TECHNIQUE

Corneal lenticule extraction assisted by a low-energy femtosecond laser

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A lenticule of intrastromal corneal tissue was cut together with 2 small incisions of 3.0 mm using a low-energy femtosecond laser system, FEMTO LDV Z8; 1 incision led to the posterior plane and 1 to the anterior, allowing dissection of the lenticule. When needed, recentering of the treatment area was possible without repeating the docking stage. Five eyes were operated, and a complete dissection and removal of the lenticule was achieved in all cases without any intraoperative complications. In addition, at postoperative day 1, all patients had a clear cornea. In conclusion, guided lenticule extraction using a low-energy femtosecond laser was a promising and easy procedure.

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Online Video

For the past 2 decades, laser-assisted in situ keratomileusis (LASIK) has become the standard procedure for corneal refractive surgery. More recently, small-incision lenticule extraction (SMILE) using the femtosecond laser has gained widespread acceptance.[1–5] Furthermore, SMILE has been reported to be comparable with femtosecond laser–assisted LASIK (FS-LASIK) for safety, efficacy, and predictability.[1–5]

SMILE was introduced in 2011 for the treatment of myopia and myopic astigmatism; it is a flapless technique in which a stromal lenticule is extracted through a small incision (2.0 to 5.0 mm).[6] The conventional technique of SMILE involves docking, femtosecond laser application, lenticule dissection from the surrounding stroma, and extraction.[6–8]

The advantage of this minimally invasive approach is maintaining integrity of the anterior cornea and protecting the subbasal innervation. Moreover, studies have suggested that using a SMILE technique resulted in better ocular surface stability and biomechanical strength when compared with FS-LASIK.[9–12] Despite the fact that SMILE has been proven a safe technique, it is not free of complications and has the disadvantage of a long learning curve for the surgeon when compared with conventional FS-LASIK procedures.[13–17]

The SMILE procedure requires greater surgical skill when compared with other refractive surgeries because the lenticule is manually removed through a small incision.[13–16] Removing the stromal lenticule in 1 piece can sometimes be challenging, especially in patients with low myopia and a thin lenticule.[18,19] Difficult lenticule dissection and extraction is the most common complication encountered during the initial learning curve, with an incidence of up to 16%.[13] Identifying the lenticule edge at the beginning of the surgery is crucial to ensure lamellar separation in the correct plane and to prevent lenticule misdissection.[13–16]

In a recent retrospective study, intraoperative complications were reported in 4.46% of cases, including suction loss, an opaque bubble layer, and tearing of the lenticule.[13] For this reason, different modifications of the surgical technique have been described to ease the process of lenticule extraction and minimize complications, such as Chung's swing technique, lenticulerhexis, lenticuloschisis, hydroexpression, and lenticule extraction guided by optical coherence tomography.[20–24] Several factors have been associated with early visual recovery after SMILE, including scanning pattern,[25] laser parameters (eg, spot distance and energy setting), and surgical skills.[26–29] Therefore, optimizing the laser parameters and modifying the surgical technique might improve postoperative visual acuity and recovery time. Suction loss is more commonly observed after SMILE because it is a low-pressure system (intraocular pressure approximately 35 mm Hg) with a longer suction time, when compared with FS-LASIK.[17] Unintended posterior plane dissection and tearing of the lenticule leads to difficulty of correctly identifying the anterior plane of the lenticule.[16]

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Table 1. Preoperative and postoperative visual acuity and refractive values of the patients.

Patient	UCVA*			CDVA*			Sphere
	Preop	Postop 1 wk	Postop 1 mo	Preop	Postop 1 wk	Postop 1 mo	Preop
1	1	0.1	0.1	0	0	0	−3.75
2	0.9	0	−0.1	0	0	−0.1	−3.25
3	0.7	0.2	0.1	0	0	0	−2.75
4	0.7	0	0	0	0	0	−3.00
5	0.7	0.1	0	0	0	0	−2.50

CDVA = corrected distance visual acuity; preop = preoperative; postop = postoperative; SE = spherical equivalent; UCVA = uncorrected distance visual acuity
*Logarithm of the minimum angle of resolution.

At the time of this study, the VisuMax Laser System (Carl Zeiss Meditec AG) was the only U.S. Food and Drug Administration–approved laser platform for the creation of an intrastromal lenticule. In addition to the VisuMax Laser System, the platform used in this study, the FEMTO LDV Z8 (Ziemer Ophthalmic Systems AG), received the Conformité Européenne mark. The FEMTO LDV Z8 is based on a low-energy concept, where the miniaturized scanning optic, integrated into the handpiece and its high numerical aperture, creates highly focused laser pulses achieving photodisruption in the low nanojoules range (<100 nJ). Thus, the advantages of the low-energy concept are the decreased stromal gas generation and an accurate laser focus. The repetition rate is of high frequency, in the range of several megahertz. Therefore, the pulses are not at spot distance from each other but are instead overlapping. The laser pulses are guided from the laser source through an articulated moveable arm to a handpiece that is adaptable in position and height with a very close working distance to the eye. In addition, the FEMTO LDV Z8 offers the possibility of recentering the treatment area after having performed the docking, which is not possible with the VisuMax Laser System.[30] The aim of this study was to describe and evaluate a new technique for lenticule extraction using a low-energy femtosecond laser, the FEMTO LDV Z8.

SURGICAL TECHNIQUE

The study followed the tenets of the Declaration of Helsinki, with the local institutional review board providing ethics approval (No. IRB00003251). All surgeries were conducted by the same surgeon (L.I.) between February 2019 and May 2019.

Preoperatively, the visual axis was marked by using the slitlamp. First, after a blink, a small slit was adjusted to the first Purkinje reflex. Second, the slit was widened on the horizontal axis and marked with ink at the limbus. Third, in the same manner, perpendicular to the horizontal axis, the vertical axis was marked (Figure 1).

After placing the patients on the surgical bed and administering topical anesthesia, patients were instructed to fixate on the fixation light to ensure accurate centration, and suction was initiated. However, if the surgeon was not satisfied with the centration of the docking, the femtosecond laser allowed recentering of the treatment area, including correction of cyclotorsion by manipulation on the monitor (Figure 2, A) without having to release the suction and start the docking procedure again. The 2 small incisions of 3.0 mm width were cut separately at 35-degree and 145-degree positions with an entrance angle of 90 degrees; each incision allowed for the posterior and anterior surfaces of the lenticule to be delineated directly and independently. The surgeon could adjust the distance between the incisions and the angle position for greater comfort and could decide if 1 or both incisions were cut and used. In all cases, the lenticule had a diameter of 6.5 mm without adding any additional thickness. During cutting of the lenticule, the applied vacuum level to the eye was 700 mbar, the same as used for LASIK flaps.

After laser application (Figures 2, B and C), first incision guiding to the anterior plane was opened using a small pointed spatula (Duckworth & Kent Ltd.), delineating the anterior edge of the lenticule. Then, the incision guiding to the posterior plane was opened in the same manner disconnecting the posterior edge of the lenticule. The anterior interface was then separated using a smooth spoon-shaped tip dissector (Duckworth & Kent Ltd.), and the posterior lenticular

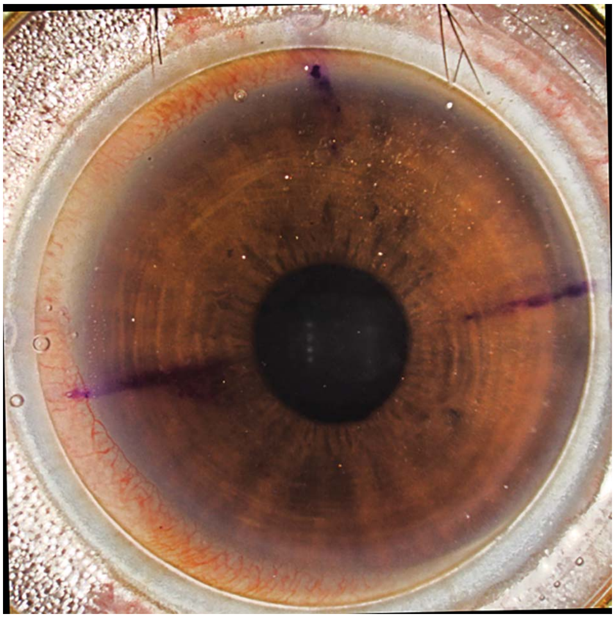

Figure 1. Marking of the visual axis (*purple*).

Table 1. Continued

Sphere		Cylinder			SE		
Postop 1 wk	Postop 1 mo	Preop	Postop 1 wk	Postop 1 mo	Preop	Postop 1 wk	Postop 1 mo
0	0	−0.75	−0.5	−0.25	−4.13	−0.25	−0.12
0	0	−0.75	0	0	−3.63	0	0
0.25	0	−0.25	−0.75	−0.50	−2.88	−0.62	−0.25
0	0	−0.25	−0.75	−0.50	−3.13	−0.37	−0.25
−0.25	0.25	−0.50	−0.50	−0.25	−2.75	−0.25	0

interface was separated in a similar fashion (Figures 2, D and E). Once both planes had been separated, the lenticule was removed from the cornea by grasping the edge of the lenticule or pushing it through the opposite incision (Figure 2, F) with a 23-gauge microforceps (Duckworth & Kent Ltd.). The technique is shown in Video 1 (see Supplemental Digital Content, available at http://links.lww.com/JRS/A94). After observing the integrity of the extracted lenticule on the cornea, the stromal bed was flushed with a balanced salt solution. Finally, massage was applied to the cornea.

RESULTS

The guided lenticule extraction technique was performed in 5 eyes of 5 patients: 3 women and 2 men. The mean age was 28.4 ± 3.9 years, and the mean sphere, cylinder, and spherical equivalents were −3.05 ± 0.48 diopters (D), 0.50 ± 0.25 D, and −3.30 ± 0.57 D, respectively. All patients had a remaining corneal residual bed thickness of 300 µm or more, measured by corneal tomography (Galilei G6, Ziemer Ophthalmic Systems AG). Table 1 summarizes the preoperative and postoperative visual acuities and refraction of the patients.

A complete dissection and removal of the lenticule was achieved in all cases without any intraoperative complications, and at postoperative day 1, all patients had a clear cornea, as shown in Figure 3. In the postoperative period, 1 patient presented with a mild stromal haze in the interface that resolved with 2 weeks of topical corticosteroids treatment 4 times a day (prednisolone acetate 1%; Pred Forte, Allergan). No other complications were observed during the follow-up period.

DISCUSSION

In this study, we reported for the first time, to our knowledge, a new guided lenticule extraction technique, using 2 small incisions of 3.0 mm that delineate directly the anterior and posterior edges of the lenticule, saving one of the most difficult and important steps of the standard technique. In all the patients, lenticule removal was complete without any intraoperative complications.

We believe that another important advantage of this technique is the ability to recenter the treatment area when necessary, without releasing the suction and starting a new docking procedure, permitting perfect centering that is less traumatic for the patient. It remains unclear whether our findings can be generalized to a general population. Therefore, further studies should investigate the safety and efficacy of the proposed technique. We believe that guided

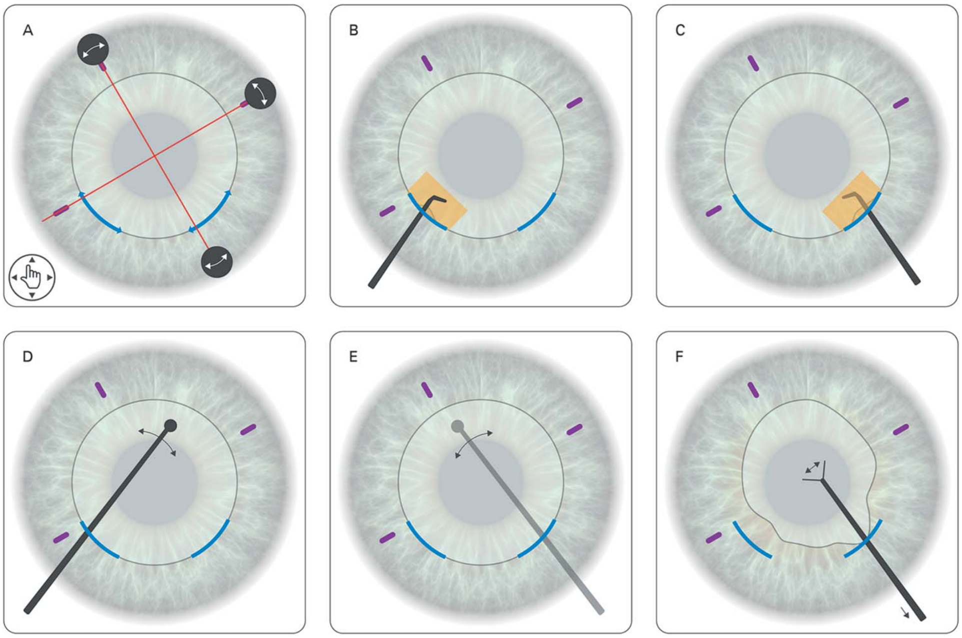

Figure 2. Guided lenticule extraction technique. *A*: Planning screen and centration screen (before cutting). Planed incisions (*blue*) and centration lines (*red*), including correction of cyclotorsion, are shown. The *blurred circle* represents the size of the planned lenticule. *B*: After cutting the lenticule, the left incision (*B*) and the right incision (*C*) were checked, and the anterior and posterior planes, respectively, were identified. Separation of the anterior plane (*D*) and posterior plane (*E*) was done by swiping the tool left and right in a circular manner. *F*: The lenticule was grabbed and pushed out through the other incision. This step was followed by a visual check of the lenticule integrity and a corneal massage.

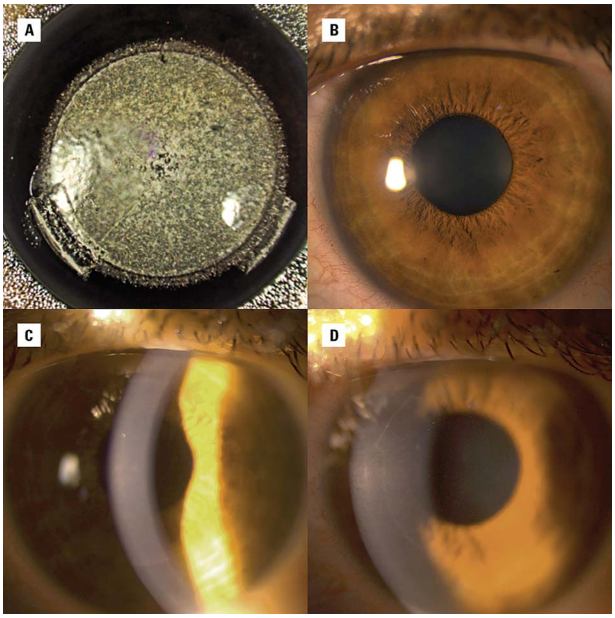

Figure 3. Evolution of a patient's right eye 24 hours postoperatively. *A*: Final result after emission of the low-energy femtosecond laser; 2 small incisions separated, and the left incision allowed the surgeon to delineate and dissect the anterior surface of the lenticule, whereas the right incision allowed the separation of the posterior surface of the lenticule. *B*: 24 hours postoperatively, the patient's cornea was completely clear. *C*: Upper and lower edges of the circumferential incision. *D*: The edge of the right incision of 3.0 mm width.

lenticule extraction with the low-energy femtosecond laser has the potential to shorten the learning curve for surgeons and lower the complication rate of lenticular extractions.

WHAT WAS KNOWN

- Small-incision lenticule extraction has been proven to be an effective and a safe technique, comparable with LASIK regarding visual acuity but requires a long learning curve.
- Of the complications related to lenticule extraction, the difficulty in identifying the anterior and posterior surfaces of the lenticule is one of the main causes of complications in small-incision lenticule extraction.

WHAT THIS PAPER ADDS

- Low-energy femtosecond laser technology was used for guided lenticule extraction, which allowed for centering of the treatment area without having to repeat docking.
- Guided lenticule extraction used 2 incisions that allowed for easy identification and separation of the anterior and posterior surfaces of the lenticule independently.

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