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Ectasia risk: A multifactorial conundrum

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Ectasia after corneal refractive surgery remains one of the most insidious and perplexing problems in the day-to-day practice of the refractive surgeon. Although the incidence of ectasia is low, it is the *raison d'être* for most of the measurements and history obtained in the course of screening patients for refractive surgery.

In this issue of the journal, Ziaei and a group of coauthors representing the Cornea Committee of the American Society of Cataract and Refractive Surgery (ASCRS) present a major review of surgical approaches to managing ectasia (pages 842–872). They summarize key advances in treatment, including combinations of treatments aimed at improving corneal optics and stabilizing progressive disease. Although great progress continues to be made on the therapeutic side of this problem, reliable characterization of ectasia risk remains a challenge. And from every vantage point, avoidance or prevention of ectasia at the preoperative planning stage is much preferred to treating it later.

Clinicians can easily assess predisposition for a disorder when a single highly predictive marker is available, such as a specific genetic mutation in a hereditary disease with high expressivity and high penetrance. Unfortunately, refractive surgeons do not have access to a single high-probability marker for ectasia. Ectasia in the setting of refractive surgery is a multifactorial problem, as Randleman et al.¹ illustrated through their landmark retrospective analysis of patient- and procedure-specific risk factors. This reality complicates efforts to quantify risk in the setting of the screening examination, where our ability to both measure and synthesize the major components of risk for a given patient is still incomplete.

Acknowledging the multivariate nature of the problem and appealing to structural principles are critically important for properly conceptualizing risk. From the vantage point of the cornea as a structure, material failure is the final common pathway of ectasia.^{2–5} The cornea's shape, and thus its optical performance, are intimately linked to its unique material composition and loading forces; "normal" material responses to surgery can be practically classified as those that generate refractive outcomes that are both predictable and stable, whereas "abnormal" responses would deviate from refractive expectations and/or show postoperative instability. Material failure is not a binary condition but rather occurs along a

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continuum^{6,7} that is modified by all the patient- and procedure-specific influences that come to bear on the structure. The key challenge, then, is to determine—with a limited amount of information and proxy variables—just where on the spectrum of structural behavior a given eye currently resides and how surgical intervention will change that.

The Case Reports section of this issue features a cautionary example of this process and the clinical stakes of different interpretations of apparent risk. El-Naggar (pages 884–888) presents what might be the first reported cases of corneal ectasia in a patient who had femtosecond small-incision refractive lenticule extraction, an intrastromal procedure that largely preserves the integrity of the anterior stromal collagen structure. Previous publications^{8,9} have presented a biomechanical rationale for the potential structural advantages of this approach, and at first glance, the case report could be taken as an indictment of this claim. However, the preoperative tomography showed bilateral evidence of ectatic predisposition suggested by asymmetric inferior topographic steepness, posterior corneal elevation, decentered thinnest corneal points, and low overall corneal thickness. The patient was advised by the author that he was not a laser in situ keratomileusis (LASIK) candidate but then had small-incision refractive lenticule extraction performed elsewhere and returned to the author's clinic 6 months later with evidence of marked progression of inferior steepening and manifest ectasia.

This case offers several learning points. First, ectasia risk assessment is currently sufficiently imprecise that the presence of even 1 perceived risk factor (particularly a topographic risk factor such as inferior steepness) should bias the surgical decision toward observation or tissue-sparing procedures. In the reported case, the patient's older age, low absolute corneal curvatures, refractive stability, and low level of myopic refractive error might have been factored into the decision to proceed with surgery despite the concerns apparent on tomography. This point is particularly important with the ever-increasing number of variables presented to the surgeon for facilitating a decision. These variables should not be seen as equally weighted in terms of predictive value because such weightings have yet to be worked out.

Second, caution is required when extrapolating general conclusions about the relative biomechanical impact of different surgical approaches to a specific eye. The surgeon who did operate on the patient might have reasoned, logically, that small-incision refractive lenticule extraction would preserve the anterior stromal integrity in ways that both LASIK and photo-refractive keratectomy would not and would therefore be the safest of the 3 approaches for treating the patient's low myopic astigmatism. However, the distribution of stromal mechanical strength as a function of depth in eyes with inferior steep features is not known, and documented loss of normal collagen orientation¹⁰ and transverse anchoring fibrils near Bowman membrane¹¹ in keratoconus could significantly alter the usual spatial distribution of material properties on which these generalizations are predicated.

Finally, the availability of a procedure that is more structurally conservative but that still uses tissue removal as a modality should not trump a patient risk factor that raises suspicions of ectasia susceptibility. Low-grade ectasia has the potential to progress with or without surgery, and the specific “tipping point” for a stable but suspicious eye is not known a priori:

It is discovered, as in this case, only after intervention. In an attempt to address this gap, our research group is exploring a structural modeling approach to risk analysis that uses patient-specific tomography data in procedure-specific surgical simulations. Our hope is that by harnessing computational power to solve complex structural problems where a qualitative solution is not sufficient, the work will add to our mechanistic understanding of risk while providing a practical tool for patient-specific risk assessment.

Ten years after the ASCRS, International Society of Refractive Surgery, and American Academy of Ophthalmology produced a consensus paper on the subject of post-refractive surgery ectasia,⁷ the problem is no less important and only slightly less enigmatic. Imaging advances and the introduction of devices for biomechanical characterization have undoubtedly enhanced our ability to assess ectasia risk; however, continued efforts to leverage the information in more comprehensive, integrated risk-assessment models should yield even greater benefits for surgical decision-making and patient safety.

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