spherical equivalent were 0.021 ± 0.311 D, -0.327 ± 0.280 D, and -0.143 ± 0.336 D, respectively. Spherical equivalent was within ± 0.50 diopters (D) in 81.0% of eyes at 1 month and 89.3% at 3 months, and within ± 1.00 D in 100.0% of eyes at both visits. Postoperative refractive astigmatism was ≤ 0.50 D in 86% of eyes and ≤ 1.00 D in 100% of eyes at 3 months. No eyes lost two or more lines of corrected distance visual acuity. Induced higher-order aberrations did not differ significantly among preoperative chord μ groups. Mean displacement magnitude was 0.049 ± 0.028 mm, and 92.9% of eyes were within 0.10 mm of the preoperative position.

Conclusions: SmartSight NOVA showed favorable early clinical outcomes at 3 months, with good visual and refractive performance, low residual astigmatism, limited higher-order aberration induction, and small postoperative displacement relative to the preoperative vertex-centered reference in most eyes.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s40123-026-01437-7.

J. E. Keum · T. K. Yoo (✉) · J.-C. Kim · J.-H. Kim
Bright St. Mary Eye Clinic, Cambridge Building, 110, Teheran-ro, Gangnam-gu, Seoul 06232, South Korea
e-mail: eyetaekeunyoo@gmail.com; fawoo2@yonsei.ac.kr

Keywords: SmartSight NOVA; Refractive lenticule extraction; Myopia; Myopic astigmatism; Centration

Key Summary Points

Why carry out this study?

SmartSight NOVA is a new refractive lenticule extraction platform for myopia and myopic astigmatism, and its early clinical outcomes have not yet been well characterized.

Because treatment centration may affect refractive accuracy and optical quality, we evaluated not only standard visual and refractive outcomes but also higher-order aberrations and postoperative positional displacement relative to preoperative reference.

What was learned from the study?

At 3 months, SmartSight NOVA showed favorable early outcomes, with good visual recovery, low residual spherical equivalent, and low residual refractive astigmatism

Spherical equivalent was within ± 0.50 D in 89.3% of eyes and within ± 1.00 D in 100.0% of eyes; residual refractive astigmatism was ≤ 0.50 D in 86% of eyes and ≤ 1.00 D in 100% of eyes.

Induced higher-order aberrations did not differ significantly across preoperative chord μ subgroups, and postoperative positional displacement relative to the preoperative reference was small in most eyes.

INTRODUCTION

Refractive lenticule extraction has become an established approach for the correction of myopia and myopic astigmatism [1]. In refractive surgery, residual refractive error, particularly residual astigmatism, remains a major clinical concern [2]. As lenticule extraction platforms evolve, evaluation extends beyond conventional measures of efficacy, predictability, safety, and stability to include treatment centration, astigmatic correction accuracy, and induction of higher-order aberrations (HOAs). These factors are clinically relevant because small differences in centration and astigmatic alignment may affect postoperative optical quality [3], particularly in eyes with larger chord μ, greater preoperative astigmatism, or increased sensitivity to postoperative visual symptoms [4].

SmartSight NOVA is an upgraded version of the ATOS SmartSight platform (SCHWIND eye-tech-solutions GmbH, Kleinostheim, Germany), a refractive lenticule extraction system designed for the correction of myopia and myopic astigmatism. Although clinical outcomes of the existing SmartSight platform have been reported [5, 6], clinical data specifically for SmartSight NOVA have not yet been studied. The NOVA platform incorporates workflow features intended to support treatment centration and astigmatic alignment, including CenTrax-assisted centration. In clinical practice, however, intended centration may be influenced by docking and suction-related positional changes, and the ability to confirm or refine alignment immediately before laser delivery may therefore be relevant. Although early clinical outcome studies of refractive lenticule extraction platforms have generally shown favorable refractive and visual results [7, 8], platform-specific data for SmartSight NOVA remain limited, particularly with respect to vertex-centered positioning, postoperative coordinate stability, vector analysis of refractive cylinder, HOAs outcomes, and the influence of preoperative chord μ on induced postoperative aberrations.

From a clinical standpoint, SmartSight NOVA appears to offer a useful workflow advantage for treatment centration. As illustrated in Fig. 1, apparent displacement of the intended centration may occur after suction application, and CenTrax allows final prelaser confirmation and adjustment of alignment. However, despite the practical relevance of this feature, clinical outcome data specifically addressing whether this workflow translates into favorable refractive accuracy, low residual astigmatism, acceptable induction of higher-order aberrations, and maintenance of a vertex-centered reference remain limited. Accordingly, an early outcome study of SmartSight NOVA should

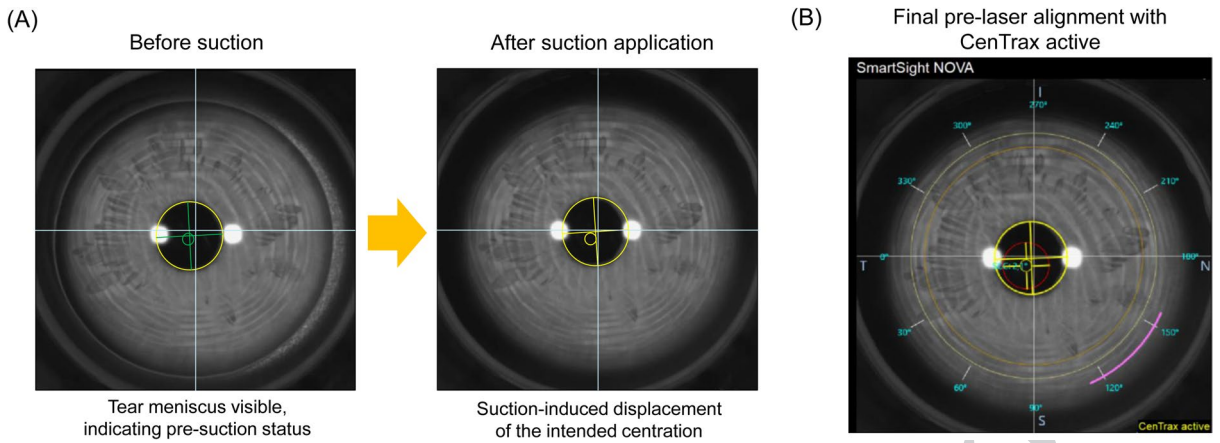


Fig. 1 Representative images showing suction-associated centration shift and final alignment with CenTrax in SmartSight NOVA. In the ATOS platform, the intended pupil-center position is displayed as a small circular marker to enable laser delivery relative to the vertex-centered reference. The difference between the center of the large crosshair and the center of the small circular marker represents the vertex–pupil offset. **A** Presuction alignment to the selected vertex-centered reference and apparent displacement after suction application. Before suction, alignment is relatively well matched, whereas after suction the apparent alignment becomes displaced. The visible tear meniscus confirms the presuction state. **B** Final prelaser image demonstrating CenTrax active for centration confirmation and adjustment. In this state, the actual pupil center remains slightly displaced from the intended pupil position (center of the small circular marker) after suction. However, the system tracks the pupil and applies compensatory alignment for the vertex–pupil offset so that laser delivery is centered as closely as possible on the compensated vertex-based treatment position rather than simply on the instantaneous pupil center

extend beyond standard refractive surgery reporting alone and assess not only visual acuity and manifest refraction but also astigmatic correction accuracy, optical quality, and postoperative positional stability.

Therefore, the purpose of the present study was to evaluate the 3-month clinical outcomes of SmartSight NOVA refractive lenticule extraction for myopia and myopic astigmatism in a retrospective case series. Specifically, we reported postoperative visual acuity, manifest refractive outcomes, refractive stability, Alpins vector analysis of astigmatic correction, preoperative and postoperative HOA profiles, HOA differences according to preoperative chord μ, and postoperative center-coordinate stability relative to the preoperative position.

METHODS

Study Design and Ethical Approval

This retrospective case series reviewed the medical records of patients who underwent SmartSight NOVA refractive lenticule extraction for myopia and myopic astigmatism at Bright St. Mary Eye Clinic, Seoul, South Korea, between November and December 2025. This study was approved by the Institutional Review Board of the Korean National Institute for Bioethics Policy (IRB no. P01-202604-01-043). The study was conducted in accordance with the tenets of the Declaration of Helsinki. The requirement for informed consent was waived because of

the retrospective nature of the study and the use of deidentified clinical data. The overall study design was aligned with prior retrospective observational and noncomparative lenticule extraction outcome studies.

Patients Selection

The study included consecutive eyes that underwent SmartSight NOVA for correction of myopia or myopic astigmatism and had postoperative follow-up data available for analysis. Eyes were considered eligible if patients were adults undergoing routine clinical refractive lenticule extraction and had preoperative and postoperative refractive and visual acuity measurements recorded in the electronic medical record. Eyes with abnormal corneal findings suggestive of ectasia, active ocular disease, significant ocular surface disease, previous ocular surgery, or other contraindications to keratorefractive surgery were excluded from treatment candidacy. Eyes with severe preoperative corneal erosion, moderate or greater dry eye, or clinically significant corneal asymmetry were excluded from surgery.

Preoperative Assessment

All patients underwent routine preoperative ophthalmic evaluation. This included uncorrected distance visual acuity (UDVA), corrected distance visual acuity (CDVA), manifest refraction, slit-lamp biomicroscopy, intraocular pressure, keratometry, central corneal thickness, and corneal imaging. Manifest sphere, cylinder, and spherical equivalent values used in this study were based on manifest refraction. In accordance with prior refractive lenticule extraction studies, visual acuity was analyzed in logarithm of the minimum angle of resolution (logMAR) notation. Preoperative chord μ and pupil-center coordinates were also recorded when available for centration-related analyses. HOA assessment was performed in all eyes, including total HOAs, spherical aberration, and vertical and horizontal coma.

Surgical Technique

All procedures were performed using the SmartSight NOVA platform, an upgraded version of the SCHWIND ATOS SmartSight system. SmartSight/ATOS platforms have been described as incorporating image-based centration and cyclotorsion-related workflow support, including treatment offset planning and automated or semi-automated rotation alignment functions [6]. The ATOS platform is integrated with SCHWIND diagnostic devices such as the SCHWIND SIRIUS, enabling corneal- and iris image–based registration for centration planning. Procedures were performed by four surgeons using a standardized clinical lenticule extraction workflow, with the same platform, centration protocol, and routine perioperative regimen applied throughout the study period.

Surgery was performed under topical anesthesia using the standard clinical lenticule extraction technique. After docking, initial centration was performed using the default ATOS marking setting, and following suction, CenTrax-assisted alignment was used to refine the treatment position relative to the marked vertex-centered reference before laser delivery. In this study, "vertex-centered reference" refers to the pupil center–based reference framework used within the clinical centration workflow for treatment planning and subsequent postoperative coordinate analysis. The intraoperative display provides a static overlay of the target pupil position, including a target hot zone with a radius of 200 µm for CenTrax-assisted alignment. Because suction-related positional change may alter the apparent treatment center, final alignment was confirmed immediately before laser application. The refractive lenticule was then created and extracted through a small incision according to the standard SmartSight technique. Surgical planning parameters such as optical zone, total zone, cap thickness, cap diameter, incision width, incision orientation, and static cyclotorsion compensation (SCC) were recorded when available. After surgery, patients were prescribed topical moxifloxacin and fluorometholone eye drops four times daily for 1 month.

Postoperative Evaluation

Postoperative examinations were performed at 1 month and 3 months. At each visit, UDVA, CDVA, and manifest refraction were assessed. Spherical equivalent and refractive astigmatism were calculated from manifest refraction. Standard refractive surgery outcome measures were derived, including the proportions of eyes within ± 0.50 diopters (D) and ± 1.00 D of spherical equivalent correction, change in CDVA lines, and refractive stability between postoperative time points. In all eyes, postoperative HOAs were evaluated and compared with preoperative values.

Outcome Measures

The primary outcomes were postoperative visual acuity and manifest refractive outcomes at 3 months, including postoperative spherical equivalent, postoperative cylinder, and the proportions of eyes within ± 0.50 D and ± 1.00 D of emmetropia. Secondary outcomes included refractive stability between 1 and 3 months, astigmatic vector outcomes according to the Alpins method, preoperative and postoperative HOA values, induced HOA changes according to preoperative chord μ group, and center-coordinate stability relative to the preoperative position. These outcome domains were selected to reflect both standard refractive surgery reporting and platform-specific clinical issues related to centration and optical quality.

Vector analysis of refractive cylinder was performed using the Alpins method [9]. The target-induced astigmatism vector (TIA), surgically induced astigmatism vector (SIA), difference vector (DV), and correction index (CI) were calculated. TIA represented the intended cylinder correction, SIA the achieved astigmatic change, DV the residual postoperative astigmatic error, and CI the ratio of SIA to TIA. Astigmatic vectors were converted to positive-cylinder notation for plotting.

HOA analysis was performed in all eyes using Pentacam (Oculus GmbH, Wetzlar, Germany) measurements obtained preoperatively and at 3 months postoperatively. Corneal HOAs were evaluated under standard scotopic light settings in the 6.0-mm zone. Total HOAs were represented as root mean square values, and spherical aberration, vertical coma, and horizontal coma were analyzed individually. Induced HOAs were defined as postoperative minus preoperative values. To explore whether preoperative decentration-related anatomy influenced optical outcomes [10], eyes were stratified by preoperative chord μ into three groups: < 0.10 mm, 0.10 to < 0.20 mm, and ≥ 0.20 mm, with the 0.20-mm threshold selected on the basis of prior refractive surgery literature suggesting greater centration-related relevance above this level [11, 12]. Overall between-group comparisons and pairwise post hoc comparisons were then performed for induced HOA parameters. This approach was chosen because prior studies have highlighted the relevance of centration and optical quality in lenticule extraction systems that incorporate image-guided alignment features.

Preoperative and postoperative coordinate-related measurements were obtained within the same Pentacam Scheimpflug–based clinical imaging workflow and compared relative to the same pupil center–based vertex-centered reference framework. Pentacam is a widely used Scheimpflug device with generally good repeatability for corneal tomography and related anterior segment measurements [13]. Because decentered optical zones may be associated with postoperative displacement of the corneal vertex reference [14], preoperative and postoperative x and y coordinates of the pupil center–based vertex-centered reference, as well as chord μ values, were analyzed. Postoperative coordinate change was summarized as Δx and Δy, and displacement magnitude was calculated as the Euclidean distance between preoperative and postoperative coordinates. The proportions of eyes remaining within 0.05 mm and 0.10 mm of the preoperative position were also determined. Because these measurements were analyzed relative to the preoperative reference frame, the analysis was intended as an indirect assessment of postoperative positional stability within the clinical workflow rather than a direct anatomical measurement of vertex immutability [15, 16]. Accordingly, small postoperative coordinate

Table 1 Preoperative demographic, refractive, visual acuity, and surgical parameters

Parameter	Value	Minimum	Maximum
Eyes, *n* (patients, *n*)	84 (42)		
Sex, male/female (patients), *n*	21/21		
Age at surgery, years (patients)	24.262 ± 4.186	19	35
Preoperative IOP, mmHg	16.488 ± 2.856	11	23
Preoperative UDVA, logMAR	1.106 ± 0.186	0.400	1.300
Preoperative CDVA, logMAR	0.006 ± 0.016	0.000	0.100
Preoperative manifest sphere, D	−3.02 ± 1.15	−6.50	−1.00
Preoperative manifest cylinder, D	−1.35 ± 0.68	−3.50	0.00
Preoperative spherical equivalent, D	−3.70 ± 1.21	−7.00	−1.375
Preoperative K1, D	42.72 ± 1.33	40.25	45.50
Preoperative K2, D	44.78 ± 1.29	41.50	46.75
Preoperative CCT, μm	560.07 ± 41.89	503.00	632.00
Optical zone, mm	6.45 ± 0.08	6.30	6.50
Total zone, mm	7.27 ± 0.06	7.10	7.30
Cap thickness, μm	120.0 ± 0.0	120.0	120.0
Cap diameter, mm	8.25 ± 0.08	8.10	8.30
Incision width, mm	3.00 ± 0.0	3.0	3.0
Incision orientation, degrees	135.0 ± 0.0	135.0	135.0
SCC value, degrees	0.13 ± 3.58	−7.30	8.50
Preoperative chord μ (offset), mm	0.175 ± 0.081	0.032	0.384

CCT, central corneal thickness; CDVA, corrected distance visual acuity; D, diopters; IOP, intraocular pressure; K1, flat keratometry; K2, steep keratometry; logMAR, logarithm of the minimum angle of resolution; SCC, static cyclotorsion compensation; UDVA, uncorrected distance visual acuity

AQ2 displacement was interpreted as indirect supportive evidence of stable vertex-centered treatment positioning within the clinical workflow (Table 1).

Statistical Analysis

Continuous variables are presented as mean ± standard deviation, with minimum and maximum values reported when appropriate. Categorical variables are presented as counts and percentages. Missing data were handled using an available-case approach [17]. Standard refractive surgery outcome plots were generated for visual acuity, refractive accuracy, refractive astigmatism, and stability. Paired comparisons were used for preoperative and postoperative coordinate-related variables. For HOA subgroup analysis, eyes were stratified by preoperative chord μ into three groups (<0.10 mm, 0.10 to<0.20 mm, and ≥0.20 mm). Overall between-group comparisons were performed using the Kruskal–Wallis test, followed by pairwise Wilcoxon rank-sum tests with Holm adjustment for post hoc analysis. Because both eyes from the same patient

were included, sensitivity analyses using one randomly selected eye per patient and generalized estimating equations with patient as the clustering variable were additionally performed for selected major refractive and positional outcomes. A two-sided *P*-value of less than 0.05 was considered statistically significant.

RESULTS

A total of 84 eyes of 42 patients were included in the analysis, with an equal sex distribution of 21 male and 21 female patients. The mean age at surgery was 24.3 ± 4.2 years. Preoperatively, mean intraocular pressure was 16.5 ± 2.9 mmHg, mean UDVA was 1.106 ± 0.186 logMAR, and mean CDVA was 0.006 ± 0.016 logMAR. Mean manifest sphere, cylinder, and spherical equivalent were −3.02 ± 1.15 D, −1.35 ± 0.68 D, and −3.70 ± 1.21 D, respectively. The treated preoperative refractive range extended up to 6.50 D for manifest sphere, 3.50 D for manifest cylinder, and 7.00 D for spherical equivalent. Mean keratometric values were 42.72 ± 1.33 D for K1 and 44.78 ± 1.29 D for K2, and mean central corneal thickness was 560.1 ± 41.9 µm. The mean preoperative chord μ was 0.175 ± 0.081 mm. Surgical planning parameters included a mean optical zone of 6.45 ± 0.08 mm, total zone of 7.27 ± 0.06 mm, cap diameter of 8.25 ± 0.08 mm, and uniform cap thickness, incision width, and incision orientation of 120 µm, 3.0 mm, and 135°, respectively.

No clinically significant intraoperative or postoperative complications were observed during the 3-month follow-up. Table 2 summarizes the postoperative visual acuity and manifest refractive outcomes at 1 and 3 months. At 1 month, mean UDVA and CDVA were 0.020 ± 0.032 and 0.002 ± 0.009 logMAR, respectively, and mean

Table 2 Postoperative visual acuity and refractive outcomes ($n = 84$ eyes)

Parameter	Value	Minimum	Maximum
UDVA at 1 month, logMAR	0.020 ± 0.032	0	0.1
CDVA at 1 month, logMAR	0.002 ± 0.009	0	0.046
Manifest sphere at 1 month, D	0.089 ± 0.362	−0.5	1
Manifest cylinder at 1 month, D	−0.432 ± 0.250	−1.000	0
Spherical equivalent at 1 month, D	−0.126 ± 0.370	−1.000	0.875
Spherical equivalent within ± 0.50 D at 1 month, *n* (%)	68 (81.0)		
Spherical equivalent within ± 1.00 D at 1 month, *n* (%)	84 (100.0)		
UDVA at 3 months, logMAR	0.006 ± 0.020	0	0.1
CDVA at 3 months, logMAR	0.001 ± 0.005	0	0.046
Manifest sphere at 3 months, D	0.021 ± 0.311	−0.750	0.750
Manifest cylinder at 3 months, D	−0.327 ± 0.280	−1.000	0
Spherical equivalent at 3 months, D	−0.143 ± 0.336	−0.875	0.750
Spherical equivalent within ± 0.50 D at 3 months, *n* (%)	75 (89.3)		
Spherical equivalent within ± 1.00 D at 3 months, *n* (%)	84 (100.0)		
Achieved correction at 3 months, D	−3.543 ± 1.206	−6.625	−1.375

CDVA, corrected distance visual acuity; D, diopters; logMAR, logarithm of the minimum angle of resolution; UDVA, uncorrected distance visual acuity

manifest sphere, cylinder, and spherical equivalent were 0.089 ± 0.362 D, −0.432 ± 0.250 D, and −0.126 ± 0.370 D, respectively. At 3 months, these values improved to 0.006 ± 0.020 and 0.001 ± 0.005 logMAR for UDVA and CDVA, respectively, with mean manifest sphere, cylinder, and spherical equivalent of 0.021 ± 0.311 D, −0.327 ± 0.280 D, and −0.143 ± 0.336 D. Spherical equivalent was within ± 0.50 D in 68 eyes (81.0%) at 1 month and 75 eyes (89.3%) at 3 months, and within ± 1.00 D in all eyes at both visits. The mean achieved correction at 3 months was −3.543 ± 1.206 D. Figure 2 illustrates the standard refractive surgery outcome graphs. Cumulative visual acuity outcomes were favorable, with postoperative UDVA approaching preoperative CDVA. At 3 months, 1 eye (1%) gained one line of CDVA, 83 eyes (99%) showed no change, and no eyes lost one or more lines of CDVA. The attempted-versus-achieved spherical equivalent plot showed a strong linear relationship, supporting good predictability of correction. Refractive stability was generally maintained between 1 and 3 months, with only 6% of eyes showing a spherical equivalent change greater than 0.50 D during this interval. Residual refractive astigmatism was low at 3 months, with 86% of eyes having 0.50 D or less and all eyes having 1.00 D or less.

Figure 3 summarizes the Alpins vector analysis of refractive astigmatism at 3 months. The arithmetic mean target induced astigmatism (TIA) was 1.36 D, whereas the arithmetic mean surgically induced astigmatism (SIA) was 1.18 D, indicating that the achieved astigmatic correction was slightly lower than the intended

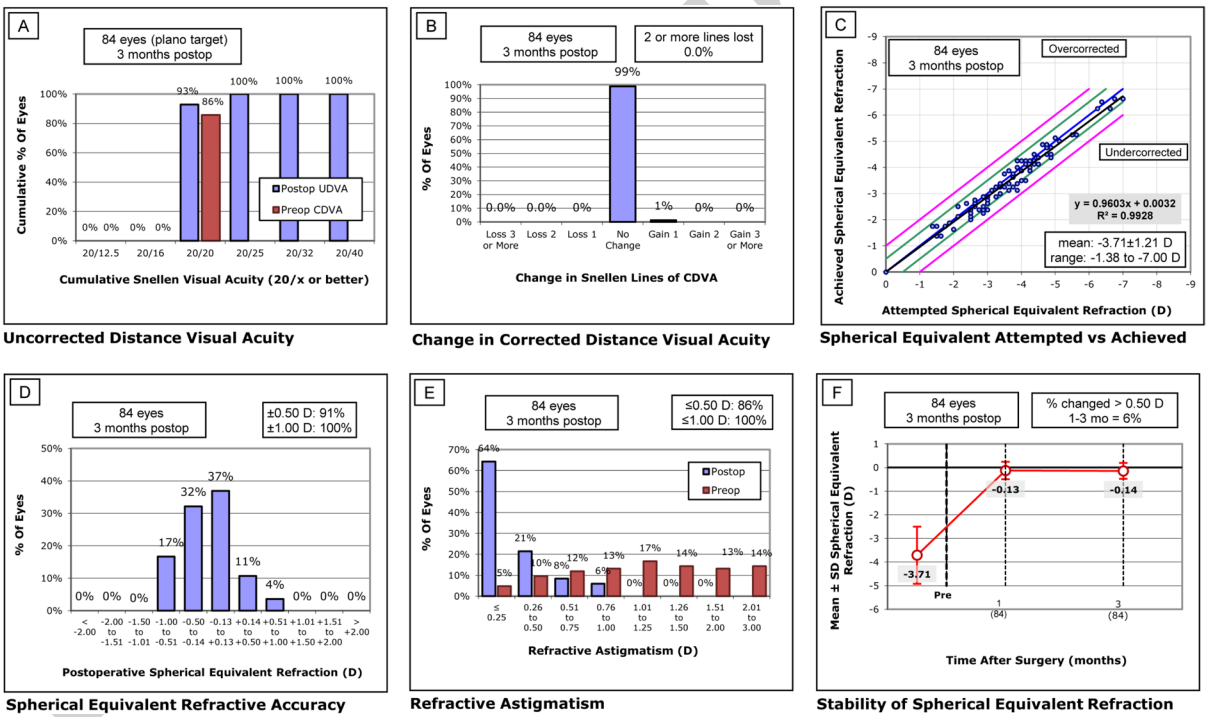


Fig. 2 Standard graphs for reporting refractive surgery outcomes 3 months after SmartSight NOVA for myopia and myopic astigmatism. **A** Cumulative Snellen visual acuity showing postoperative uncorrected distance visual acuity (UDVA) in comparison with preoperative corrected distance visual acuity (CDVA). **B** Change in CDVA expressed as Snellen lines gained or lost. **C** Attempted versus achieved spherical equivalent refraction (SEQ). **D** Distribution of postoperative SEQ, showing refractive accuracy relative to emmetropia. **E** Distribution of refractive astigmatism before and after surgery. **F** Stability of SEQ over time, presented as mean ± standard deviation (SD). Postop, postoperative; Preop, preoperative; UDVA, uncorrected distance visual acuity; CDVA, corrected distance visual acuity; SEQ, spherical equivalent refraction; D, diopters

Journal : Large 40123 | Article No : 1437 | Pages : 16 | MS Code : 1437 | Dispatch : 20-6-2026

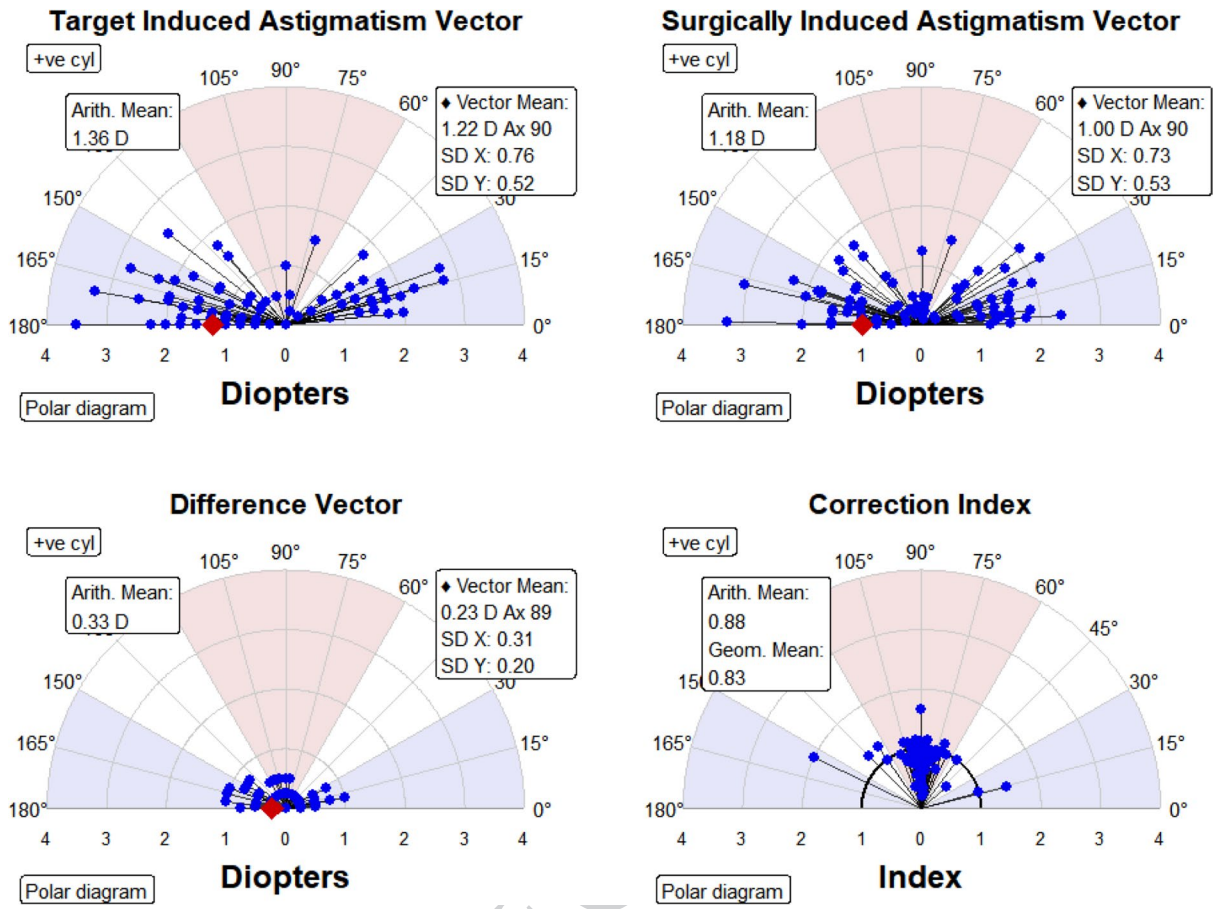


Fig. 3 Alpins vector analysis of refractive astigmatism 3 months after SmartSight NOVA for myopia and myopic astigmatism. The polar diagrams show the target induced astigmatism vector (TIA), surgically induced astigmatism vector (SIA), difference vector (DV), and correction index (CI). The arithmetic mean and vector mean are displayed for each panel. TIA represents the intended astigmatic correction, SIA the achieved astigmatic correction, DV the residual astigmatic error, and CI the ratio of achieved to intended astigmatic correction. Astigmatic vectors were converted to positive-cylinder notation for plotting

correction overall. The arithmetic mean difference vector was 0.33 D, reflecting a relatively low residual postoperative astigmatic error. The correction index showed an arithmetic mean of 0.88 and a geometric mean of 0.83, further supporting a mild tendency toward undercorrection rather than overcorrection. Overall, the vector analysis suggested that astigmatic correction was generally accurate, with low residual error, although a small systematic undercorrection was observed.

Table 3 summarizes the preoperative and postoperative HOA results for all 84 eyes. Mean total HOAs (root mean square) increased significantly from 0.383 ± 0.098 µm preoperatively to 0.493 ± 0.127 µm at 3 months (mean change, 0.110 ± 0.179 µm; $P < 0.001$). Mean spherical aberration decreased significantly from 0.251 ± 0.070 µm to 0.143 ± 0.113 µm (mean change, −0.108 ± 0.108 µm; $P < 0.001$), and vertical coma also changed significantly from 0.071 ± 0.185 µm preoperatively to −0.095 ± 0.182 µm postoperatively (mean change, −0.166 ± 0.152 µm; $P < 0.001$). In contrast, horizontal coma did not change significantly overall, remaining 0.021 ± 0.108 µm preoperatively and 0.021 ± 0.187 µm postoperatively (mean change, −0.000 ± 0.162 µm;

Table 3 Preoperative and postoperative higher-order aberrations ($n = 84$ eyes)

Parameter	Preoperative	Postoperative at 3 months	Mean change	Paired *P*-value
Total HOAs (RMS), μm	0.383 ± 0.098	0.493 ± 0.127	0.110 ± 0.179	< 0.001
Spherical aberration, μm	0.251 ± 0.070	0.143 ± 0.113	−0.108 ± 0.108	< 0.001
Vertical coma, μm	0.071 ± 0.185	−0.095 ± 0.182	−0.166 ± 0.152	< 0.001
Horizontal coma, μm	0.021 ± 0.108	0.021 ± 0.187	−0.000 ± 0.162	0.995

Data are presented as mean ± standard deviation

HOAs, higher-order aberrations; RMS, root mean square

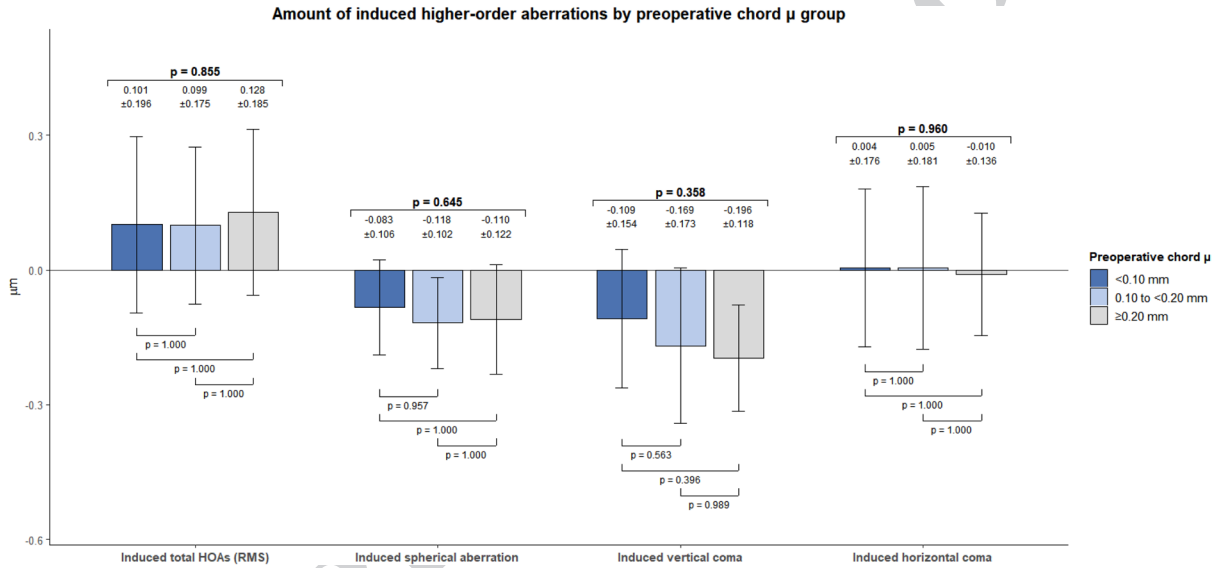
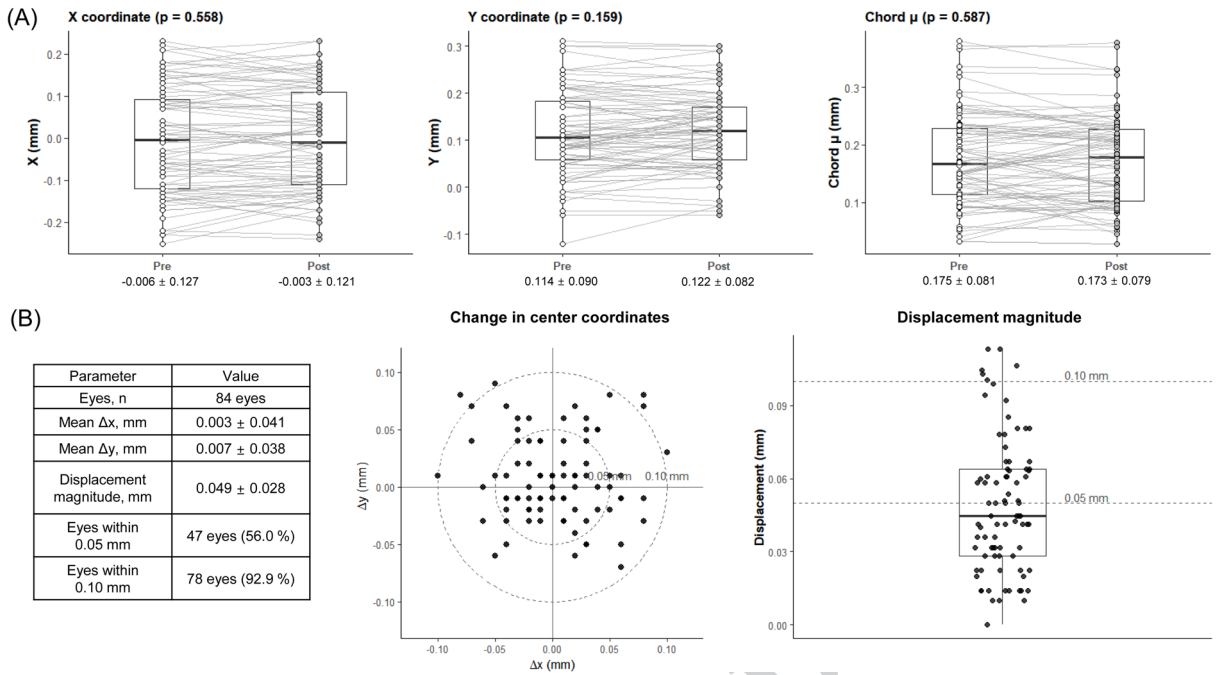


Fig. 4 Induced higher-order aberrations by preoperative chord μ group. Bars show mean induced total HOAs (RMS), spherical aberration, vertical coma, and horizontal coma at 3 months according to preoperative chord μ category (< 0.10 mm, 0.10 to < 0.20 mm, and ≥ 0.20 mm), with error bars indicating standard deviation. Values above the bars indicate mean ± standard deviation. Induced aberrations were defined as postoperative minus preoperative values. Upper brackets show overall three-group comparisons, and lower brackets show pairwise post hoc comparisons. Overall *P*-values were calculated using the Kruskal–Wallis test, and pairwise *P*-values using pairwise Wilcoxon rank-sum tests with Holm adjustment

$P = 0.995$). Figure 4 shows the induced HOA changes stratified by preoperative chord μ group. Induced total HOAs, spherical aberration, vertical coma, and horizontal coma did not differ significantly among the three chord μ groups on overall comparison ($P = 0.855$, 0.645, 0.358, and 0.960, respectively), and pairwise post hoc comparisons were likewise not significant.

Figure 5 demonstrates that postoperative center-coordinate changes were small overall. Paired comparisons showed no significant differences between preoperative and postoperative x coordinate, y coordinate, or chord μ values ($P = 0.558$, 0.159, and 0.587, respectively). The mean changes were 0.003 ± 0.041 mm for Δx and 0.007 ± 0.038 mm for Δy, with a mean displacement magnitude of 0.049 ± 0.028 mm.



Parameter	Value
Eyes, n	84 eyes
Mean Δx, mm	0.003 ± 0.041
Mean Δy, mm	0.007 ± 0.038
Displacement magnitude, mm	0.049 ± 0.028
Eyes within 0.05 mm	47 eyes (56.0 %)
Eyes within 0.10 mm	78 eyes (92.9 %)

Fig. 5 Stability of center coordinates relative to the preoperative position. **A** Paired preoperative and postoperative x coordinate, y coordinate, and chord μ measurements. **B** Summary of coordinate changes and displacement magnitude. **C** Scatter plot of Δx and Δy with 0.05-mm and 0.10-mm reference circles, and box plot of displacement magnitude. Postoperative coordinate changes were small overall, with 92.9% of eyes remaining within 0.10 mm of the preoperative position

The scatter plot showed that most eyes remained clustered close to the origin, and the displacement plot confirmed that 47 eyes (56.0%) were within 0.05 mm and 78 eyes (92.9%) were within 0.10 mm of the preoperative position. Overall, these findings suggest limited postoperative displacement relative to the preoperative vertex-centered reference in most eyes.

Additional analyses accounting for inter-eye correlation yielded results consistent with the primary analyses (Table 4). In a sensitivity analysis restricted to one randomly selected eye per patient, manifest spherical equivalent at 3 months was –0.126 ± 0.353 D, manifest cylinder was –0.327 ± 0.279 D, spherical equivalent within ± 0.50 D and ± 1.00 D was 88.1% and 100.0%, respectively, Δx was 0.004 ± 0.042 mm, Δy was 0.002 ± 0.040 mm, mean displacement magnitude was 0.050 ± 0.030 mm, and postoperative chord μ was 0.181 ± 0.078 mm. THe generalized estimating equations (GEE) estimates were likewise consistent with the primary results.

DISCUSSION

In this retrospective case series, SmartSight NOVA refractive lenticule extraction demonstrated favorable early clinical outcomes at 3 months in eyes with myopia and myopic astigmatism. Visual recovery, refractive accuracy, and safety were all satisfactory, with low residual refractive error and low residual astigmatism overall. No clinically significant intraoperative or postoperative complications were observed, and no eye lost two or more lines of corrected distance visual acuity. Induced higher-order aberration changes were limited, and postoperative displacement relative to the preoperative vertex-centered reference was generally small. Optical outcomes also remained comparable across the preoperative chord μ subgroups. Taken together, these findings support the clinical feasibility of SmartSight NOVA for the correction of myopia and myopic astigmatism,

Table 4 Sensitivity analyses accounting for intereye correlation

Outcome	Full dataset	One-eye-per-patient sensitivity analysis	GEE estimate (95% CI)
Manifest spherical equivalent at 3 months, D	−0.143 ± 0.336	−0.126 ± 0.353	−0.143 (−0.217 to −0.068)
Manifest cylinder at 3 months, D	−0.327 ± 0.280	−0.327 ± 0.279	−0.327 (−0.390 to −0.265)
Spherical equivalent within ± 0.50 D at 3 months, %	89.3	88.1	89.3 (80.0 to 94.6)
Spherical equivalent within ± 1.00 D at 3 months, %	100.0	100.0	100.0 (100.0 to 100.0)
Δx, mm	0.003 ± 0.041	0.004 ± 0.042	0.003 (−0.006 to 0.012)
Δy, mm	0.007 ± 0.038	0.002 ± 0.040	0.007 (−0.001 to 0.016)
Displacement magnitude, mm	0.049 ± 0.028	0.050 ± 0.030	0.049 (0.042 to 0.056)
Postoperative chord μ, mm	0.173 ± 0.079	0.181 ± 0.078	0.173 (0.152 to 0.193)

Data are presented as mean ± standard deviation or percentage, as appropriate. The one-eye-per-patient sensitivity analysis was performed using one randomly selected eye per patient. GEE models were fitted with patient as the clustering variable to account for intereye correlation. Δx and Δy represent postoperative minus preoperative coordinate changes

CI, confidence interval; D, diopters; GEE, generalized estimating equations

while the coordinate analysis provides indirect supportive evidence of favorable treatment positioning within this workflow.

These findings are broadly consistent with prior lenticule extraction studies reporting good early efficacy, predictability, and safety. Published early outcome studies of contemporary refractive lenticule extraction platforms, including VISUMAX-based SMILE/SMILE Pro [7, 18], ATOS-based SmartSight [6], and CLEAR using the FEMTO LDV Z8 [19], have generally shown postoperative spherical equivalent values clustered close to emmetropia, high proportions of eyes within ± 0.50 D and ± 1.00 D of target, and low rates of clinically meaningful visual acuity loss. Within this context, the present results appear to fall within the expected performance range for current lenticule extraction technology. Although direct comparison across studies should be made cautiously because of differences in patient selection, nomogram strategy, follow-up schedules, and reporting conventions, the overall refractive and visual outcomes observed in the present series support the early clinical feasibility of SmartSight NOVA as an effective treatment option for myopia and myopic astigmatism.

An important feature of the current study is that the evaluation was not limited to standard refractive surgery reporting alone. SmartSight NOVA is an upgraded version of the ATOS SmartSight platform and introduces CenTrax-assisted final alignment, a workflow feature not described in earlier ATOS SmartSight outcome reports [5] and distinct from the centration and cyclotorsion-assist functions reported for VISUMAX 800 SMILE Pro [18]. In conventional ATOS SmartSight and VISUMAX 800 SMILE Pro workflows, centration still depends largely on surgeon-guided manual alignment, and exact centration may be difficult to achieve consistently because corneal shape and docking-related factors can alter the apparent treatment center. SmartSight NOVA appears to represent a workflow-oriented refinement intended to support treatment centration and astigmatic alignment, particularly through final alignment immediately before laser delivery. This difference is clinically relevant because treatment decentration is not merely a technical issue; even small centration errors may induce higher-order aberrations, particularly coma-like aberrations, reduce optical quality, and contribute to residual astigmatism or suboptimal visual outcomes [20].

In the present series, postoperative coordinate displacement relative to the preoperative vertex-centered reference was small in most eyes. However, because the analysis was indirect and noncomparative, this finding should be interpreted only as supportive evidence of favorable treatment positioning within this workflow, rather than proof of platform-specific superiority.

The vector analysis findings provide additional insight into the astigmatic correction achieved in this series. The arithmetic mean target induced astigmatism was greater than the surgically induced astigmatism, and the correction index was less than 1.0, suggesting mild undercorrection overall. However, the mean difference vector remained low, postoperative refractive cylinder was modest at 3 months, and the predictability of astigmatic correction appeared clinically satisfactory. This pattern indicates that although a small systematic undercorrection may have been present owing to nomogram, the clinical magnitude of the residual astigmatic error was limited in most eyes. Similar findings have been reported in previous lenticule extraction studies [5, 8], in which slight undercorrection on vector analysis coexisted with good overall astigmatic correction and favorable refractive predictability.

The HOA findings also warrant consideration. Induced total HOAs, spherical aberration, vertical coma, and horizontal coma did not differ significantly among the preoperative chord μ subgroups. This is noteworthy because previous refractive surgery studies have suggested that larger preoperative pupil-offset parameters, including chord μ, may predispose eyes to decentration-related optical degradation [21]. Therefore, the absence of a significant HOA penalty in eyes with larger preoperative chord μ may suggest that SmartSight NOVA maintained comparable optical outcomes despite greater preoperative offset, potentially reflecting the effectiveness of its vertex-centered centration workflow [22]. Nevertheless, this interpretation should be made cautiously because the sample sizes were limited and the study did not include a comparator platform.

The postoperative reduction in corneal spherical aberration also merits comment. Although myopic corneal refractive procedures often increase spherical aberration, the present study showed a significant decrease in mean corneal spherical aberration measured by Pentacam Scheimpflug analysis in the 6.0-mm zone. Representative Pentacam cases in Supplementary Material 1 illustrate this postoperative reduction in selected eyes, and Supplementary Material 2 further showed that spherical aberration decreased in 74 of 84 eyes (88.1%), indicating that this pattern was not limited to a few outlier cases. Vertical coma also showed a significant negative shift overall, and Supplementary Material 2 demonstrated that vertical coma decreased in 72 of 84 eyes (85.7%). Published SmartSight/ATOS data have not consistently shown the same pattern, with prior reports describing unchanged whole-eye spherical aberration and increased corneal spherical aberration after SmartSight [5, 6], suggesting that the present finding may depend on the measurement domain and analysis method. One possible explanation is that the ATOS/SmartSight platform may have platform-specific corneal optical characteristics related to its pulse-energy strategy and asymmetric spot/track spacing, which could influence the postoperative corneal wavefront profile. Additional contributions from lenticule geometry or transition-zone characteristics are also possible [23]. Favorable treatment centration may also have contributed. Nevertheless, because this was a noncomparative study, and the mechanism was not directly evaluated, this finding should be interpreted cautiously.

The positional stability analysis should likewise be interpreted with appropriate caution. Prior refractive surgery studies have suggested that optical zone decentration may lead to displacement of the corneal vertex reference [14, 24], while also contributing to increased higher-order aberrations and reduced optical quality [16]. However, most previous studies have focused on optical zone decentration or ablation/lenticule centration relative to the corneal vertex [3, 20] rather than directly tracking the pre- to postoperative displacement of a vertex-centered reference. Accordingly, the present analysis was designed to assess positional stability relative to the preoperative reference system. The finding that 92.9% of eyes remained within 0.10 mm of the preoperative position suggests

only limited postoperative displacement relative to the preoperative vertex-centered reference in most cases, but does not demonstrate that the anatomical vertex itself was unchanged. Minimizing displacement relative to the preoperative vertex-centered reference may also be advantageous from the standpoint of neural adaptation [25]. Because the visual system is adapted to the eye's habitual aberration pattern [26], smaller postoperative positional changes may reduce abrupt alterations in retinal image structure and thereby facilitate early adaptation to the postoperative optical state. This interpretation, however, remains indirect and hypothetical.

Several limitations should be acknowledged. First, the study was retrospective, single-center, and noncomparative, which limits causal inference. Prospective studies will be needed to further validate these findings. Second, follow-up was limited to 3 months; therefore, longer-term refractive stability, optical quality, regression, and positional stability could not be assessed. In particular, potential later changes related to epithelial remodeling, wound healing, or refractive regression could not be evaluated within the current follow-up period. Third, although additional sensitivity analyses using one eye per patient and generalized estimating equations were performed to address potential intereye correlation, inclusion of both eyes remains a general methodological consideration in retrospective eye-level studies. Fourth, the coordinate analysis was based on a preoperative reference frame and therefore provided indirect rather than direct evidence of stable vertex-centered positioning. Small coordinate differences may also have been influenced by fixation, acquisition conditions, and measurement variability. In addition, eyes with moderate or greater dry eye, clinically significant corneal asymmetry, and severe corneal erosion were excluded from surgery. Although these exclusions were clinically appropriate, they may have contributed to the favorable outcomes observed and limit generalizability to broader refractive surgery populations. Accordingly, the present cohort may be regarded as a relatively selected or ideal surgical population. Finally, no comparator platform was included, and it therefore cannot be concluded from this study alone that SmartSight NOVA is superior to other refractive lenticule extraction systems. In practice, direct comparison between refractive surgery platforms is challenging without randomized controlled trials or carefully matched comparative studies, given differences in patient selection, surgical planning, nomogram use, and clinical workflow.

CONCLUSIONS

SmartSight NOVA demonstrated favorable early clinical outcomes at 3 months for the treatment of myopia and myopic astigmatism. Refractive and visual performance was good overall, astigmatic correction was generally accurate despite a mild undercorrection tendency on vector analysis, HOA induction was limited, and postoperative displacement relative to the preoperative vertex-centered reference was small in most eyes. Larger prospective comparative studies with longer follow-up are needed to determine whether these favorable early findings are sustained and to clarify the clinical relevance of the NOVA centration workflow relative to other platforms.

ACKNOWLEDGEMENTS

The authors thank the clinical staff involved in the routine care and follow-up of the patients included in this study.

Medical Writing, Editorial, and Other Assistance. The authors used ChatGPT (OpenAI, San Francisco, CA, USA) for language editing during manuscript preparation. All outputs were critically reviewed, revised, and approved by the authors. No external funding was received for this assistance.

Author Contribution. Ji Eun Keum and Tae Keun Yoo conceived and designed the study, collected and interpreted the data, performed the analysis, and drafted the manuscript. Ji Eun Keum, Jong-Chan Kim, and Jun-Hyung Kim contributed to data acquisition, critical revision of the manuscript, and final approval of

the submitted version. All authors read and approved of the final manuscript.

Funding. No funding or sponsorship was received for the conduct of this study or publication of this article.

Data Availability. The datasets generated and/or analyzed during the current study are not publicly available because they contain potentially identifiable clinical information but are available from the corresponding author on reasonable request, subject to institutional and ethical requirements.

Declarations

Conflict of Interest. Ji Eun Keum, Tae Keun Yoo, Jong-Chan Kim, and Jun-Hyung Kim declare that they have no conflicts of interest related to this work.

Ethical Approval. This study was approved by the Institutional Review Board of the Korean National Institute for Bioethics Policy (IRB no. P01-202604-01-043). The study was conducted in accordance with the tenets of the Declaration of Helsinki. The requirement for informed consent was waived because of the retrospective nature of the study and the use of deidentified clinical data.

REFERENCES

1. Reinstein DZ, Archer TJ, Gobbe M. Small incision lenticule extraction (SMILE) history, fundamentals of a new refractive surgery technique and clinical outcomes. Eye Vis. 2014;1:3. https://doi.org/10.1186/s40662-014-0003-1.

2. Choi JY, Ryu SY, Yoo TK. Epidemiological insights into complication and outcomes in corneal refractive surgery population: findings from KNHANES 2010–2012. BMC Ophthalmol. 2025;25:154. https://doi.org/10.1186/s12886-025-03981-5.

3. Liu M, Sun Y, Wang D, Zhang T, Zhou Y, Zheng H, et al. Decentration of optical zone center and its impact on visual outcomes following SMILE. Cornea. 2015;34:392. https://doi.org/10.1097/ICO.0000000000000383.

4. Park CY, Oh SY, Chuck RS. Measurement of angle kappa and centration in refractive surgery. Curr Opin Ophthalmol. 2012;23:269. https://doi.org/10.1097/ICU.0b013e3283543c41.

5. Pradhan KR, Arba MS. Comparing high and low energy outcomes on day one for SmartSight myopic-astigmatism treatments with the SCHWIND ATOS: a retrospective case series. BMC Ophthalmol. 2023;23:328. https://doi.org/10.1186/s12886-023-03076-z.

6. Gabric I, Bohac M, Gabric K, Arba MS. First European results of a new refractive lenticular extraction procedure—SmartSight by SCHWIND eye-tech-solutions. Eye. 2023;37:3768–75. https://doi.org/10.1038/s41433-023-02601-0.

7. Yoo TK, Kim D, Kim JS, Kim HS, Ryu IH, Lee IS, et al. Comparison of early visual outcomes after SMILE using VISUMAX 800 and VISUMAX 500 for myopia: a retrospective matched case–control study. Sci Rep. 2024;14:11989. https://doi.org/10.1038/s41598-024-62354-y.

8. Yoon H, Magnago T, Yeom D-J. Three-month clinical outcomes to correct myopia or myopic astigmatism using a femtosecond laser for lenticule creation with automated centration and cyclotorsion compensation. J Refract Surg. 2024;40(1):e30-41. https://doi.org/10.3928/1081597X-20231212-03.

9. Alpins N. Astigmatism analysis by the Alpins method. J Cataract Refract Surg. 2001;27:31–49.

10. Guo L, Cheng Z, Kong X, Huang Z, Xu X, Wu J, et al. The effect of different angle kappa on higher-order aberrations after small incision lenticule extraction. Lasers Med Sci. 2023;38:277. https://doi.org/10.1007/s10103-023-03934-8.

11. Huang J, Zhou X, Qian Y. Decentration following femtosecond laser small incision lenticule extraction (SMILE) in eyes with high astigmatism and its impact on visual quality. BMC Ophthalmol. 2019;19:151. https://doi.org/10.1186/s12886-019-1153-7.

12. Ning J, Zhang L. Comparison of Scheimpflug tomography, Placido disc, and combined Placido Scheimpflug in the measurement of pupil offset in myopic population. Front Med (Lausanne). 2024;11:1490674. https://doi.org/10.3389/fmed.2024.1490674.

13. McAlinden C, Khadka J, Pesudovs K. A comprehensive evaluation of the precision (repeatability and reproducibility) of the Oculus Pentacam HR. Investig Ophthalmol Vis Sci. 2011;52:7731–7. https://doi.org/10.1167/iovs.10-7093.

14. Keller PR, van Saarloos PP, Yellachich D. Computer simulation of centration effects on corneal-topography analysis of excimer laser photorefractive keratectomy ablations. Cornea. 1997;16:54–63.

15. Meng X, Ding H, He H, Yang Z, Chen X, Hu S, et al. Distance of corneal vertex and effective optical zone margin following keratorefractive lenticule extraction in myopic astigmatism. Transl Vis Sci Technol. 2025;14:21. https://doi.org/10.1167/tvst.14.5.21.

16. Mrochen M, Kaemmerer M, Mierdel P, Seiler T. Increased higher-order optical aberrations after laser refractive surgery: a problem of subclinical decentration. J Cataract Refract Surg. 2001;27:362–9. https://doi.org/10.1016/s0886-3350(00)00806-3.

17. Ranganathan P, Hunsberger S. Handling missing data in research. Perspect Clin Res. 2024;15:99–101. https://doi.org/10.4103/picr.picr_38_24.

18. Reinstein DZ, Archer TJ, Potter JG, Gupta R, Wiltfang R. Refractive and visual outcomes of SMILE for compound myopic astigmatism with the VISUMAX 800. J Refract Surg SLACK Incorp. 2023;39:294–301. https://doi.org/10.3928/1081597X-20230301-02.

19. Bteich Y, Assaf JF, Gendy JE, Awwad ST. Keratorefractive lenticule extraction using the Ziemer FEMTO LDV Z8 platform (CLEAR): one-year results. J Refract Surg. 1995;40:e898-905. https://doi.org/10.3928/1081597X-20241016-01.

20. Lee H, Roberts CJ, Arba-Mosquera S, Kang DSY, Reinstein DZ, Kim T. Relationship between decentration and induced corneal higher-order aberrations following small-incision lenticule extraction procedure. Investig Ophthalmol Vis Sci. 2018;59:2316–24. https://doi.org/10.1167/iovs.17-23451.

21. Moshirfar M, Hoggan RN, Muthappan V. Angle kappa and its importance in refractive surgery. Oman J Ophthalmol. 2013;6:151–8. https://doi.org/10.4103/0974-620X.122268.

22. Xie M, Deng Y, Sun C, Qiu L, Tang J. Higher-order aberrations and visual quality after incision lenticule extraction surgery with intraoperative angle kappa adjustments between small and large kappa patients: a 2-year follow-up. Indian J Ophthalmol. 2023;71:1849. https://doi.org/10.4103/IJO.IJO_3017_22.

23. Mosquera SA, Verma S. Optimum asymmetric spatial and temporal distribution of femtosecond laser pulses in refractive surgery. J Eur Opt Soc. 2026;22:24. https://doi.org/10.1051/jeos/2026012.

24. Bueeler M, Iseli HP, Jankov M, Mrochen M. Treatment-induced shifts of ocular reference axes used for measurement centration. J Cataract Refract Surg. 2005;31:1986–94. https://doi.org/10.1016/j.jcrs.2005.03.068.

25. Pesudovs K. Involvement of neural adaptation in the recovery of vision after laser refractive surgery. J Refract Surg. 1995;21:144–7. https://doi.org/10.3928/1081-597X-20050301-08.

26. Artal P, Chen L, Fernández EJ, Singer B, Manzanera S, Williams DR. Neural compensation for the eye's optical aberrations. J Vis. 2004;4:281–7. https://doi.org/10.1167/4.4.4.

Journal:	**40123**
Article:	**1437**

Author Query Form

Please ensure you fill out your response to the queries raised below and return this form along with your corrections

Dear Author

During the process of typesetting your article, the following queries have arisen. Please check your typeset proof carefully against the queries listed below and mark the necessary changes either directly on the proof/online grid or in the 'Author's response' area provided below

Query	Details Required	Author's Response
AQ1	Author names: Please confirm if the author names are presented accurately and in the correct sequence (given name, middle name/initial, family name) for authors [Ji Eun Keum, Tae Keun Yoo]. Also, kindly confirm the details in the metadata are correct.	
AQ2	Kindly check citation of Table 1.	