Small-incision Lenticule Extraction: Something to Smile About

by Dan Z. Reinstein, MD, MA, FRCSC | September 2012

With a US clinical trial underway and increasing momentum in Europe and Asia, all-femtosecond laser refractive surgery has the potential to one day dominate the refractive surgery market.

Over the last year I have found myself performing all-femtosecond intrastromal lenticule extraction for a growing proportion of my refractive surgery cases. Currently I use the ReLEx small-incision lenticule extraction (SMILE) procedure (developed by Carl Zeiss Meditec) on about 20% of my myopic patients, with excellent results. ReLEx SMILE involves using the femtosecond laser to create a precise lenticule within the corneal stroma and a small (2 mm to 4 mm) incision, through which the lenticule is manually removed.

Advantages of ReLEx SMILE

Intrastromal lenticule procedures have several inherent advantages over PRK or LASIK. All excimer laser procedures are subject to inconsistency based on differences in stromal hydration, laser fluence projection, reflection losses, and other environmental factors that are hard to control. In the ReLEx SMILE procedure, the only variable affecting tissue removal is the accuracy of the femtosecond laser's optomechanics, which are unaffected by environmental conditions. It is likely that with the ReLEx SMILE procedure there will be less need to develop personalized nomograms for different machines, locations, or surgeons.

RELEx SMILE

- ☑ Advantages
  - — Simple, all-femtosecond procedure
  - — No tissue ablation
  - — Environmental conditions do not affect treatment outcomes
  - — No flap-related risks
  - — Enables correction of higher myopia
  - — Low impact on corneal nerves, less postop "dry eye" than LASIK
  - — Preserves strong anterior stromal tissue; less biomechanical impact
  - — Flap-less minimally invasive "keyhole" procedure attractive to patients
- ☑ Future
  - — Lenticule profiles for hyperopia, presbyopia, and custom (wavefront- or topography-guided) correction
  - — Inserting donor lenticules into corneal pockets for refractive correction

In addition, the accuracy of ReLEx SMILE remains similar for low and high corrections, as the only variable is the distance between the upper and lower lenticular cuts. Since it is a relatively new technique, there is limited published data; but early reports are encouraging and appear to demonstrate increased accuracy in high myopia with ReLEx SMILE.[1]

Corneal Innervation and Dry Eye

The cornea is one of the most densely innervated peripheral tissues in the body. Nerve bundles within the anterior stroma grow radially in from the periphery toward

the central cornea. The nerves then penetrate Bowmans layer to create a network of nerve fibers known as the sub-basal nerve plexus, which branches out both vertically and horizontally between Bowmans layer and the basal epithelial cells.

In LASIK, sub-basal nerve bundles and superficial stromal nerve bundles in the flap interface are cut by the microkeratome or femtosecond laser—the only nerves spared are those that enter the flap through the hinge. Subsequent excimer laser ablation severs stromal nerve fiber bundles, with the overall result that patients experience dry eye symptoms and decreased corneal sensitivity while the nerves regenerate following surgery.

In ReLEx SMILE, on the other hand, the anterior stromal nerve plexus is disrupted significantly less, since there are no side cuts created. This should result in fewer dry eye symptoms and a faster recovery of postoperative patient comfort; and early results appear to support this hypothesis. We have measured corneal sensation in 39 eyes after ReLEx SMILE, and the results compare favorably with the average data taken from similar published LASIK studies. We have found corneal sensation recovering to baseline levels by 3 months after ReLEx SMILE, compared with 6 to 12 months after LASIK.

Corneal Biomechanics

In 2008, Randleman and colleagues measured the tensile strength of strips of stromal lamellae cut from different depths within the cornea, finding a strong negative correlation between stromal depth and tensile strength.[2] Specifically, tissue from the anterior 40% of the central corneal stroma was found to be the strongest, whereas tissue in the posterior 60% of the stroma was at least 50% weaker.

Recently, Knox Cartwright and colleagues performed a study on human cadaver eyes and found that creating just the side cut for a LASIK flap resulted in as much biomechanical strain as creating a whole flap, with a significantly greater increase in strain when the depth was increased from 90 to 160 microns.[3] On the other hand, the increase in strain was the same at both depths when a delamination cut only was performed. The authors concluded that vertical side cuts contribute to greater loss of corneal integrity than delamination cuts.

Since no anterior side cut is created in ReLEx SMILE, there will be slightly less increase in biomechanical strain with ReLEx SMILE than with thin-flap LASIK, and a significant difference in corneal strain compared to LASIK with a thicker flap.

Knowing that the increase in corneal strain with a delamination cut is independent of depth, and that a ReLEx SMILE lenticule can be created at any depth within the stroma, we can use our knowledge of the relationship between corneal strength and depth to create lenticules deeper in the corneal, thus preserving the stronger anterior cornea. In essence, moving the lenticule deeper increases the biomechanical integrity of the cornea after surgery—making it possible that ReLEx SMILE will extend the range of myopia correction beyond what is safely possible with excimer laser refractive surgery.

Surgical Technique

The surgical technique for ReLEx SMILE is remarkably straightforward and simple for an ophthalmic surgeon used to cataract and other intraocular surgery. I had done over 20,000 LASIK procedures before I performed ReLEx SMILE, so I assumed that I found the latter easy because of my LASIK experience. However, I recently trained a fellow, Dr. Kishore, at the Tilganga Institute of Ophthalmology in Kathmandu, Nepal. There we installed the

MEL80 excimer laser and the VisuMax femtosecond laser (both Carl Zeiss Meditec), as part of a humanitarian project supported by Carl Zeiss Meditec.

FIGURE 1 After being separated from the stromal cap and from the stromal bed, the lenticule is extracted with forceps via a 2.25-mm incision. *(Photo courtesy of Dan Z. Reinstein, MD.)*

On Dr. Kishore's very first day of refractive surgery, he operated on a ReLEx SMILE patient followed by a LASIK patient. Afterwards, it struck us just how much less complicated the ReLEx SMILE procedure was for him than the LASIK procedure because of the complexities of working with an excimer laser—including having to manage tissue hydration, room conditions, perfume, calibration, and centration of the tracker. While I have grown accustomed to performing LASIK and have reduced all of these to routine, for Dr. Kishore it was clearly much easier to do the ReLEx SMILE procedure. The steps are simply docking the patient, waiting for less than a minute of laser cutting, and then performing the manual lenticule extraction (Figure 1).

Possible Complications

Complications with ReLEx SMILE are few: the most likely being loss of suction during the lamellar cuts. In this event, the procedure can simply be aborted with no risk to the patient's vision. The surgery can then be performed at a later date, or the patient can be switched to LASIK or PRK. The other risk unique to ReLEx SMILE is incomplete lenticule removal; however, this can be managed by routinely checking the edges of the lenticule under the microscope immediately after removing it.

In the event that ReLEx SMILE patients do not achieve target refraction and require enhancement, options include PRK or, ideally, thin-flap LASIK. The latter is feasible so long as 1) the original ReLEx SMILE procedure was done with a thick enough cap to leave space for a new flap plus the ablation, 2) the maximum epithelial thickness is confirmed before making the new flap to avoid a buttonhole, and 3) the residual stromal thickness below the lenticule is above the standard LASIK safety limits (which is not necessary for a primary ReLEx SMILE procedure).

The Future of ReLEx SMILE

Currently, the VisuMax laser can be programmed to create lenticules that incorporate rotationally symmetric higher order aberrations, allowing spherical aberration to be compensated to some degree. However, true custom ablation, with wavefront or topography guided profiles, is outside the scope of the current hardware.

There are a number of new projects in the development pipeline at Carl Zeiss Meditec, including an aspheric lenticule for controlled spherical aberration induction, for use in high myopic corrections and for incorporating Laser Blended Vision. There is also work being done on developing a hyperopia lenticule profile.

Studies on extracted stromal lenticules that have been cryopreserved suggest their viability for re-use.[4] It is possible that these highly accurate lenticules may be inserted into a pocket incision created by the femtosecond laser in order to correct hyperopia—basically resurrecting epikeratophakia but now calling it "endokeratophakia."

THE BOTTOM LINE

With the ReLEx SMILE procedure in use internationally for more than a year, Carl Zeiss Meditec announced the initiation of an FDA clinical trial in early 2012. If and when it is approved in the US, there is good reason to believe that ReLEx SMILE may eventually come to challenge LASIK for the lion's share of the refractive surgery market. Our data suggests that the small incision used in ReLEx SMILE should result in better postoperative corneal sensation and less dry eye than LASIK, as the anterior nerves are left intact. In addition, with ReLEx SMILE, the strong anterior stromal tissue remains intact and can better contribute to the overall biomechanical strength of the cornea. Finally, this minimally invasive procedure is attractive to patients.

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