

Impact of Pre-Suction Corneal Contact Area on Postoperative Refractive Outcomes in SMILE Surgery: A Retrospective Study

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Objective: To investigate the relationship between corneal contact area before suction initiation and postoperative refractive outcomes in SMILE surgery.

Methods: A retrospective study was conducted in the refractive department of Shanghai Aier Eye Hospital. Eligible patients who underwent SMILE surgery between January and May 2023 were included. Preoperative and postoperative visual acuity and refractive outcomes were assessed at 1 and 3 months. The pre-suction corneal contact area was quantified using Adobe Photoshop.

Results: A total of 53 patients (28 males, 25 females; mean age, 25 years) were enrolled. A significant positive correlation was found between the pre-suction corneal contact area and postoperative refraction (Spearman's $r = 0.65$, $p < 0.05$). Receiver operating characteristic (ROC) curve analysis indicated an area under the curve (AUC) of 0.803 (Std. Error = 0.066, $p = 0.001$), indicating good predictive ability for overcorrection, with the optimal threshold identified at 70%.

Conclusion: Pre-suction corneal contact area plays a critical role in the refractive outcomes of SMILE surgery. Optimizing this parameter may reduce the risk of overcorrection and enhance surgical precision and patient satisfaction.

Keywords: SMILE, refractive surgery, corneal biomechanics, corneal contact area

Introduction

Small-Incision Lenticule Extraction (SMILE) has emerged as a promising refractive surgery technique in which a femtosecond laser is used to create and extract an intrastromal lenticule.^{1,2} This procedure offers biomechanical advantages³ and reduces corneal denervation^{4,5} compared to traditional methods.

Several perioperative factors have been reported to affect surgical outcomes, including suction loss and decentration, which are among the leading causes of suboptimal postoperative vision.⁶ During SMILE, suction is employed to stabilize the eye, ensuring accurate lenticule creation. The corneal contact area before suction initiation could affect corneal biomechanics and, consequently, the refractive outcome.

Previous studies have explored various factors affecting SMILE outcomes, but the specific impact of pre-suction corneal contact area has received little attention.

However, the optimal pre-suction corneal contact area remains an area of interest and investigation. While the manufacturer generally recommends maintaining a contact area of 80%-90%, there is a lack of empirical evidence defining an optimal range.

Understanding how variations⁷ in corneal contact area influence the stability of lenticule creation and separation is crucial for refining surgical techniques and improving postoperative refractive results. This study aims to determine the relationship between pre-suction corneal contact area and postoperative refractive outcomes in SMILE surgery.

Methods

Study Design and Patients

A retrospective study was conducted involving 53 patients (106 eyes) with myopia and/or astigmatism, who underwent small-incision lenticule extraction (SMILE) surgery at Shanghai Aier Eye Hospital between January and May 2023. All procedures were performed by the same experienced surgeon.

The study aimed to evaluate whether the proportion of pre-suction corneal contact area is associated with post-operative refractive predictability. We hypothesized that a smaller contact area would be associated with less favorable refractive outcomes.

Inclusion and Exclusion Criteria

Inclusion criteria were as follows: age between 18 and 32 years, stable refractive error (manifest refractive spherical equivalent [MRSE] change ≤ 0.50 D) for over 1 year within the past 2 years, and discontinuation of contact lens wear for at least 2 weeks before corneal tomography. Exclusion criteria included inadequate preoperative corneal pachymetry (less than 500 μm), residual stromal bed thickness after SMILE less than 280 μm , corneal tomographic abnormalities such as keratoconus or pellucid marginal degeneration, corneal scars, pregnancy or lactation, and ocular comorbidities like cataract, glaucoma, or ocular inflammation.

Ethical Considerations

This study adhered to the tenets of the Declaration of Helsinki and received approval from the Institutional Review Board of Shanghai Aier Eye Hospital (Approval No. SHAIER2025YN010). Written informed consent was obtained from all patients for the use of their anonymized data.

Surgical Procedure

All SMILE procedures were performed under topical anesthesia using the VisuMax femtosecond system (Carl Zeiss Meditec, Jena, Germany) with standardized parameters of 130 μm cap thickness, 140 nJ power, and 3 mm corneal side-cut length. The planned optical zone diameter was 6.5 mm, and the cap diameter was 7.5 mm. The small-cone package (500 kHz laser, standard mode) was applied in all cases to ensure consistency across patients.

Measurement of Pre-Suction Corneal Contact Area

The corneal contact area before suction initiation was automatically captured by the VisuMax system and exported as TIFF images (Figure 1). Image analysis was performed using Adobe Photoshop CC (Adobe Systems, San Jose, CA, USA) with standardized pixel-based segmentation. Two independent observers repeated the measurements on a random subset of 20 eyes to evaluate reproducibility. Both intra- and inter-observer intra-class correlation coefficients (ICCs) exceeded 0.90, indicating excellent reliability. Patients were divided into two groups according to the proportion of corneal contact area relative to the total corneal surface: Low contact group: $\leq 70\%$ and High contact group: $>70\%$. The cutoff value of 70% was determined using receiver operating characteristic (ROC) curve analysis.

Clinical Examinations

Comprehensive ophthalmic examinations were performed preoperatively and at 1-month, and 3-month postoperative visits, including: uncorrected and corrected distance visual acuity (UCVA, CDVA), manifest and cycloplegic refraction, intraocular pressure (Goldmann applanation tonometry), slit-lamp biomicroscopy and dilated fundus examination, corneal tomography (Pentacam, OCULUS Optikgeräte GmbH), and contrast sensitivity assessment. A single experienced optometrist with over 20 years of clinical practice conducted all refraction measurements.

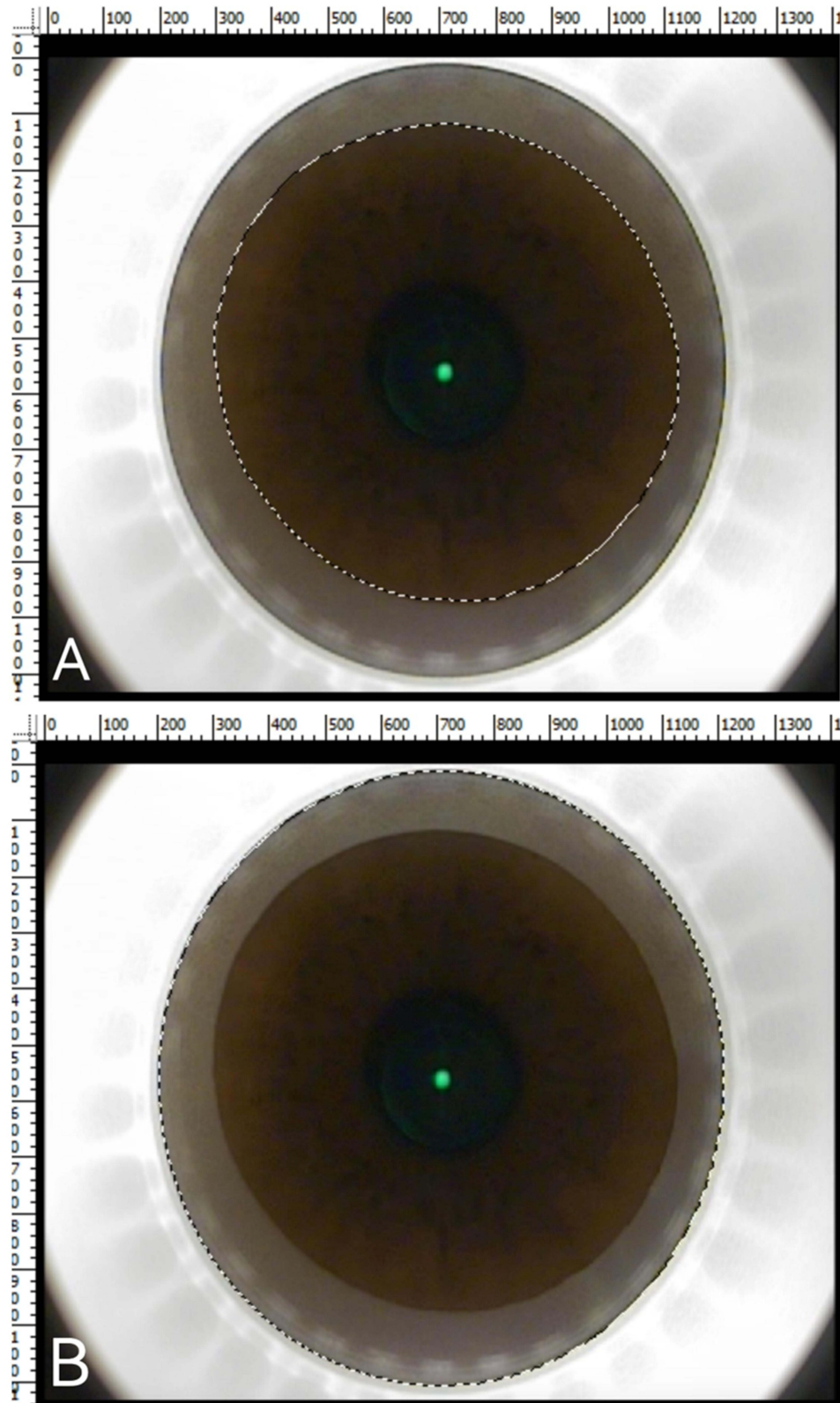


Figure 1 Calculation of pre-suction corneal contact area as the proportion of the dotted region to the total corneal area. (A) Calculation of the corneal contact area (delineated by the dashed line). (B) Calculation of the total corneal area (delineated by the dashed line). The corneal contact area ratio was calculated as A / B , where A represents the contact area and B represents the total corneal area.

Table 1 Comparison of 1 month Postoperative Parameters Between the Study Groups

| Preoperative Parameters | Study Group | | P-value |
|-----------------------------------|------------------|------------------|---------|
| | Contact Area<70% | Contact Area≥70% | |
| Sphere in diopter (mean±SD) | 0.1875±0.213 | 0.5179±0.249 | 0.000 |
| Cylinder in diopter, median (IQR) | -0.3875±0.249 | -0.3214±0.206 | 0.422 |
| MRSE in diopter (mean±SD) | -0.00625±0.169 | 0.35714±0.254 | 0.000 |
| CDVA in logMAR, median (IQR) | 1.10±0.102 | 1.14±0.093 | 0.224 |

Notes: Correlation Analysis: Correlation between pre-suction corneal contact area and postoperative spherical equivalent (Spearman's $r = 0.65$, $p < 0.05$).

Abbreviations: IQR, interquartile range; logMAR, logarithm of minimum angle of resolution; MRSE, mean refractive spherical equivalent; SD, standard deviation.

Postoperative Medication

The postoperative medication regimen included topical corticosteroids (0.1% Fluorometholone Eye Drops, Santen) for 1 month (four times a day for the first week, tapered weekly), topical antibiotics (0.5% Levofloxacin Eye Drops) four times daily for 1 week, and lubricants (Systane Ultra Eye Drops) four times daily for 3 months.

Outcomes

The primary outcome was postoperative refractive predictability, defined as the difference between attempted and achieved MRSE at 1 month. Secondary outcomes included CDVA, safety index, and contrast sensitivity changes. Spearman correlation analysis was performed to evaluate the relationship between pre-suction corneal contact area and postoperative refractive outcomes (Table 1). Linear regression was used to quantify the effect size, and Receiver Operating Characteristic (ROC) curve analysis was conducted to determine the optimal threshold for corneal contact area in predicting overcorrection.

Statistical Analysis

Statistical analysis was performed using SPSS version 10.0 (SPSS Inc., Chicago, IL, USA). Data normality was assessed using the Shapiro–Wilk test. CDVA values were converted from Snellen acuity to logMAR for analysis. Continuous variables were presented as mean \pm standard deviation (SD), and categorical variables as counts and percentages. Student's *t*-test or Mann–Whitney *U*-test for continuous variables, χ^2 -test or Fisher's exact test for categorical variables. Spearman correlation coefficient was performed to evaluate the association between pre-suction corneal contact area and postoperative refractive outcomes. Multivariable linear regression was used to quantify the effect of contact area while adjusting for potential confounders (age, preoperative MRSE, central corneal thickness). Additionally, Receiver Operating Characteristic (ROC) curve analysis was conducted to determine the optimal cutoff value of contact area, with sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) calculated using the Youden index. A *p*-value < 0.05 was considered statistically significant.

Results

Demographics

A total of 53 patients (106 eyes) were included, comprising 28 males and 25 females, with a mean age of 25.0 ± 3.2 years (range: 18–32 years). Baseline demographic and preoperative clinical characteristics are summarized in Table 2. No significant differences were observed between the low ($\leq 70\%$) and high ($> 70\%$) corneal contact groups regarding age, sex distribution, preoperative MRSE, or central corneal thickness ($p > 0.05$).

Table 2 Comparison of Preoperative Parameters Between the Study Groups

| Preoperative Parameters | Study Group | | P-value |
|--|------------------|------------------|---------|
| | Contact Area<70% | Contact Area≥70% | |
| Age, median (IQR) | 24 (18–32) | 26 (18–32) | 0.275 |
| Gender, n | | | |
| Male | 30 | 28 | 0.172 |
| Female | 24 | 24 | 0.301 |
| Sphere in diopter (mean±SD) | −3.32±0.53 | −3.14±0.41 | 0.183 |
| MRSE in diopter (mean±SD) | −4.27±0.61 | −3.97±0.57 | 0.194 |
| Contact area (%) | 61.10±3.608 | 80.10±4.610 | 0.000 |
| Flat keratometry in diopter (mean±SD) | 42.21±1.009 | 42.58±1.28 | 0.234 |
| Thinnest pachymetry in μm (mean±SD) | 549.20±19.155 | 540.21±24.335 | 0.296 |
| CDVA in logMAR, median (IQR) | −0.041±0.040 | −0.057±0.035 | 0.048 |

Notes: Demographics: Baseline characteristics of the 53 patients included in the study. CDVA presented in logMAR units (0 = 20/20 Snellen).

Abbreviations: IQR, interquartile range; logMAR, logarithm of minimum angle of resolution; MRSE, mean refractive spherical equivalent; SD, standard deviation.

Visual and Refractive Outcomes

At both 1 and 3 months postoperatively, the majority of eyes achieved uncorrected distance visual acuity (UDVA) of 20/20 or better. Postoperative MRSE was closer to the intended correction in the high-contact group compared with the low-contact group (data shown in Table 1). No significant complications were observed during surgery or follow-up.

Correlation Analysis

Spearman correlation analysis demonstrated a significant positive correlation was found between the proportion of pre-suction corneal contact area and postoperative MRSE at 1 month ($r = 0.65$, $p < 0.05$). Larger contact area was correlated with smaller residual refractive error (Table 1).

Regression Analysis

In the multivariable linear regression model including age, central corneal thickness, and preoperative MRSE, pre-suction corneal contact area showed a positive association with postoperative spherical equivalent but did not reach statistical significance ($\beta = 0.447$, $p = 0.346$). Although the variance inflation factor (VIF) values indicated no multicollinearity among the included variables, the limited sample size may have reduced the statistical power to detect an independent effect (Table 3).

Table 3 Multivariable Linear Regression Analysis of Factors Associated with Postoperative Spherical Equivalent (SE)

| Variable | β | 95% CI | β (Standardized) | t | P-value | VIF |
|--|---------|--------------|------------------------|-------|---------|-------|
| Age (years) | 0.005 | −0.006–0.017 | 0.090 | 0.906 | 0.367 | 1.038 |
| CCT (μm) | 0.001 | −0.002–0.003 | 0.054 | 0.540 | 0.590 | 1.035 |
| Km (D) | 0.031 | −0.019–0.082 | 0.123 | 1.220 | 0.225 | 1.068 |
| Pre-suction corneal contact area (ratio) | 0.447 | −0.489–1.383 | 0.096 | 0.947 | 0.346 | 1.060 |

Notes: Multivariable Regression Analysis: Results of the multivariable regression analysis adjusting for age, central corneal thickness, and K1.

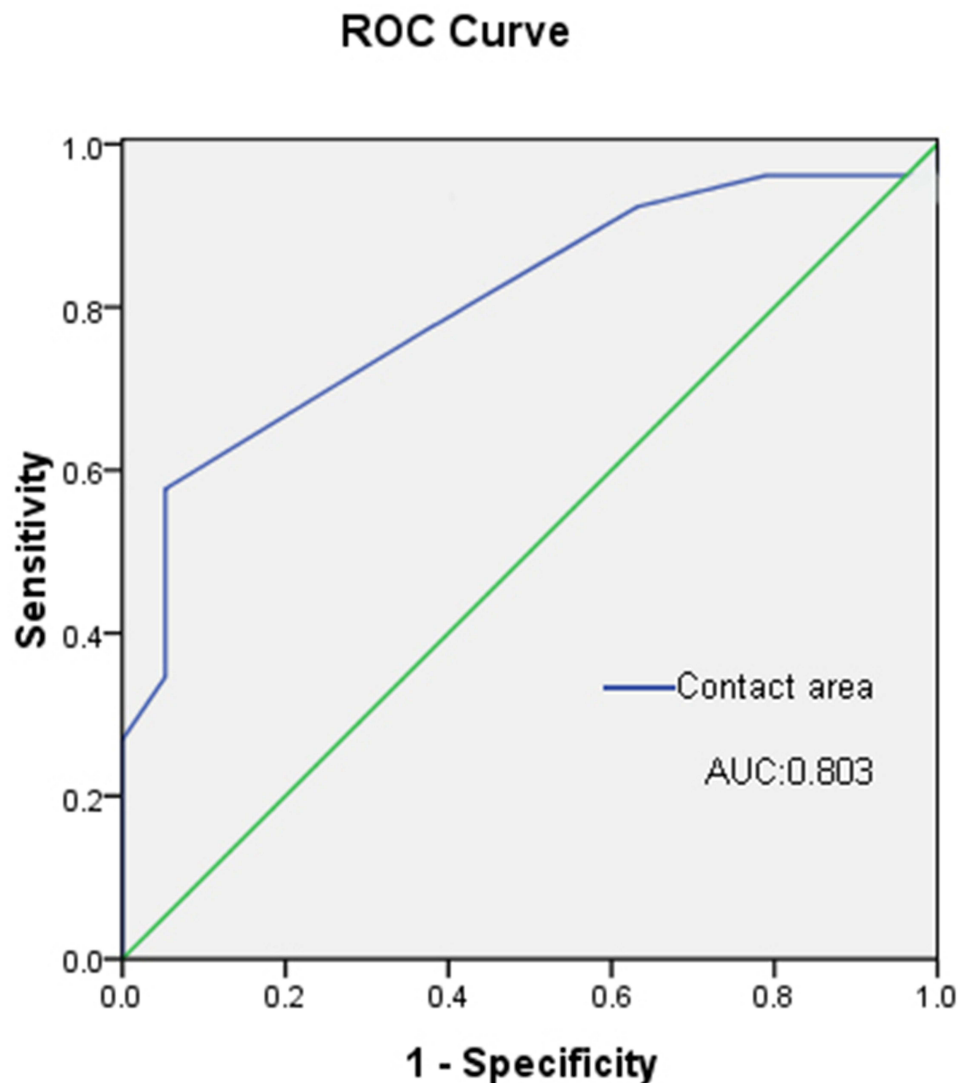


Figure 2 ROC curve of corneal contact area predicting postoperative overcorrection (AUC = 0.803).

ROC Analysis

The ROC curve analysis indicated an area under the curve (AUC) of 0.803 (Std. Error = 0.066, $p = 0.001$), with an asymptotic 95% confidence interval ranging from 0.674 to 0.931 (Figure 2). The optimal threshold was identified at 70% contact area, determined using the Youden index. At this cutoff, the sensitivity was 78.2%, specificity was 72.5%, positive predictive value (PPV) was 69.2%, and negative predictive value (NPV) was 82.2%, suggesting good discriminatory ability of corneal contact area in predicting postoperative overcorrection (Figure 2).

Discussion

The study demonstrates that larger corneal contact areas prior to suction initiation is associated with overcorrection following SMILE surgery. These results suggest that suction-induced corneal deformation may alter lenticule extraction accuracy (Table 1) and thereby affect refractive predictability. Although SMILE is considered less invasive compared to LASIK due to the absence of a flap, our results indicate that the biomechanics of corneal–suction interface remain critical for surgical outcomes.

The underlying mechanism is likely biomechanical. Previous studies have shown that central corneal thickness and intraocular pressure (IOP) are strongly correlated, with thicker corneas exhibiting greater IOP elevations during

suction.^{8,9} Similar effects are observed in LASIK, where suction ring pressure can alter corneal curvature and biomechanics.¹⁰ In SMILE, a larger contact area amplifies this effect by compressing a greater portion of the cornea, resulting in transient thinning and increased IOP. This deformation reduces corneal hysteresis, diminishing the tissue's ability to absorb and dissipate energy during femtosecond laser application.^{11–13} Consequently, laser–tissue interaction may become inconsistent, producing subtle variations in lenticule thickness and shape, and ultimately leading to overcorrection or residual refractive error.¹⁴

Comparisons with other corneal refractive procedures further highlight this mechanism. In LASIK, flap creation itself induces biomechanical weakening, whereas in SMILE the femtosecond laser is applied within an intact corneal cap. This theoretically preserves corneal strength, but also makes outcomes more dependent on the uniformity of suction and lenticule cutting. Studies on corneal biomechanics after LASIK versus SMILE have reported higher corneal hysteresis preservation in SMILE.¹⁵ However, our findings suggest that this advantage may be partly offset when suction contact is excessive, as increased compression alters corneal rigidity before cutting. Thus, optimizing suction parameters may be particularly relevant for SMILE.

From a clinical perspective, these findings highlight the importance of optimizing suction parameters to minimize excessive contact. Although manufacturer guidelines recommend a corneal contact area of 80–90%, our data suggest that a threshold of approximately 60–70% may achieve better refractive predictability by reducing biomechanical stress during the procedure. Real-time feedback on contact area could allow surgeons to individualize suction levels for each patient, taking into account baseline corneal thickness, biomechanics, and refractive error. The integration of automated image analysis or intraoperative monitoring into femtosecond systems may therefore enhance procedural consistency and safety in the future.

Another consideration is suction loss, which can occur at various stages of SMILE and necessitates redocking. Previous studies have shown that immediate reapplication without parameter adjustment does not significantly affect outcomes.^{16,17} However, our findings suggest that changes in corneal contact area during redocking may influence refractive predictability. Contact area could therefore serve as an additional parameter in deciding whether adjustments are needed after suction loss.

In the multivariable regression analysis, pre-suction corneal contact area lost its statistical significance as an independent predictor of postoperative spherical equivalent after adjusting for age, central corneal thickness, and preoperative MRSE. This result may be attributed to the relatively small sample size, which could reduce the statistical power of the model. Moreover, some degree of intercorrelation among ocular biometric parameters might dilute the independent effect of corneal contact area, even though variance inflation factors (VIFs) indicated no obvious collinearity. Importantly, the consistent trend of positive association between larger contact areas and postoperative overcorrection across both univariable and multivariable models suggests a potential predictive role. These findings highlight the need for larger prospective studies with more balanced covariate distributions to validate the independent contribution of pre-suction corneal contact area to SMILE refractive outcomes.

Implications

These findings highlight the critical importance of optimizing corneal contact area in SMILE surgery to enhance refractive outcomes. Proper management of corneal contact areas can improve surgical precision and patient satisfaction. Future research is needed to establish comprehensive guidelines for ideal contact area parameters to further refine surgical techniques and outcomes.

Limitations

This study is limited by its retrospective design and relative small sample size, which may affect the generalizability of the results. In addition, corneal contact area was measured by a single observer, and inter-observer reproducibility was not assessed. Finally, we did not account for inter-individual differences in corneal biomechanics, such as baseline corneal hysteresis or elasticity, which could also influence outcomes. Future prospective studies with larger cohorts and standardized measurement protocols are needed to confirm the optimal contact area threshold and validate its role in

improving surgical predictability. Such studies will help confirm the optimal contact area for minimizing complications and achieving the best possible refractive outcomes.

Conclusion

The pre-suction corneal contact area is a crucial factor influencing refractive outcomes in SMILE surgery. Adjusting this parameter can enhance surgical precision, leading to improved patient satisfaction and reduced risk of complications. Understanding and optimizing the contact area are essential for achieving the best possible results in SMILE surgery.

Ethics Statement

This study was reviewed and approved by the Ethics Committee of Shanghai Aier Eye Hospital. Written informed consent was obtained from all participants prior to their inclusion in the study. All procedures involving human participants were conducted in accordance with the ethical standards outlined in the Declaration of Helsinki and its later amendments.

Disclosure

The authors declare that they have no conflicts of interest in this work.

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