Comparison of Postoperative Safety, Efficacy, and Visual Quality after SMILE for Myopic Patients with Different Corneal Thicknesses

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ABSTRACT

Purpose: To investigate the safety, efficacy, and visual quality of small incision lenticule extraction (SMILE) in different corneal thickness patients with myopia or myopic astigmatism.

Methods: This prospective cohort study included 191 right eyes of 191 patients. Eyes were divided into three groups according to preoperative central corneal thickness (CCT) (Preoperative central corneal thickness (CCT) was the group indicator.) There were 31 eyes in the thin cornea group (CCT ≤500 μm (l), TC), 94 eyes in the moderate corneal thickness group (CCT ≥501 um (l) and ≤550 um (l), MD) and 66 eyes in the thick cornea group (CCT ≥550 um (l), TK). Comparisons in uncorrected (UDVA) and best-corrected distance visual acuity (BDVA), manifest refractive spherical equivalent (SE), preoperative mesopic/photopic contrast sensitivity (CS), ocular higher-order aberrations (HOAs) at a 6mm analytical pupil diameter, and visual quality questionnaires were made (performed) among the three groups during the postoperative six months. Subgroup analyses were made based on preoperative SE.

Results: The safety indices at six months were 1.15 ± 0.18, 1.14 ± 0.17, and 1.18 ± 0.17, respectively (p = 0.374), and the efficacy indices at six months were 1.07 ± 0.25, 1.12 ± 0.22, and 1.11 ± 0.21, respectively (p = 0.599). The postoperative SE was -0.07 ± 0.52D, -0.14 ± 0.38D, and -0.05 ± 0.46D after SMILE in the three groups, respectively (p = 0.376). No significant difference was found in mesopic/photopic CS, HOAs, and visual quality among different corneal thickness groups and SE groups. Postoperative SE and efficacy indices were the lowest in thin cornea eyes with ultra-high myopia (over -9.00 D).

Conclusions: SMILE provides comparable safety, efficacy, and visual quality results in different corneal thickness patients. Those with myopia higher than -9.00 D had less efficacy after surgery, especially in thin cornea patients.

Introduction

The importance of safety in refractive surgery cannot be overemphasized. Few cases of postoperative keratoectasia after SMILE have been reported, featuring in (delete “in”) relatively thin residual stromal beds, abnormal corneal topographies (subclinical keratoconus), and thin cornea (central corneal thickness less than 500 μm preoperatively. The safety and efficacy of refractive surgery are the major concerns for thin cornea patients.

SMILE derives (offers) good efficacy, predictability, and stability in patients with low to moderate myopia. It has been reported to have comparable or higher visual quality, better preservation of ocular surface microenvironment, and corneal biomechanical strength than the other corneal refractive surgeries. However, whether preoperative corneal thickness affects the surgical design followed by the compromise of visual quality is still controversial.

Materials and methods

Subjects

This is a prospective cohort study, consecutively enrolling myopic candidates in the optometry center of Eye and ENT hospital from December 2017 to November 2019. This study adhered to the tenets of the Declaration of Helsinki and was...
approved by the institutional review board of Eye and ENT hospital. The right eyes of the participants were divided into three groups according to the central corneal thickness (CCT) examined by Pentacam HR: thin cornea (CCT ≤500 μm, TC group), moderate corneal thickness (CCT ≥501μm and ≤550 μm, MD group) and thick cornea (CCT >550 μm, TK group). The inclusion criteria consisted of an age range of 17–45 years, a stable refractive status of less than 0.25D change for the past two years, suspension of rigid gas permeable contact lens (RGP) for more than three weeks, or soft contact glasses for more than two weeks, and bilateral best-corrected distance visual acuity (BDVA) better than or equals to 20/25. The exclusion criteria consisted of acute or chronic conjunctival or corneal inflammation, serious dry eye complaints, any kinds of cataracts, glaucoma, or untreated fundus disease that might further deteriorate the visual acuity and visual quality.

**Examination**

All the patients underwent a set of examinations including uncorrected distance visual acuity (UDVA), BDVA, manifest refractive spherical equivalent (SE), corneal topography (with Pentacam HR, Wetzlar, Germany), contrast sensitivity (CS, with CGT-1000, Toyama, Japan) and ocular higher-order-aberrations (HOAs, with WASCA Analyzer, Jena, Germany) preoperatively and at postoperative 1, 3, and 6 months. The safety index was calculated as postoperative BDVA divided by preoperative BDVA, and the efficacy index was calculated as postoperative UDVA divided by preoperative BDVA. A subjective visual symptom questionnaire was conducted at postoperative six months.

**Surgical procedure**

The surgical procedure was described elsewhere. The parameters were designed as followed (follows): the cap thickness was 110 μm (μm), with a diameter of 7.5 mm (without astigmatism) or 7.6 mm (with astigmatism). The lenticule diameter range in the current study was 5.1–6.6 mm. All the procedures were conducted by an experienced surgeon (JHD).

**Statistical analysis**

Only the data from the right eye of every patient were taken into analysis. Continuous variables were shown as mean±standard deviation or meridian and interquartile range (IQR), while categorical variables were presented as numbers (percentage). One-way analysis of variance (ANOVA) followed by Bonferroni post-hoc was used to compare the normally distributed data among three groups; if not normally distributed, Kruskal–Wallis tests were applied and the meridians were compared. Differences between groups at all follow-up times were analyzed using ANOVA for repeated measurements. Correlating factors of postoperative SE were conducted with multivariable linear regression analysis. A double-sided p value of less than 0.05 was rendered significantly different.

**Results**

The current study enrolled 191 patients (191 right eyes), and the mean age of patients was 27.3 ± 5.6 years (range: 18–49), including 62 males (mean age 25.1 ± 5.7 years) and 129 females (mean age 27.8 ± 6.4 years). Preoperative clinical characteristics are provided in Table 1. There were no significant differences in age, sex, and preoperative refractive error in the three groups.

**Safety**

Figure 1(A) showed that five eyes (5.3%) in the MD group and four eyes (6.1%) in the TK group lost 1 line of BDVA at postoperative six months, while no eyes in the TC group lost 1 line of BDVA or more. The six-month safety indices in the three groups were 1.15 ± 0.18, 1.14 ± 0.17, and 1.18 ± 0.17 (p = 0.374).

**Efficacy**

Figure 1(B) showed that five eyes (16.2%) in the TC group, four eyes (4.3%) in the MD group and three eyes (4.5%) in the TK group had UDVA less or equal to 20/25 at six months, respectively. The six-month efficacy indices in the three groups were 1.07 ± 0.25, 1.12 ± 0.22, and 1.11 ± 0.21 (p = 0.599).

**Predictability**

In Figure 1(C,D), there were 74.2, 89.4, and 86.4% of eyes that had within ±0.50 D of the target correction, and 96.8, 98.9, and 94.5% of eyes that had within ±1.00 D of the target correction, respectively.

**Stability**

The postoperative SE at postoperative 1, 3, and 6 months in different corneal thickness groups were presented in Figure 1(E). Significant differences were found between preoperative SE and postoperative SE during the three follow-ups (p < 0.001). Intergroup differences in postoperative SE were not statistically significant.
Percentage of tissue altered (PTA) and modified percentage of tissue altered (mPTA) were calculated and compared in Figure 1(F). Residual stromal bed (RSB) was calculated by preoperative CCT – cap thickness (CT) – lenticule thickness (LT). PTA was 41.1 ± 2.4%, 41.4 ± 3.8%, and 38.6 ± 4.6% in the three groups (p < 0.001), and mPTA was 25.9 ± 2.6%, 27.4 ± 3.8%, and 25.6 ± 4.6% in the three groups, respectively (p = 0.018).
Subgroup analysis

Subgroup analysis was performed in Table 2. The efficacy index was 0.65 ± 0.14, 1.07 ± 0.08, and 0.83 ± 0.12 in ultra-high myopia, respectively. No significant difference was found in the efficacy index in eyes with moderate to high myopia. In low myopic eyes, the efficacy index in the TC group was even better (1.35 ± 0.14) than those in the MD group (1.11 ± 0.08) or TK group (1.17 ± 0.09).

Lenticule diameter (LD) was correlated with both preoperative SE and preoperative corneal thickness. LD in the TC group was 6.11 ± 0.42 mm, 6.46 ± 0.24 mm in MD group and 6.55 ± 0.15 mm in TK group (p < 0.001). In ultra-high myopia, LD was significantly less (5.93 ± 0.30 mm) than that in high myopia (6.32 ± 0.32 mm), moderate myopia (6.53 ± 0.20 mm), and low myopia (6.59 ± 0.05 mm) (p < 0.001). Meanwhile, the residual stroma thickness index (RST index) was significantly higher in the TK group (6.53 ± 0.20 mm, and low myopia (6.59 ± 0.05 mm) (p < 0.001). Meanwhile, the residual stroma thickness index (RST index) was significantly higher in the TK group (6.53 ± 0.20 mm, and low myopia (6.59 ± 0.05 mm) (p < 0.001). Meanwhile, the residual stroma thickness index (RST index) was significantly higher in the TK group (6.53 ± 0.20 mm, and low myopia (6.59 ± 0.05 mm) (p < 0.001). Meanwhile, the residual stroma thickness index (RST index) was significantly higher in the TK group (6.53 ± 0.20 mm, and low myopia (6.59 ± 0.05 mm) (p < 0.001). Meanwhile, the residual stroma thickness index (RST index) was significantly higher in the TK group (6.53 ± 0.20 mm, and low myopia (6.59 ± 0.05 mm) (p < 0.001). Meanwhile, the residual stroma thickness index (RST index) was significantly higher in the TK group (6.53 ± 0.20 mm, and low myopia (6.59 ± 0.05 mm) (p < 0.001). Meanwhile, the residual stroma thickness index (RST index) was significantly higher in the TK group (6.53 ± 0.20 mm, and low myopia (6.59 ± 0.05 mm) (p < 0.001).

Visual quality

HOAs in the three groups at postoperative 1 and 3 months were all negatively correlated with preoperative SE in three groups, but only correlations between preoperative SE and postoperative HOA in the MD group were found at six months (Table 3). There was no significant difference in contrast sensitivity of different spatial frequencies (Figures 2 and 3) in all the groups. CS was not significantly decreased after surgery. Furthermore, there was no significant difference in a postoperative visual quality questionnaire at six months in all three groups.

Discussions

The current study showed that there was good safety, efficacy, and visual quality in eyes with different corneal thicknesses after small incision lenticule extraction (SMILE). Thin cornea patients with relatively high myopia are often associated with undercorrection due to a small optical zone diameter; however, we found that the efficacy and visual quality of SMILE in thin corneas were still promising in myopic eyes of less than –9.00 D. Moreover, there was no significant difference in the postoperative BDVA and safety indices, implying that SMILE also yields satisfying safety results in thin corneas.

Previous studies also showed good safety and efficacy profile for myopia correction in thin corneas (Supplemental Table 1). The mean safety index and the mean efficacy index were around 1 in all the studies, and the number of patients that were within ±0.50 D of intended to treat myopic astigmatism or within ±0.50 D of refractive error was above 60% and 70% in a short term after surgery. Preoperative corneal topographical examinations should be done with great prudence since it could ensure the safety and efficacy of the corneal refractive surgery and maximally reduce the risk of postoperative keratoconus, especially in thin cornea patients.

There was an increasing risk of ectasia when PTA > 40% or mPTA >25%,1,16–18 while no postoperative ectasia was found in patients included in our study. In contrast, no postoperative ectasia was found in patients included in our study despite the value of PTA and mPTA being beyond the upper limit. As was known, most of the corneal biomechanical strength lay in the anterior third of the stromal layer, and the thickness of the lenticule represented the loss of corneal biomechanical strength. Fu et al.25 illustrated patients with the same amount of lenticule removal could have a similar amount of biomechanical change, irrespective of preoperative corneal thickness. In other words, it is feasible to reduce the thickness of the lenticule to have the most preservation of the corneal biomechanical strength.

Postoperative fluctuations of HOAs were contributed to the wound healing process or off-axis decentration during corneal surgical procedure. However, whether a limited optical zone would result in attenuated visual quality was inconclusive. A theoretical study conducted by Alarcón et al.24 showed that the effect of the optical zone on visual quality was associated with the preoperative myopic degree. In epi-LASEK and LASEK, a larger optical zone diameter helped reduce spherical aberrations in high myopia, which could also be observed in LASIK (7.0 mm vs. 6.5 mm). Those with mesopic pupil diameter >7mm or a difference of optical zone and mesopic pupil diameter beyond 0.2 mm had significantly different visual outcomes after SMILE. However, a longer follow-up investigation showed no reduction in night vision or contrast sensitivity one year after SMILE.27 These reports did not investigate the difference in HOA in different corneal thicknesses or different myopic degrees.
We compared the difference in HOA in different corneal thickness groups, and we found no significant difference in glare or blurriness at night, ocular HOAs, or contrast sensitivity. It showed that visual quality after SMILE was comparable in eyes with different corneal thicknesses. As is known, corneal fiber remodeling is vibrant in the early postoperative period, and it is related to the correction of myopia correction. Therefore, we concluded that the fluctuations of HOA were mainly affected by preoperative SE in postoperative three months. However, even the algorithm has been optimized, it should be noted that functional optical zone was variable after surgery, and corneal epithelial growth after surgery was also one of the variables in the predictability of postoperative visual acuity and quality. More in-depth analyses of a proper optical zone diameter are warranted.

There were some limitations in the current study. First, the lack of a large cohort lowered the power of statistical analysis, and a longer follow-up period was required to investigate the long-term safety and predictability of the surgery in this special group. Second, the assessment of visual quality would be more complete with a comparison of both pre- and postoperative subjective visual quality questionnaires and in-depth research into HOA. Finally, since corneal properties changed significantly after refractive surgery,
correlations between corneal elastic or resistant properties and visual quality were worthy of further analysis. Therefore, further detailed research of visual quality and corneal biomechanical changes after SMILE in thin corneas was recommended.

In conclusion, SMILE has been proved to be a safe and efficacious procedure for myopic patients with thin corneas with myopia or myopic astigmatism of less than -9.00 D. Corneal thickness is also an important parameter to consider before coming to refractive surgery.

**Disclosure statement**

No potential conflict of interest was reported by the author(s).

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**Data availability statement**

The data that support the findings of this study are available on request from the corresponding author, Jinhui Dai, upon reasonable request.

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