Point/Counterpoint:
Is Corneal Thickness a Risk F

Central corneal thickness as a pre-LASIK consideration.

BY LEE T. NORDAN, MD

Although LASIK has become a routine refractive surgical procedure performed worldwide, a small but significant number of these procedures result in corneal ectasia. Fortunately, surgeons can prevent many cases of post-LASIK ectasia by identifying and acting upon preoperative warning signs.

WHAT TO CONSIDER

The most important parameters to consider before performing LASIK are central corneal thickness, the central-to-inferior corneal thickness profile (at the 7-mm optical zone), and the presence or absence of corneal irregularities such as stromal-induced irregular astigmatism (mild existing ectasia) and asymmetric corneal steepening. Patients who do not meet the predetermined standards for these parameters may have an unacceptably high risk of developing post-LASIK ectasia. In essence, the surgeon must try to detect the presence of forme fruste corneal ectasia, a condition in which corneas that function normally preoperatively become too weak to withstand an increase in IOP and develop irregular astigmatism or ectasia postoperatively.

Surgeons usually use automated corneal topography to screen for forme fruste ectasia, but in some cases, a manual keratometer can detect mild amounts of irregular astigmatism. The pattern displayed by the automated topography is more important than the actual dioptric values, because specific dioptric values can usually be in a normal or abnormal zone when viewed in isolation. Because all ectatic corneas manifest irregular astigmatism, we must be aware that an eye that has even a mild degree of this deformity is predisposed to developing post-LASIK ectasia.

IDENTIFYING NORMAL VERSUS ABNORMAL CORNEAS

In order to identify an abnormal cornea that is functioning normally preoperatively, we need to understand the association between central corneal thickness, abnormal corneal pachymetry, and post-LASIK ectasia.

I believe that our experience with lamellar refractive surgery, LASIK, and keratomileusis during the past 40 years has provided us with a substantial but still incomplete amount of information for identifying corneas at risk, as evidenced by generally excellent results, some spectacular failures, and an increasing number of high-profile lawsuits concerning post-LASIK ectasia.

Surgeons' knowledge of corneal ectasia has increased by the following considerations.

• The advent of automated topography increased our awareness of corneal pellucid marginal degeneration. The condition appears to be more prevalent than previously

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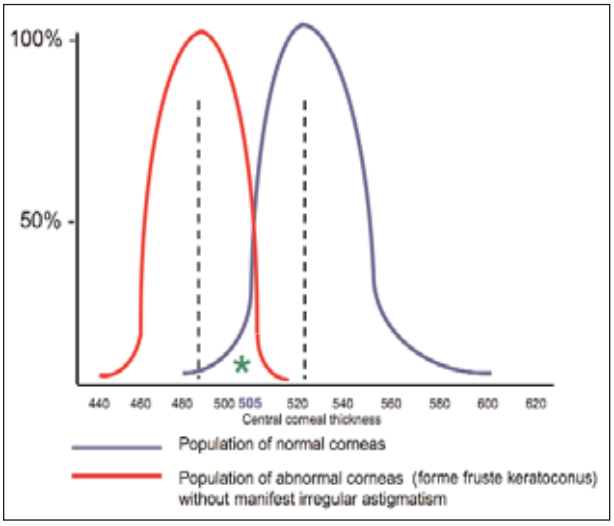

Figure 1. The bell curve distributions show the pachymetry of a normal adult cornea (blue line) and a cornea with keratoconus (red line). Notice the area of overlap between the two curves (asterisk), which indicates that an eye with a thinner central cornea has a greater chance of belonging to the forme fruste keratoconus corneal ectasia group than one with a thicker central cornea. The author created figure 1 based upon his data.

actor for Post-LASIK Ectasia?

The "500-µm rule."

BY WILLIAM B. TRATTLER, MD

For refractive surgeons, one important aspect of delivering optimal care is performing a comprehensive preoperative evaluation to determine if a patient is an appropriate candidate for LASIK. The screening process has changed over the years, especially as surgeons have gained a newfound understanding that certain preoperative findings may increase a patient's risk of developing post-LASIK ectasia. This article explores the risk factors surrounding the occurrence of this complication.

CORNEAL THICKNESS

Known Risk Factors

The medical literature has identified mild and advanced cases of keratoconus and corneal pellucid marginal degeneration as risk factors for post-LASIK ectasia, regardless of the depth of ablation.[1,2] Other potential independent risk factors include a residual stromal bed of 250 µm or less, younger age, and a family history of keratoconus.[3,4] Although some researchers have noted that the corneas of post-LASIK ectasia patients tend to be thinner than those of control subjects, the medical literature has not determined that thin corneas (< 500 µm) as an isolated finding increase the probability of ectasia.[5] Because many post-LASIK ectasia patients have pre-existing forme fruste keratoconus, keratoconus, and pellucid marginal degeneration, and these ectatic conditions tend to have thin corneas, it is not surprising that the average corneal thicknesses in post-LASIK ectasia cases are thinner than "average." Studies that try to determine if central corneal thickness is an independent risk factor must therefore exclude patients with pre-existing ectatic disorders.

Thin Corneas With Normal Topographies

As refractive surgeons continue to debate the role of corneal thickness in ectasia, one wonders how some doctors chose 500 µm as a dividing point for whether or not to proceed with LASIK. Lee Nordan, MD, of Carlsbad, California, provided one explanation when he wrote "Corneal thickness of 500 µm is more than three standard deviations from the norm. By definition, it is an abnormal cornea."[6] Dr. Nordan further noted, "virtually all corneas that are 490 µm thick have keratoconus, but those that are 600 µm thick are normal," before concluding that thinner corneas are at increased risk for post-LASIK ectasia. In my opinion, the aforementioned logic is flawed, because there is no evidence in the medical literature that thin corneas with otherwise normal topography have reduced integrity or have a greater risk of developing post-LASIK ectasia than thicker corneas. Because there is no exact relationship of corneal thickness to corneal strength, the fact that a cornea in a middle-aged person may be two or more standard deviations from average in regards to corneal thickness does not mean that the cornea is necessarily at an increased risk for developing keratoconus or post-LASIK ectasia. Otherwise, one would expect topographic abnormalities in virtually all corneas less than 500 µm. Because there are plenty of sub–500-µm corneas with normal topography, these thin corneas must have normal or even higher than normal biomechanical properties.[7]

Ethnicity

I also believe that Dr. Nordan's logic is imperfect because it does not account for ethnicity. Although the average corneal thickness for white patients is 550 µm, this value can vary among ethnic groups.[8] For example, black patients tend to have average central corneal thicknesses that are 20 to 30 µm thinner than those of white patients.[9,10] Following Dr. Nordan's logic, the minimum "magic number" below for which black patients are likely to develop ectasia would drop to between 470 and 480 µm. Furthermore, corneal thickness is an independent risk factor for corneal weakness, and there is no scientific literature that confirms an increased risk of keratoconus

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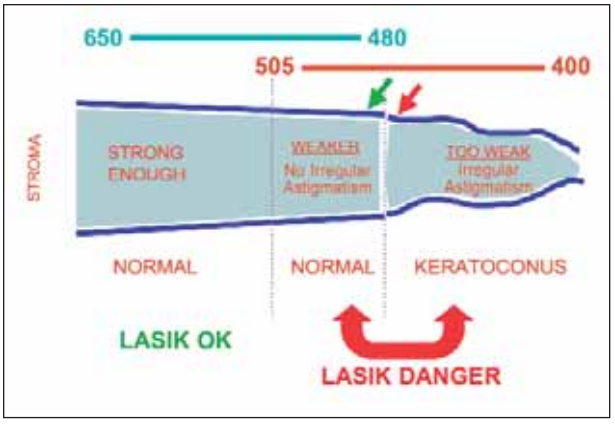

Figure 2. The association between the progression from normal corneal thickness to keratoconus and/or corneal pellucid marginal degeneration, with forme fruste corneal ectasia as the link between these two conditions. Within this continuum will lay corneas with a thin/normal thickness but abnormal stromal strength.

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thought only because we did not have a reliable way to diagnose early corneal changes. Many cases diagnosed as atypical keratoconus were really corneal pellucid marginal degeneration.

• Keratoconus and corneal pellucid marginal degeneration are probably different aspects of the same corneal pathophysiology (the cause of which is unknown) but with a different primary focus (inferocentral for keratoconus and generally inferior for corneal pellucid marginal degeneration).

• A healthy cornea with a central thickness of 300 µm can often maintain its functional shape either postinjury or after keratorefractive surgery without developing irregular astigmatism.

The term *forme fruste keratoconus* is really a misnomer when applied to a cornea with mild irregular astigmatism. In the past, it referred to mild keratoconus due to the presence of corneal irregular astigmatism. Corneas with true forme fruste keratoconus have a weakened stroma but no irregular astigmatism until after they undergo LASIK or another procedure that reduces the cornea's strength. Our task is to identify any parameters associated with an increased chance of identifying abnormal stromal strength.

With respect to the danger of post-LASIK ectasia, the cause of the corneal irregular astigmatism, whether keratoconus or corneal pellucid marginal degeneration, makes no difference.

A cornea is considered thin if its central pachymetry measurement is more than three standard-deviation units (between 6 and 20 µm) from the average of 520 µm. Within this range, a cornea has only a 5% chance of being statistically "normal." The standard deviation for the thinner aspect of corneal pachymetry is about 6 µm and 20 µm for the thicker aspect (Figure 1). Conversely, a cornea that measures 580 µm in its center (more than three standard-deviation units from

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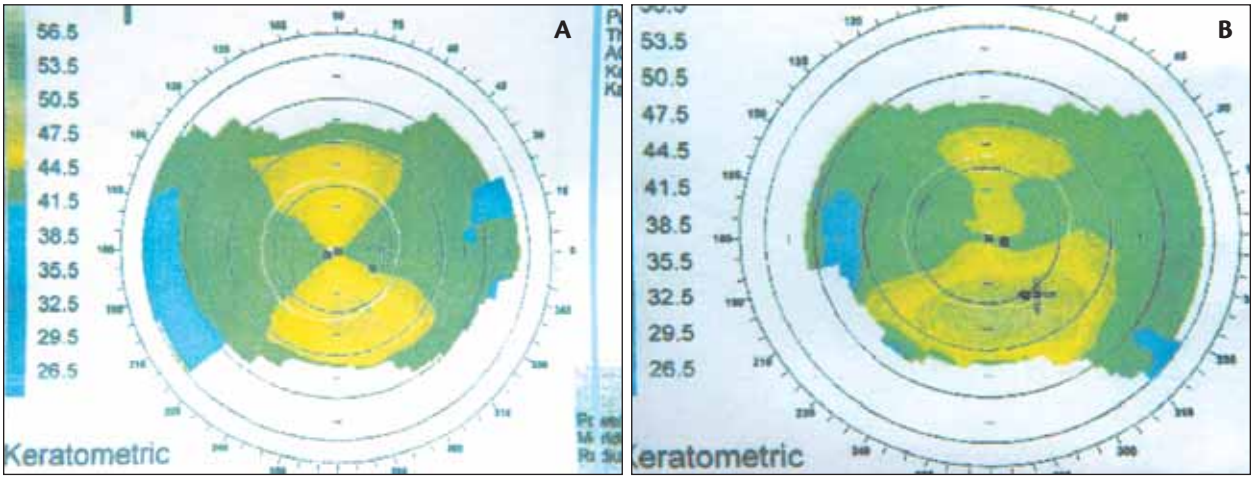

(Images courtesy of Ed Holland, MD.)

Figure 3. A cornea with regular astigmatism along with a localized, asymmetrical steepening inferiorly (all other corneal parameters were well within normal values) (A). This area of localized irregularity indicates that this portion of the cornea is steeper than the surrounding stroma, a phenomenon that does not occur in normal corneas. This cornea underwent LASIK and then progressed to corneal ectasia 6 years later. The automated topography of the other eye of the patient's inferior cornea (B) is clearly abnormal, with an increased amount of irregular astigmatism. This eye underwent LASIK and then progressed to corneal ectasia. Its corneal topography indicated severe corneal pellucid marginal degeneration.

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in black patients, even though they have thinner corneas than other ethnic groups.

Contact Lens Wear, Dry Eye, and Age

Even within ethnic groups, however, corneal thickness differs noticeably in relation to contact lens wear, dry eye, and age. Corneal thinning has been associated with long-term contact lens wear,[11] dry eye,[12,13] and increasing age.[14,15] There are therefore a variety of factors that affect corneal thickness.

LEARNING FROM EXPERIENCE

Real-world knowledge of LASIK outcomes in thin corneas with normal topographies is important. To date, retrospective studies have not found a relationship between thin corneas (< 500 µm) with normal topographies and post-LASIK ectasia, although more data and longer follow-up are needed.[16-18] On the other hand, post-LASIK ectasia has been reported in eyes with thick corneas but no other risk factors.[19] Anecdotally, two patients in my practice with thick corneas and otherwise normal topographies developed ectasia after LASIK.

We can potentially learn more about the relationship between preoperative corneal thickness and ectasia by conducting retrospective chart reviews. For example, in my database of post-LASIK ectasia cases, only five of 37 patients who developed postoperative ectasia after undergoing LASIK had central corneal thicknesses of 500 µm or less. Of these five patients, four had obvious forme fruste keratoconus. The single patient with thin corneas and normal topography had only stopped wearing his rigid gas-permeable contact lenses 1 week before surgery. Perhaps if he had discontinued wearing his contact lenses earlier, the true shape of his cornea would have been more apparent. Because this patient was also a high myope whose flap was created with a metal microkeratome fitted with a 160-µm head, and intraoperative pachymetry was not performed, he may have also developed ectasia due to excessive thinning of the stromal bed.

In this same database, 12 post-LASIK ectasia patients had preoperative pachymetries greater than 500 µm and normal topographies, although some of these ectasia cases had final residual stromal beds less than 200 µm.

WHO IS A CANDIDATE FOR LASIK?

Why are some surgeons limiting LASIK to eyes with corneal thicknesses greater than 500 µm? In my opinion, the answer is fear—not fear of an increased risk of ectasia, but fear of lawsuits. Additionally, I question the wisdom of refractive surgeons' promoting, in print and at the podium, a minimum of 500 µm as a safe corneal thickness for LASIK procedures, when there is no scientific evidence that corneal thickness, in isolation, is a risk factor for ectasia. By associating an unsubstantiated "magic number" of corneal thickness to a heightened risk of post-LASIK ectasia, we might make ourselves vulnerable to lawsuits for cases in any cornea of 499 µm or thinner.

Another important factor to remember when screening patients for LASIK is that the procedure is significantly different in 2007 from its initial incarnation. Many surgeons are now using the FS femtosecond laser (IntraLase Corp., Irvine, CA), which can consistently provide a customized smaller-diameter, thin, planar flap (LASIK performed in this manner was recently coined *sub-Bowman's keratomileusis* [SBK] by Steven G. Slade, MD, of Houston, and Daniel S. Durrie, MD, of Overland Park, Kansas[20,21]). John Marhsall, PhD, of London, United Kingdom, has conducted studies on the corneal biomechanics of SBK and found that these flaps do not reduce the integrity of the cornea to the same degree as thicker flaps created by a metal microkeratome. In 2007, many surgeons using metal microkeratomes are also targeting a thinner average flap thickness, and many surgeons are performing intraoperative pachymetry to ensure that an excessively deep flap is not accidentally created.

CONCLUSION

What is the next step? First, I suggest that refractive surgeons scientifically investigate whether or not a thin cornea is a risk factor for post-LASIK ectasia. R. Doyle Stulting, MD, PhD, of Atlanta, Georgia, has created an invaluable online database of reported cases of post-LASIK ectasia, available at http://www.ectasiaregistry.com, for peer review and analysis. With more cases available for analysis, we can collectively better understand and identify the various risk factors of ectasia.

In the meantime, scientific research does not currently support the hypothesis that eyes with thin corneas and normal topographies have an increased risk of developing post-LASIK ectasia. Therefore, evaluating LASIK candidates preoperatively with a careful assessment of an eye's topography is one of the most important steps for identifying patients that may be at increased risk for this complication. Surgeons can also use various scoring systems to quantify a patient's potential risk of developing ectasia.[5] Then, assuming that an eye is normal besides a thin cornea, and that a patient will have a sufficiently thick residual stromal bed, the surgeon and patient can determine whether standard LASIK, SBK, or surface ablation is the best treatment option. Finally, I urge our colleagues involved in medicolegal pursuits to examine the med-

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520 µm) would be considered unusually thick; however, this characteristic is not significant with respect to complications from LASIK.

I believe corneas with central corneal thicknesses of 500 µm or less are abnormal. Does this mean that every cornea thinner than 500 µm has forme fruste keratoconus? Not in my opinion and experience; but a higher percentage of corneas in this pachymetric range are likely to have forme fruste keratoconus than those thicker than 500 µm. Notice the overlap of the keratoconus and normal pachymetry curve in Figure 1. The area of overlapping curves represents pachymetric values of corneas that may have either normal stromal strength or forme fruste keratoconus with abnormally weak stromal strength. The surgeon must decide the central corneal thickness at which the chance of post-LASIK ectasia becomes unacceptable (Figure 2). For me, it is 505 µm; for others, it might be 480 µm. I believe that most eyes with central corneal thicknesses of less than 460 µm are more likely abnormal in the majority of cases, and the chance of post-LASIK ectasia would be unacceptably high, despite the thinness of the prospective flap.

I consider the presence of an inferior corneal pachymetric value at the 7-mm optical zone that is the same or thinner than the central cornea's pachymetry is a warning sign for, and is associated with, an increased chance of ectasia. These pachymetric values are perhaps the first and mildest manifestation of corneal pellucid marginal degeneration.

CONCLUSION

In my opinion, a cornea that exhibits any degree of irregular astigmatism that is not related to a surface abnormality or exhibits an area of localized asymmetric steepening (especially inferiorly) should be considered abnormal and thus too weak to undergo LASIK (Figure 3).

Should surgeons use only corneal thickness to identify appropriate LASIK candidates? If a patient's central corneal thickness is below the surgeon's preferred limit, then LASIK is contraindicated, even if the cornea appears to be completely normal. If the patient's central corneal thickness is within the surgeon's preferred standard, then the decision to proceed with surgery depends on whether the other corneal parameters fall within an acceptable range for preventing postoperative ectasia. ■

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ical literature carefully prior to stating that a specific corneal thickness is a singular risk factor for post-LASIK ectasia. ■

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