

Comparison of four different techniques for lenticule dissection in small incision lenticule extraction

Man-Li Liu, Jia-Bei Zhou, Quan Liu, Chong-De Long

State Key Laboratory of Ophthalmology, Zhongshan Ophthalmic Center, Sun Yat-sen University, Guangdong Provincial Key Laboratory of Ophthalmology and Visual Science, Guangdong Provincial Clinical Research Center for Ocular Diseases, Guangzhou 510060, Guangdong Province, China

Co-first Authors: Man-Li Liu and Jia-Bei Zhou

Correspondence to: Quan Liu and Chong-De Long, Zhongshan Ophthalmic Center, Sun Yat-sen University, 54 Xianlie Road, Guangzhou 510060, Guangdong Province, China. drliuquan@163.com; longchd@mail.sysu.edu.cn

Received: 2025-05-22 Accepted: 2025-09-16

Abstract

• **AIM:** To compare the safety, efficacy, and technical demands of four lenticule-dissection techniques—dry dissection, continuous curvilinear lenticulorrhesis (CCL), wet dissection, and Viscoat-assisted dissection—in small incision lenticule extraction (SMILE), and to identify the method that minimizes tissue damage while preserving corneal clarity and early visual quality.

• **METHODS:** Twenty-eight eyes undergoing SMILE were assigned to four groups: dry dissection ($n=10$), CCL ($n=5$), wet dissection ($n=10$), and Viscoat-assisted dissection ($n=3$). Surgical interfaces were evaluated with *in vivo* confocal microscopy and the anterior and posterior lenticule surfaces were examined by scanning electron microscopy. Two masked observers scored surface quality using four predefined criteria (surface relief, regularity of surface structure, proportion of irregular surface, and location of irregular area). Intraoperative dissection time, operator-reported technical difficulty, and early postoperative corneal clarity/interface reaction were recorded.

• **RESULTS:** Mean anterior surface scores were: dry 10.87 ± 1.28 ; CCL 13.60 ± 0.51 ; wet 13.67 ± 0.48 ; Viscoat 4.22 ± 0.44 . Mean posterior surface scores were: dry 10.87 ± 1.53 ; CCL 13.60 ± 0.63 ; wet 14.10 ± 0.48 ; Viscoat 4.33 ± 0.50 . Lenticules obtained *via* CCL and wet dissection showed significantly better surface quality than those from dry dissection and Viscoat-assisted dissection (all $P<0.01$).

Wet dissection produced surface quality comparable to CCL while being technically easier to perform; dissection times were similar between dry (48.8 ± 3.58 s) and wet (48.4 ± 1.71 s) techniques ($P=0.123$). Viscoat-assisted cases demonstrated transient early postoperative corneal opacity that resolved as the viscoelastic was absorbed in 2wk; no significant early interface residue or lasting opacity was observed after wet dissection.

• **CONCLUSION:** Wet dissection achieves lenticule surface quality comparable to CCL but with lower technical difficulty and without significant early postoperative adverse effects, making it a safe, effective, and easily adoptable option for lenticule separation in SMILE. Lenticule surface-quality scoring provides a practical surrogate for assessing tissue damage across dissection methods.

• **KEYWORDS:** small incision lenticule extraction; lenticule dissection; scanning electron microscopy; *in vivo* confocal microscopy

DOI:10.18240/ijo.2026.05.13

Citation: Liu ML, Zhou JB, Liu Q, Long CD. Comparison of four different techniques for lenticule dissection in small incision lenticule extraction. *Int J Ophthalmol* 2026;19(5):933-938

INTRODUCTION

Small incision lenticule extraction (SMILE) surgery has gained widespread acceptance in corneal refractive surgery due to its predictability, safety, efficacy^[1-5], and absence of flap-lifting^[6-8]. In the standard technique that described by the previously papers^[9-11], first the eye undergoes femtosecond laser cutting to create a refractive lenticule. Next, a thin spatula is inserted through the peripheral incision dissecting the anterior and posterior surface of the lenticule. At last, the lenticule is subsequently grasped with non-toothed serrated microforcep and removed. However, it is reported that the mechanical disturbance could induce perioperative and postoperative complications, such as perforation of the cap^[4,12], lenticule rupture^[13], microdistortions in Bowman's layer^[14], interface debris^[15-16], retained lenticule^[17-18], long-term trends of decreasing corneal densitometry^[19-20], and persistent haze-like interface opacity^[21]. The more difficulty in separating the

tissue bridge of the surface of the lenticule, the more seriously complications would be induced. Therefore, some surgeon has been working to improve the technique of SMILE and tried to develop new methods to extract the lenticule with minimal invasiveness. The use of balanced salt solution—referred to as wet dissections associated with smoother lenticular surfaces, improved tear film stability, and faster visual recovery compared to conventional dry dissection^[22]. Zhao *et al*^[23-24] developed a new technique which they named “continuous curvilinear lenticulerrhexis” (CCL) exhibited good lenticule quality compare with traditional lenticule dissection, however, the CCL could not be widely carried out for it needs the surgeon with superior skill, and it can be performed only when the femtosecond laser system develops a good cellular effect of photodisruption. A safe and effective way for lenticule dissection is still needed. In the current study, we combined hydromechanics with mechanical removal to improve the technique of lenticule dissection.

PARTICIPANTS AND METHODS

Ethical Approval The study was conducted in accordance with the guidelines of the Declaration of Helsinki and approved by the Ethics Committee of Zhongshan Ophthalmic Center of Sun Yat-sen University. Oral approval was received at the ethics meeting on 28 October 2017, and document approval was obtained on 25 January 2018 (Approval Code: CCF20180125). All patients signed informed consent in accordance with the tenets of the Declaration of Helsinki.

Participants Twenty-eight eyes of 28 participants treated with SMILE were recruited for this study. All participants enrolled in the study were between the ages of 20 to 25y. Furthermore, gender was randomly distributed across all four study groups. The eyes were divided into four groups: 10 eyes in dry-dissection group (traditional lenticule dissection technique), 5 eyes in CCL group, 10 eyes in wet-dissection group, and 3 eyes in Viscoat-dissection group.

Surgical Techniques Surgery in both eyes of each patient was performed using the VisuMax[®] femtosecond system by a single surgeon (Liu Q) following standard procedures. Oxybuprocaine eye drops (Benoxil[®], Santen Pharmaceutical, Osaka, Japan) were used as preoperative anesthesia. The following laser parameters were used: the thickness of the cap was 120 μm, the diameter of cap was 7.5 mm, the refractive lenticule’s diameter was 6.5 mm, and the side cut for accessing the lenticule was set 90° apart at a circumferential width of 2.0 mm. Traditional lenticule dissection technique (dry-dissection group) was performed as described previously^[9]. The CCL technique was performed based on one used previously by Zhao *et al*^[24]: after the cap-lenticule interface was dissected through the side incision, a microforcep was used to grasp the edge of the lenticule and turn in a clockwise motion. The

lenticule was taken out when it separated completely.

In the wet-dissection group and the Viscoat-dissection group, the following steps were used: after the suction was released, a sharp spatula was used to dissect the lenticule edge of the lenticule through the side incision. Then, the balance-salt solution (wet-dissection group) or the viscoelastic substance (Viscoat-dissection group) was gently irrigated around the opened side incision. Last, a thin spatula (S33427 Geuder) which was wetted with the balance-salt solution (wet-dissection group) or the viscoelastic substance (Viscoat-dissection group) was inserted through the side incision and dissected the anterior and posterior surface of the lenticule. After the lenticule was separated completely, it was removed through the side incision with a forcep smoothly.

Surface Quality Analysis Ocular anterior segment examinations were examined by slit lamp microscopy and *in vivo* confocal microscopy. The surface morphology of the lenticule was analyzed using a scanning electron microscope (Quanta 200, FEI, Hillsboro, Oregon, USA).

The smoothness of both the anterior and posterior surfaces of the lenticule was assessed at 400× original magnifications. For each lenticule surface, three images were used to assess the surface quality. One was scanned at the center and the other two were scanned at the peripheral positions. An established scoring system was used to evaluate lenticule surface quality^[23,25-26]. Four criteria were used to assess and grade the surface morphology: surface relief, regularity of surface structure, portion of surface irregular, and position of the irregular area (Table 1). Surface quality was evaluated and scored by two investigators (Huan Wang and Li-Jun Cai) in a blinded fashion.

RESULTS

Lenticule Dissection Duration Time The duration of the lenticule dissection procedure was meticulously recorded and compared between the dry-dissection and wet-dissection groups. The total dissection time was 48.8±3.58s in the dry-dissection group and 48.4±1.71s in the wet-dissection group. An independent samples *t*-test revealed that this difference was not statistically significant ($P=0.123$).

Slit Lamp Photograph The immediate slit lamp examinations showed slightly corneal opacity in the Viscoat-dissection group (Figure 1) but not in the other three groups. After 2wk postoperatively, the cornea became clear again until the Viscoat was absorbed.

***In vivo* Confocal Microscope** At one day postoperatively, some activated and unusually large keratocytes were visible at the surgical interface in the dry-dissection group, CCL group, and the wet-dissection group comparing to normal cornea stroma. But some thick snowflake-like areas were found in the Viscoat-dissection group (Figure 2).

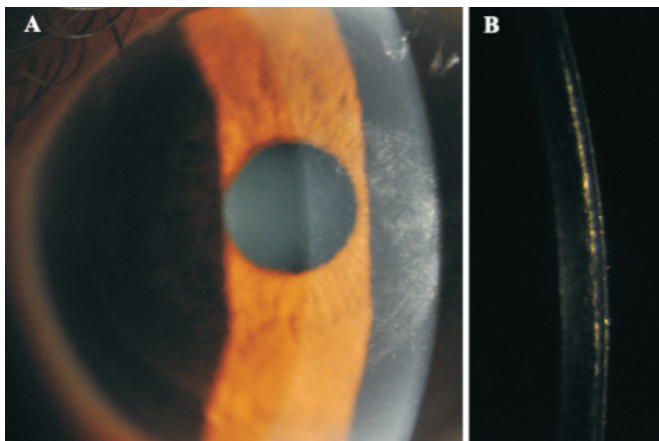


Figure 1 The appearance of immediate slit lamp photographs of one eye in Viscoat-dissection group A: Examined with a diffuse light; B: Examined with a slit of light.

Table 1 Criteria for evaluating surface characteristics

Criterion (400× original magnification)	Scores
Surface relief	
Very smooth	4
Smooth	3
Rough	2
Very rough	1
Regularity of surface structure	
Completely regular	4
Regular	3
Partially regular	2
Not regular	1
Portion of surface irregular	
Less than 10% of cut surface	4
11% to 25% of cut surface	3
26% to 50% of cut surface	2
More than 50% of cut surface	1
Position of the irregular area	
No irregularities	4
Peripheral only	3
Large region	2
All over	1

Scanning Electron Microscopy Figure 3 showed the ultrastructural characteristics of fractured tissue bridges in the lenticule surface. The corneal collagen fibres intercross enwound like a reel of thread, and some spherule bodies adhered to the broken ends of fractured fibres.

Representative scanning electron microscopy images of the anterior and posterior surface of lenticules were shown in Figure 4. The average scores of anterior surfaces were 10.87 ± 1.28 for the dry-dissection group, 13.60 ± 0.51 for the CCL group, 13.67 ± 0.48 for the wet-dissection group, and 4.22 ± 0.44 for the Viscoat-dissection group. For the posterior surfaces, the average score was 10.87 ± 1.53 , 13.60 ± 0.63 , 14.10 ± 0.48 , and 4.33 ± 0.50 for the four groups, respectively. The smoothness for the anterior and posterior lenticules

surfaces appeared the same in the CCL group and the wet-dissection group.

DISCUSSION

As we know, the VisuMax femtosecond laser system creates a near-infrared laser beam, it produces ultra-short pulses of light at a repetition rate of 200 kHz with energy density of approximately 300 nJ. Each pulse can focus at a precise depth in the corneal tissue, creating a photodisruption of stromal tissue, and eventually making the corneal tissue convert into a gas bubble. When millions of bubbles are created in the stroma, a cleavage plane is developed^[27]. Because the cellular effects of laser photodisruption vary with corneal depth, stromal anatomy and the femtosecond laser energy level^[28], it will result in different intrastromal dissection resistance and lead to different stromal bed quality. The tissue damage resulting from the SMILE lamellar dissection process will induce complications and cause visual symptoms.

Ivarsen *et al*^[4] performed a clinical control cohort study with 1800 SMILE eyes, they reported the incidence of complications including lenticule extraction difficulties in 34 eyes (1.9%), cap perforation in 4 eyes (0.22%), and lenticule extraction impossible in 1 eye (0.06%). Moshirfar *et al*^[29] reviewed 56 articles about 2345 SMILE eyes and summarized that the incidence of lenticule extraction difficulties was 1.5%, cap perforation was 0.3%, lenticule extraction impossible was 0.04%. Most of these reported complications were related to the dissection process, thus methods of dissection are of paramount importance to avoid iatrogenic injuries during SMILE procedure. And irregular cleavage of tissue bridges could associate with postoperative topographic irregularities. Hence it is crucial to find an efficient way to improvement the manual dissection process.

Since SMILE procedure has been created as a new refractive surgery modality, many surgeons have been working to make the dissection process easier, such as developed various types interface separation instruments^[30], used different cap thicknesses^[10,31], used different laser energy settings (including the laser cut energy index and the spot spacing)^[4], as well as created new dissection technique of SMILE^[24]. However, none of the measures seemed to ease the lenticule dissection and extraction or provide an even better quality dissection interface. Some of them may increase the incidence of complications and lengthen the learning curve.

CCL was a new dissection technique of SMILE which was developed by Zhao *et al*^[24]. The difference between CCL and the traditional lenticule dissection technique was in the process of separating the lenticule-stromal bed interface. Unlike the traditional lenticule dissection technique, after the cap-lenticule interface was separated with a spatula, the lenticule was directly torn clockwise in a continuous,

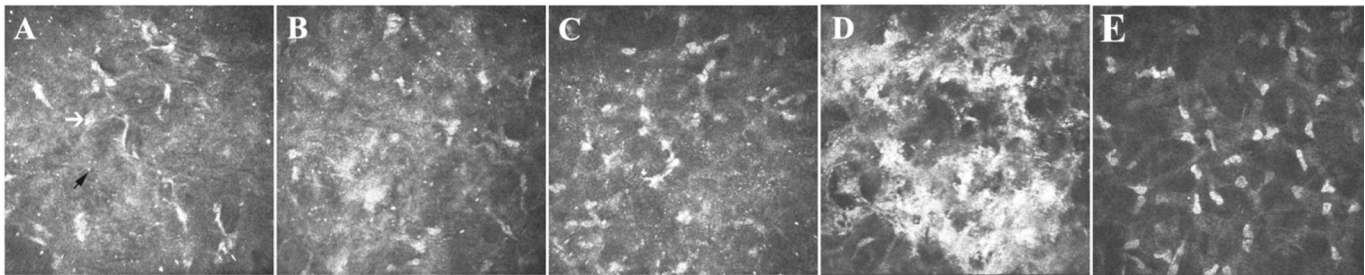


Figure 2 Representative *in vivo* confocal microscope images of the interface of eyes in four groups and healthy cornea A: Dry-dissection group, black arrow showed particulate matter and white arrow showed activated keratocyte; B: Continuous curvilinear lenticulerrhexis group; C: Wet-dissection group; D: Viscoat-dissection group; E: Normal corneal stroma.

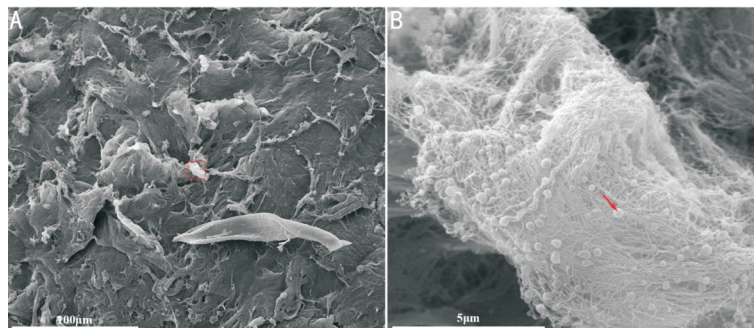


Figure 3 Scanning electron microscopic images of the ultrastructural characteristics of fractured tissue bridges A: The details of the fractured corneal collagen fibres ($\times 1000$); B: Red arrow showed the spherule body ($\times 24\ 000$).

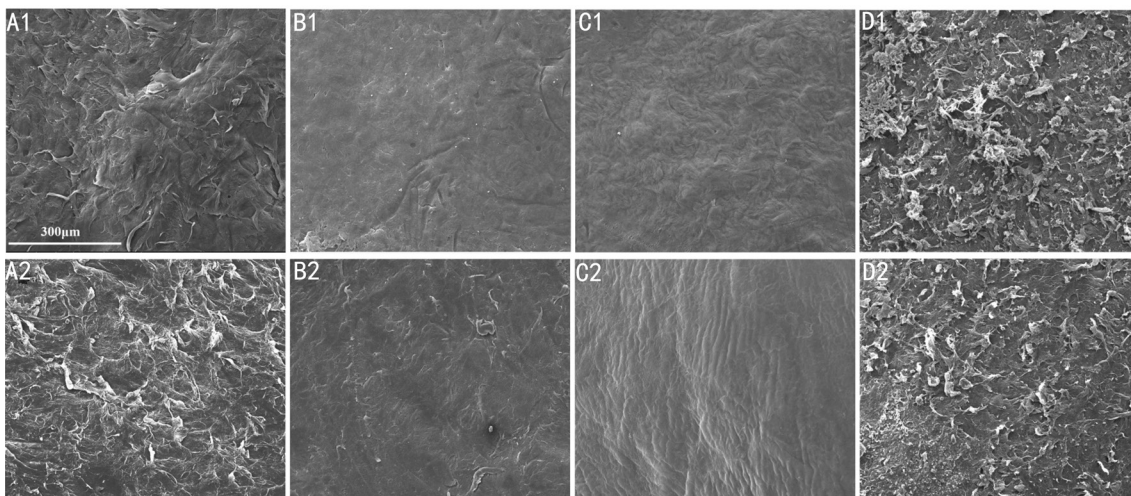


Figure 4 Scanning electron microscopic images of the surface of lenticule Anterior surface: A1: Dry-dissection group $\times 400$; B1: Continuous curvilinear lenticulerrhexis group $\times 400$; C1: Wet-dissection group $\times 400$; D1: Viscoat-dissection group $\times 400$. Posterior surface: A2: Dry-dissection group $\times 400$; B2: Continuous curvilinear lenticulerrhexis group $\times 400$; C2: Wet-dissection group $\times 400$; D2: Viscoat-dissection group $\times 400$.

circumferential manner by a microforcep and extracted in CCL technique. CCL technique might reduce the amount of manual intervention by using less instrumental contact. However, CCL was not recommended in the difficult lenticule dissection and extraction cases and not suitable for the new SMILE surgeons. In the present study, we compared four different surgical techniques for lenticule dissection. *In vivo* confocal microscopy revealed activated and unusually large keratocytes along with particulate matter attributable to femtosecond laser photodisruption and mechanical manipulation in the dry-dissection, CCL, and wet-dissection groups. In contrast, thick

snowflake-like areas were observed at the interface in the Viscoat- dissection group likely due to residual viscoelastic material between the interface. Scanning electron microscopy further showed intertwined corneal collagen fibres with spherical bodies adhering to fractured ends, suggesting possible tissue damage caused by tissue tearing during either laser cutting or mechanical dissection—particularly in techniques involving greater mechanical manipulation, such as dry-dissection.

In current study, which consisted of our first cases of adding hydromechanics during the traditional lenticule dissection

technique, we found that it made the lenticule dissection easier. This technique was a simple and safe technique without technical barrier for lenticule dissection. Compare with viscoat, the balance-salt solution was particularly well suited to serve as a dissection fluid: it was isoosmolar, well tolerated in cornea stromal space, and was rapidly cleaned up. No interface foreign matter accumulation was identified in the cap-bed interface at the immediate follow-up slit lamp examination. However, in the Viscoat-dissection group we found that the viscoat was hard to clean thoroughly in a small space, and we stop to use this method after performing 3 eyes. Viscoat residues could cause transient corneal opacity, and the patient was not satisfactory with the immediate visual result. This symptom will last for about 2wk until the viscoat was absorbed.

In our preliminary study, the wet-dissection group showed better quality of lenticule surface than the dry-dissection group. We speculated this might have contributed to the addition of surface tension of fluids and the decreasing of superficial friction of lenticule. The surface tension of fluids may weaken the difficulty in separating the tissue bridge and the decreasing of superficial friction may smooth the lenticule surface. Though, we found the surfaces of lenticule extracted by the CCL technique after SMILE were of better quality than the dry-dissection group as well. We believe this result might be more contributed to the good cellular effects of laser photodisruption, but not the dissection technique. Because in order to minimize the challenging dissection technique of CCL, we only performed the CCL in five cases with tight laser spot and homogeneous laser cut. In these cases, even without separation process, the lenticule can be extracted directly. The limitation to this study was the small number of cases. To establish the advantages of this described technique, large-scale studies and further comparative study with visual outcomes would be needed.

In summary, we describe our first results with a new dissection technique of SMILE. Our results indicate that with minor modifications of the traditional lenticule dissection technique, the wet-dissection technique was associated with less irregular cleavage of tissue bridges, and fewer disturbances to the corneal tissue. It will be particularly helpful in difficult cases that the dissection part was challenging.

ACKNOWLEDGEMENTS

We would like to thank Li-Jun Cai from Zhongshan Ophthalmic Center, Sun Yat-sen University and Huan Wang from South China University of Technology for their blinded scoring of surface quality. As they are not members of our research group, their evaluation provided an independent and objective assessment of the images.

Foundations: Supported by the Natural Science

Foundation of Guangdong Province (No.2017A030313680; No.2021A1515010513).

Conflicts of Interest: Liu ML, None; Zhou JB, None; Liu Q, None; Long CD, None.

REFERENCES

- 1 Jorge FA, Taguchi F, Campos M. The 18-month outcomes of a contralateral, randomized, prospective clinical trial comparing photorefractive keratectomy and SMILE for myopia. *J Refract Surg* 2023;39(3):180-186.
- 2 Zhou JH, Gu W, Gao Y, *et al.* Survival analysis of myopic regression after small incision lenticule extraction and femtosecond laser-assisted laser *in situ* keratomileusis for low to moderate myopia. *Eye Vis (Lond)* 2022;9(1):28.
- 3 Yildirim Y, Çakmak S, Sucu ME, *et al.* Comparative study of small-incision lenticule extraction and phakic intraocular lens implantation for the correction of high myopia: 6-year results. *J Cataract Refract Surg* 2021;47(2):221-226.
- 4 Ivarsen A, Asp S, Hjortdal J. Safety and complications of more than 1500 small-incision lenticule extraction procedures. *Ophthalmology* 2014;121(4):822-828.
- 5 Sun XT, Zhang Y, Mei XK, *et al.* Changes in posterior corneal elevation after small incision lenticule extraction for different myopic diopters. *Int J Ophthalmol* 2024;17(3):491-498.
- 6 Ang M, Gatinel D, Reinstein DZ, *et al.* Refractive surgery beyond 2020. *Eye (Lond)* 2021;35(2):362-382.
- 7 Chen KY, Chan HC, Chan CM. How effective is keratorefractive lenticule extraction surgery (KLEx) in reducing dry eye outcomes compared to LASIK: a systematic review and Meta-analysis. *J Refract Surg* 2025;41(8):e839-e854.
- 8 Liu C, Lin MT, Lee IXY, *et al.* Impact of corrected refractive power on the corneal denervation and ocular surface in small-incision lenticule extraction and LASIK. *J Cataract Refract Surg* 2023;49(11):1106-1113.
- 9 Shah R, Shah S, Sengupta S. Results of small incision lenticule extraction: all-in-one femtosecond laser refractive surgery. *J Cataract Refract Surg* 2011;37(1):127-137.
- 10 Jun I, Kang DSY, Roberts CJ, *et al.* Comparison of clinical and biomechanical outcomes of small incision lenticule extraction with 120- and 140- μ m cap thickness. *Transl Vis Sci Technol* 2021;10(8):15.
- 11 Shaaban Y, Badran T. Evaluation of the retinal nerve fiber layer and ganglion cell layer after laser-assisted *in situ* keratomileusis, femtosecond-laser *in-situ* keratomileusis, and small incision lenticule extraction using optical coherence tomography. *Clin Ophthalmol* 2025;19:973-984.
- 12 Hamed AM, Heikal MA, Soliman TT, *et al.* SMILE intraoperative complications: incidence and management. *Int J Ophthalmol* 2019;12(2):280-283.
- 13 Wang Y, Xie LX, Yao K, *et al.* Evidence-based guidelines for keratorefractive lenticule extraction surgery. *Ophthalmology* 2025;132(4):397-419.

- 14 Zhou XY, Qin B, Han T, *et al.* Long-term observation of higher-order aberrations and microdistortions in Bowman's layer after small incision lenticule extraction for the correcting myopia with spherical equivalent higher than -9.0 diopters. *Front Med* 2022;9:814810.
- 15 Moshirfar M, Zhang S, Pandya S, *et al.* Incidence and management of epithelial-related complications after SMILE. *Clin Ophthalmol* 2023;17:2777-2789.
- 16 Wang Y, Ma JN, Zhang L, *et al.* Postoperative corneal complications in small incision lenticule extraction: long-term study. *J Refract Surg* 2019;35(3):146-152.
- 17 Chung B, Kang DSY, Arba-Mosquera S, *et al.* Customized wavefront-optimized transepithelial photorefractive keratectomy for a retained lenticule fragment after primary SMILE. *J Refract Surg* 2020;36(6):395-399.
- 18 Fu GB, Pan JX, Yu H, *et al.* Delayed-onset diffuse lamellar keratitis due to retained SMILE lenticule: a case report and literature review. *Medicine* 2025;104(16):e42095.
- 19 Han XS, Xia F, Chen ZY, *et al.* Ten-year observation of corneal densitometry and associated factors following small incision lenticule extraction. *Int J Ophthalmol* 2024;17(3):485-490.
- 20 Wei RY, Li MY, Yang WM, *et al.* Corneal densitometry after small incision lenticule extraction (SMILE) and femtosecond laser-assisted LASIK (FS-LASIK): 5-year prospective comparative study. *Front Med* 2020;7:521078.
- 21 Kim BK, Chung YT. Clinical outcomes of epithelial basement membrane dystrophy after keratorefractive lenticule extraction. *J Cataract Refract Surg* 2024;50(6):558-564.
- 22 Weng SB, Yang XN, Liu F, *et al.* Development of a liquid dissection technique for small-incision lenticule extraction: Clinical results and ultrastructural evaluation. *J Cataract Refract Surg* 2018;44(9):1080-1089.
- 23 Zhao Y, Li MY, Sun L, *et al.* Lenticule quality after continuous curvilinear lenticulerrhexis in SMILE evaluated with scanning electron microscopy. *J Refract Surg* 2015;31(11):732-735.
- 24 Zhao Y, Li MY, Yao PJ, *et al.* Development of the continuous curvilinear lenticulerrhexis technique for small incision lenticule extraction. *J Refract Surg* 2015;31(1):16-21.
- 25 Wilhelm FW, Giessmann T, Hanschke R, *et al.* Cut edges and surface characteristics produced by different microkeratomes. *J Refract Surg* 2000;16(6):690-700.
- 26 Ziebarth NM, Lorenzo MA, Chow J, *et al.* Surface quality of human corneal lenticules after SMILE assessed using environmental scanning electron microscopy. *J Refract Surg* 2014;30(6):388-393.
- 27 Sekundo W, Kunert KS, Blum M. Small incision corneal refractive surgery using the small incision lenticule extraction (SMILE) procedure for the correction of myopia and myopic astigmatism: results of a 6 month prospective study. *Br J Ophthalmol* 2011;95(3):335-339.
- 28 Santhiago MR, Wilson SE. Cellular effects after laser *in situ* keratomileusis flap formation with femtosecond lasers: a review. *Cornea* 2012;31(2):198-205.
- 29 Moshirfar M, McCaughey MV, Reinstein DZ, *et al.* Small-incision lenticule extraction. *J Cataract Refract Surg* 2015;41(3):652-665.
- 30 Liu YC, Pujara T, Mehta JS. New instruments for lenticule extraction in small incision lenticule extraction (SMILE). *PLoS One* 2014;9(12):e113774.
- 31 Zarei-Ghanavati S, Jafarzadeh SV, Es'haghi A, *et al.* Comparison of 110- and 145- μ m small-incision lenticule extraction cap thickness: a randomized contralateral eye study. *Cornea* 2024;43(2):154-158.