20 Years of LASIK: 10 Lessons Learned

These pointers on corneal biomechanics and optics can lead to happier patients postoperatively.

BY MARC MULLIE, MD, FRCSC

Since we began practicing LASIK in 1994, Gordon Balazsi, MD, and I have performed approximately 100,000 procedures. This article presents 10 lessons I have learned, the first five of which concern biomechanics and the last five corneal optics.\(^1\)

Through the years, I have used a number of excimer laser technologies, beginning with the Excimed 200 (Summit Technology; no longer available) for PRK and including most recently the Amaris (Schwind eye-tech-solutions). Microkeratome technologies have also evolved, from mechanical microkeratomes such as the Automated Corneal Shaper (ACS; Chiron) and the Hansatome (Bausch + Lomb) to femtosecond lasers. The most recent iteration of this evolution for me is the Femto LDV Z6 PowerPlus (Ziemer).

CORNEAL BIOMECHANICS

Lesson No. 1: LASIK can potentially weaken a normal cornea. LASIK creates a dormant weakened state in a normal cornea. Also, the flap never completely heals, which we know because we can relift a flap easily after 20 years. This is good in that it allows flap lifting when retreatment is needed; it is bad in that ectasia is a potential byproduct. The key word is potential; most post-LASIK corneas remain normal, but just in a dormant weakened state. Another potential complication of a corneal flap is epithelial ingrowth.

Lesson No. 2: A thin flap weakens the cornea less than a thick flap. The main advantage of a thinner flap is better corneal biomechanics, with fewer fibrils cut in the underlying corneal stroma. Additionally, there are fewer slipped flaps and folds with thinner flaps. In only 48 of the 100,000 eyes that we have treated has post-LASIK ectasia developed; 43 were performed with the ACS from 1994 to 2003, with flap thickness of 160 to 200 µm, and only five had flaps of 100 to 110 µm thickness (Figure 1).

Lesson No. 3: A femtosecond laser flap is stronger than a microkeratome blade flap. The femtosecond laser allows creation of better flap architecture. The laser can create a sidecut with a steep 90° angle, leading to a solid flap with a tight fit to the corneal bed—much like a manhole cover. The laser also makes flaps of uniform thickness; these are planar rather than meniscus-shaped as with a mechanical microkeratome. Also, the hinge can be located where we want it. All of these characteristics lead to fewer slipped or avulsed flaps and less epithelial ingrowth.

Lesson No. 4: Ectasia is caused by cutting fibrils in an eye at risk for post-LASIK ectasia or cutting too many fibrils in a normal eye. The result is thinning, bulging, and herniation of the wall of the eye. The difficulty for the surgeon lies in identifying the eye at risk, which may range from suspicious indices on tomography to forme fruste keratoconus (FFK). Another concern is that the cornea changes over the patient’s life, and tomography is merely a snapshot of this dynamic process. Therefore, selecting patients for LASIK has become an exercise in risk management. There is no reliable

POST LASIK ECTASIAS 1994-2014: 100,000 eyes n = 48 (32 pts)
- None in 5000 PRK EYES 1991-95 (many > -10)
- 43\^1/4 EYES: ACS 160-200u thick flaps 1994-2003
- 2 TO 12 YEAR LAG PERIOD AFTER LASIK
  - 38\^1/4 eyes > 5y after.
  - 14\^1/4 eyes > 10y after

Figure 1. Incidence of post-LASIK ectasia in 100,000 eyes: 1994 to 2014.

POST-LASIK ECTASIAS 1994-2014 PREOP TOPOGRAPHIES n = 48
43/48 EYES PRE-ORBSCAN (2003) ie PLACIDO ONLY
PLACIDO TOPOGRAPHY PREOP
- 15/48 NORMAL
- 15/48 SUGGESTION OF CRABCLAW
- 13/48 OTHER (MILD FFK)

Figure 2. Retrospective analysis of preoperative Placido-disc–based corneal topography showed abnormalities in about 65% of eyes.
index or foolproof method for detecting a cornea at risk for post-LASIK ectasia. Screening tests have improved, but they fall short of providing an index with hard numerical values.

From 1991 to 1995, before we adopted LASIK, we performed PRK in 5,000 eyes. None have developed ectasia. On the other hand, of the 48 cases of post-LASIK ectasia I have seen, 38 presented more than 5 years and 14 more than 10 years after LASIK. Most of these eyes (n=43) were operated in the days when only Placido-disc–based corneal topography was available. Looking back now at their topography results, one can see that 15 appeared normal, 15 had a suggestion of a crab-claw appearance, and 13 showed signs of mild FFK (Figure 2). Would these patients have undergone LASIK if more advanced diagnostics were available at the time? Perhaps not.

Will corneal collagen crosslinking (CXL) be the answer to ectasia? Is this a technology that should be used in all eyes undergoing LASIK, even normal ones? If we consider everyone to be at risk for ectasia, should we be doing LASIK at all? Is this an argument in favor of PRK over LASIK? Or will CXL save LASIK, as mitomycin C saved PRK? All of these questions remain to be answered.

Lesson No. 5: Prevent ectasia by performing preoperative Scheimpflug-based tomography. Shape indices are now the most important diagnostic tools, with Placido-based maps as back-ups. The cornea is an evolving shape, and these indices are biomechanical clues about its properties. Scheimpflug indices are based mostly on corneal shape, not power or curvature. Many surgeons do not take the time to study these maps adequately preoperatively or do not yet have the knowledge to properly interpret them. All surgeons who perform LASIK should have a Scheimpflug-based tomographer and learn what it can teach them.

Along with pachymetry and Placido-based topography, we look at eight Scheimpflug maps for each eye undergoing LASIK. Important shape factors include anterior and posterior elevation, anterior and posterior best-fit toric asphere, cone location magnitude index, thickness progression index, and eccentricity.

If preoperative Scheimpflug tomography reveals high indices with a strong suspicion of FFK, we do not touch the cornea. In appropriate cases, a phakic IOL may be an alternative. With moderate risk, we discuss PRK with the patient, and with low risk we consider LASIK. Still to be determined is the role of CXL in the event of moderate or high indices of suspicion.

With Scheimpflug tomography, about 20% of new patients in our practice show evidence of corneas at risk for post-LASIK ectasia. This is much higher than the statistic of 1 in 1,000 patients with keratoconus and FFK that is often cited. This may be because ours is a private refractive practice, but the numbers among the general population seem to be about 5% or 10% with keratoconus or FFK; the percentage is even higher among family members of patients with keratoconus.

CORNEAL OPTICS

Lesson No. 6: Good centration is mandatory.
Decentraions cause bad aberrations. These can be fixed; however, modern eye trackers are far from perfect and, therefore, a good fixation light is still valuable.

Lesson No. 7: Large optical zones are forgiving.
In the early years of LASIK, with 4.5-mm ablations, decentrations could lead to terrible aberrations. In 2014, optical zones of 7.5 mm and larger camouflage mild decentrations and prevent the edge of the pupil from catching the edge of the optical zone. Scotopic symptoms are now rarely problematic, and patient complaints of difficulty driving at night are minimal.

Lesson No. 8: In our experience, treatments based on corneal wavefront are best.
The large preponderance of optical aberrations (80%) are in the cornea. This is especially true of coma, which is independent of pupil size and accommodation state. Treating coma is more important than preventing spherical aberration. Scheimpflug-based tomographers, such as the Sirius (Schwind eye-tech-solutions), can generate corneal wavefronts to use as the basis for treatments to improve corneal optics. The results are excellent.

Lesson No. 9: Strive to create smooth optics.
This lesson has two parts.
Part No. 1: Respect the pupil fraction. The pupil fraction is defined as the fraction of the pupil area for which optical quality is reasonably good. A smooth pupil fraction is desirable. The pupil fraction is the most impor-
Lesson No. 10: Eliminate second-order aberrations, and do not ignore third-order aberrations. The second-order aberrations, sphere and cylinder, and the third-order aberrations, coma and trefoil, are more important to patients than fourth-order spherical aberration. Patients seek refractive surgery because they feel handicapped to their spectacles, and their main aim is to get rid of the second-order aberrations, not the fourth.

A purely spherical error of 0.30 D has the same negative effect as all higher-order aberrations combined in lowering the modulation transfer function curve, as Krueger and colleagues have observed. Humans are daytime animals; experiencing a few haloes around streetlights at night is better than being saddled with a -0.50 D spherical error postoperatively. Remember that the main goal of refractive surgery is to eliminate sphere and cylinder; a bit of added spherical aberration postoperatively is not the end of the world. Additionally, strive to treat coma and avoid creating it. The aim is to wipe out second-order aberrations and leave a smooth central cornea.

FURTHER THOUGHTS

If we learn these 10 lessons, on postoperative day 1 we will encounter a smiling patient who never returns with complaints. This patient is satisfied because he or she had the following: (1) a normal preoperative Scheimpflug tomography; (2) a 100-µm thick LASIK flap created with a femtosecond laser; (3) a well-centered ablation; (4) a large optical zone; (5) no residual myopia or astigmatism; and (6) smooth pupil optics postoperatively. This well-selected patient should also remain free of postoperative ectasia.

For continued success with LASIK, my dream is to acquire a diagnostic technology that can provide two things reliably: (1) a numerical index of suspicion for an eye at risk and (2) a prediction of corneal integrity over time. I doubt that these things will be forthcoming any time soon. Therefore, I wonder about the future prospects for LASIK. If we cannot address these biomechanical concerns, I predict that LASIK will soon be replaced by some other refractive option.

What procedure can replace LASIK? An obvious choice would be to return to PRK. There are a number of reasons to consider this: (1) With the use of Scheimpflug tomography, we are seeing a high incidence (5–20%) of abnormal corneas; (2) some seemingly normal corneas become ectatic only years after surgery; (3) we have seen no cases of ectasia in 5,000 eyes that underwent PRK from 1992 to 1995; (4) transepithelial PRK with mitomycin C is a different procedure from the one we used in earlier years; and (5) now there is the opportunity to add CXL to further reinforce the cornea. A second possibility is ReLEX SMILE (Carl Zeiss Meditec). This procedure is already in use at 200 sites worldwide, with excellent results reported after more than 90,000 procedures. The procedure, in which a small sliver of tissue is removed from a corneal pocket, should provide safer biomechanics with an all-femtosecond technique.

For now, however, remember the five pearls outlined in the Take-Home Message box for encountering happy patients postoperatively.

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<th>TAKE-HOME MESSAGE</th>
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<td>• Pearl No. 1: Pick the right patients.</td>
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<td>• Pearl No. 2: Establish realistic expectations; under-promise and over-deliver.</td>
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<td>• Pearl No. 3: Communicate!</td>
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<td>• Pearl No. 4: If a problem arises, admit it and try to fix it; maintain hope at all times, not defeat.</td>
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<td>• Pearl No. 5: Empathize. Being the patient’s friend is more important than informed consent.</td>
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