

# PERSPECTIVE

## Avoidance, Recognition, and Management of LASIK Complications

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- **PURPOSE:** To provide important concepts of the latest developments in laser in situ keratomileusis (LASIK) complication avoidance, recognition, and management.
- **DESIGN:** A perspective.
- **METHODS:** A comprehensive literature search and review of a total of 816 publications that discussed LASIK complications from 1992 to 2005 was conducted.
- **RESULTS:** The risk of visually threatening complications is inherent in any ophthalmologic surgical procedure. Not only does LASIK require the use of several complex medical devices, but there can be significant human variation in response to this surgical intervention. As a result, many potential complications can occur after LASIK. The risk of many complications can be mitigated by appropriate patient selection and preoperative, surgical, and postoperative care. Unforeseen complications will occur, despite meticulous planning, and must be managed. Important current developments in the avoidance, recognition, and management of LASIK complications are reviewed.
- **CONCLUSIONS:** Complications as a result of LASIK can threaten vision and may cause debilitating symptoms in an otherwise healthy eye. Advancing our understanding of the prevention and management of the complications of LASIK is an endeavor that must be continued as long as refractive surgery is performed. (*Am J Ophthalmol* 2006;141:733–739. © 2006 by Elsevier Inc. All rights reserved.)

**B**ECAUSE LASER IN SITU KERATOMILEUSIS (LASIK) REQUIRES the use of several complex medical devices and there can be significant human variation in response to surgical intervention, many potential complications can occur. The most current concepts in avoidance of common

LASIK complications, the prompt recognition of complications when they occur, and their management will be discussed in four categories as shown in the [Table](#).

- **KERATOME AND FLAP COMPLICATIONS:** A mechanical keratome or femtosecond laser can be used to create the LASIK flap. Although femtosecond laser use for LASIK flaps is a newer technology, it is known that miscreated flaps, flap striae, interface inflammation, traumatic flap tears with initial flap lift, loss of suction, and epithelial defects are some possible complications. Recent reports suggest that creating a flap with a femtosecond laser, with careful surgical technique to avoid trauma during flap lift, may offer advantages such as comparable attained spheric equivalent and acuity, with less induced astigmatism and better flap thickness predictability when compared with mechanical keratomes.<sup>1</sup> Further investigation is needed to understand the complications that are specific to the femtosecond flaps that could be expected commonly and the effective management strategies.

- **INTRAOPERATIVE COMPLICATIONS:** Complications during LASIK that are specific to the mechanical keratome include free flaps, thin flaps, incomplete flaps, flap buttonholes, flap decentration, and epithelial defects. The total incidence of all intraoperative LASIK flap complications that have been published in studies of  $\geq 1000$  eyes ranges from 0.3% to 5.7%. A learning curve exists for the beginning LASIK surgeon, and experience decreases the incidence of keratome-related complications.<sup>2</sup> The surgical team must have thorough knowledge of the specific operating procedures for the keratome that is being used. Careful examination and testing of all equipment before commencing surgery are essential to avoid an intraoperative surprise. The surgeon should evaluate the flap immediately after cutting and before laser ablation to ensure a consistent thickness, an intact hinge, good centration, and adequate diameter and should identify any epithelial defects or other potential issues that may affect healing.

A flap that lacks a hinge that attaches it to the cornea is known as a free flap or cap. Loss of suction during the keratome pass can cause shallow engagement of the keratome

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**TABLE. LASIK Complications and Management**

Keratome and flap complications
Intraoperative complications
Ectasia
Flap striae
Flap dislocation
Laser complications
Misinformation/improper ablation
Decentered or improperly registered ablation
Reduced quality of vision
Complications of healing/infection/inflammation
Recurrent corneal erosions
Infectious keratitis
Epithelial ingrowth
Diffuse lamellar keratitis (DLK)
Post-LASIK dry eye
Other complications of LASIK
Intraocular pressure measurement after LASIK
Optic neuropathy and glaucoma

on the corneal surface, which allows the blade to skim across the top of the cornea and produce a cap, a thin flap, or an incomplete flap. After suction is engaged, to avoid free caps and other problems associated with inadequate suction, the surgeon should complete four checks before cutting the flap: (1) Ensure sufficient intraocular pressure with a tonometer, (2) confirm that the patient's vision has dimmed, (3) palpate the cornea for firmness, and (4) ensure the suction ring has a firm grasp of the eye. Another suction problem that can affect flap creation is occlusion of the suction port other than at the globe, sometimes referred to as "pseudosuction"; this problem should be ruled out before the flap is cut by gentle traction on the globe with suction on. A flat keratometry reading on the preoperative cornea should be factored into preoperative planning, because flatter corneas are associated with free flaps and thin flaps. If a free flap is cut, the surgeon can still proceed with LASIK, as long as the cap is found and the bed diameter allows adequate space to ablate the cornea safely. The cap is replaced after ablation, usually without sutures. Each cornea should be marked before flap creation (for example, with a radial keratotomy corneal marking device) so that, if a free flap is created, it can be replaced in the proper meridian; otherwise, an irregular astigmatism is likely to be created, and other aberrations invite epithelial ingrowth because of mismatched flap edges. If a thin or incomplete flap occurs, the keratome should be stopped; ablation should be aborted, and the flap should be replaced and allowed to heal for 3 to 6 months before another procedure is attempted.

LASIK flap buttonholes are ring-shaped flaps with a central hole or thin area. Flap buttonholes can result in the loss of best-corrected visual acuity (BCVA) or other visual disturbances such as glare, starburst, or diplopia. Blade imperfections, power decrease in the keratome motor, and loss of suction during the aforementioned procedure can cause buttonholes. Barring keratome or suction difficulties, preopera-

tive steep corneal curvature appears to be a factor that contributes to flap buttonholes. General guidance to avoid flap buttonholes includes the use of a small diameter keratome ring and deeper cutting plate when operating on corneas with keratometry readings of >46. Extremely steep corneas also must be scrutinized clinically and with topography and pachymetry to rule out keratoconus.

The causes of flap decentration include improper alignment of the suction ring or drift after suction engagement. A significantly decentered flap whose edge lies within the ablation optical zone can induce astigmatism and visually disabling higher order aberrations. This should be avoided by the attention of the surgeon to anatomic landmarks during the application of suction.

An epithelial defect during LASIK is one of the most common intraoperative complications and is associated with pain and delayed visual recovery. Other complications can result, including diffuse lamellar keratitis (DLK), epithelial ingrowth, and microbial keratitis. Epithelial defects usually occur as a result of trauma from the keratome pass but may be indicative of underlying epithelial basement membrane disease (EBMD). A bandage contact lens usually is applied and left in place until the epithelium heals. Prevention of epithelial defects involves the avoidance of preoperative eye medications, the restriction of the application of anesthetic drops to immediately before surgery, and copious irrigation during the keratome pass.

- **ECTASIA:** Ectasia of the cornea is a progressive anterior shift of the cornea that is associated with central steepening and thinning, myopic shift, and visual symptoms. Ectasia after LASIK is vision-threatening and is one of the more difficult complications to manage, requiring a penetrating keratoplasty in severe cases. Because of this, avoidance is crucial. Pre-existing keratoconus and a thin residual bed are two identified risk factors that can be avoided in most cases by proper preoperative evaluation and include corneal topography and pachymetry. A computation of the estimated residual bed should be performed in all LASIK cases. The estimated flap thickness and ablation depth is subtracted from the preoperative central pachymetry. A better estimate is to perform intraoperative pachymetry after the flap is lifted and subtract the estimated ablation depth to account for keratome variability in flap thickness. A generally accepted minimum is 250  $\mu\text{m}$ . However, there have been reports of postoperative ectasia after a residual bed thickness over 250  $\mu\text{m}$  is confirmed.<sup>3</sup> Rigid gas permeable (RGP) contact lenses and penetrating keratoplasty are treatment modalities that are available for visually debilitating keratectasia after LASIK. The use of intrastromal corneal rings such as Intacs (Addition Technology, Inc, Fremont, California, USA) is being investigated for viability as an alternative to penetrating keratoplasty for post-LASIK corneal ectasia. Given the encouraging results of intrastromal corneal ring therapy for keratoconus, patients with post-LASIK corneal ectasia

have also been treated with Intacs with good results.<sup>4,5</sup> Most treated eyes had improvement in BCVA and uncorrected visual acuity, and delay of penetrating keratoplasty was achieved.

- **FLAP STRIAE:** Flap striae (wrinkles or folds in the LASIK flap) can be seen as a complication immediately after the flap is replaced or thereafter. The incidence of flap striae has been reported as high as 10% in the early stages of the surgeon's experience, which suggests that surgical skill plays a role in the cause.<sup>6</sup> Careful examination after the replacement of the flap intraoperatively and a postoperative examination can help identify folds early and expedite management if needed. *Microstriae* are defined as folds in the epithelium on post-LASIK examination. Pooling of fluorescein can be used to distinguish microstriae from full-thickness folds. If there is no pooling, then the flap folds are considered microstriae. Microstriae usually are not visually significant and do not have deleterious long-term consequences, and surgical intervention usually is not indicated.

Full-thickness folds, or macrostriae, involve the stroma and are associated with a loss of visual acuity. To help differentiate from microstriae, fluorescein pooling and an asymmetric gutter will be seen with macrostriae. The treatment includes irrigation underneath and replacement of the flap and putting the flap on tension to eliminate the folds, either with instruments specifically designed to smooth the flap or by the placement of sutures. Removal of the epithelium of a flap with chronic stromal folds may increase success in flattening macrostriae.

- **FLAP DISLOCATION:** Both early and late flap dislocation has been reported as complications of LASIK. Studies of  $\geq 1000$  eyes after LASIK have reported up to 2.0% incidence of spontaneous flap dislocation, mostly within the first 24 hours after surgery. Careful and consistent techniques are needed when positioning the flap during surgery and at examination of the flap in the first hour and first day after LASIK. Immediate replacement of partially or completely dislocated flaps in the early postoperative period, as with full-thickness folds, usually results in the maintenance of preoperative BCVA. Typically, the flap is repositioned by simple irrigation and reapproximation of the flap, and prophylactic antibiotic and corticosteroid drops are used. The longer a flap is dislocated, the greater the chance of other complications such as striae, epithelial ingrowth, or DLK and possible loss of visual acuity. If epithelium has grown under the flap during displacement, it should be removed before replacement, with or without the use of sutures to hold the flap in place. Late traumatic flap dislocation is a rare but well-known complication that requires intensive therapy and may lead to further complications such as a loss of BCVA and loss of the flap.

- **LASER-RELATED COMPLICATIONS:** The excimer laser uses a sophisticated, computer-controlled beam delivery

system with a software interface. Laser ablation can result in complications from a variety of sources.

- **MISINFORMATION/IMPROPER ABLATION:** One of the most common, most feared, and most easily avoided complication is unintentional ablation, which is caused by the entry of incorrect patient treatment information into the excimer laser system. An error (such as entering the wrong sign or a misplaced decimal) can result in a dramatic under or over-correction and may induce astigmatism.

Real-time chart review and a verbal confirmation from the patient before the start of treatment will lessen the opportunity for error. Advanced systems that can autorecognize the patient (for example, iris detail) may reduce the likelihood of this type of error dramatically. A nomogram adjustment is applied commonly to the preoperative manifest refraction to increase the predictability of the outcome that is based on the results of previous patient treatments. However, a nomogram that is miscalculated, misinterpreted, or improperly applied can result in over- or undercorrection.

Significant accommodation during refraction or acquisition of wavefront measurements can result in overcorrection when myopia is treated and undercorrection when hyperopia is treated. A cycloplegic refraction is essential when accommodation is suspected, especially in young patients.

It is important to develop and standardize a surgical technique with regard to timing and hydration to produce consistent results and lessen the likelihood of over- or undercorrection.<sup>13</sup> A stromal bed that has pooled moisture or is very dry can affect results, as can flap-to-treatment time, duration of ablation, and flap replacement technique. Most of these issues can be factored into a nomogram, but only if the surgical technique is consistent.

- **DECENTERED OR IMPROPERLY REGISTERED ABLATION:** A decentered ablation occurs when the correct laser treatment is displaced peripherally relative to the visual axis. Decentration is assessed by postoperative corneal topography or by a difference map between the postoperative and preoperative topography. A displacement of  $\geq 1$  mm generally is considered significant and can result in debilitating visual symptoms such as monocular diplopia, glare, halos, and starburst phenomena.<sup>7</sup> However, even a subclinical decentration of 0.5 mm potentially can impact the visual outcome.<sup>8</sup> This would be most apparent when a smaller optical zone treatment diameter is used, such as is used commonly to treat hyperopia.

We recommend five current techniques to avoid decentration: First, the full attention of the surgeon is needed to confirm that the automated eye tracker has engaged properly and remains active throughout treatment. Second, the laser manufacturer's calibration methods must be performed routinely to ensure that the eye tracker remains properly aligned. Third, it is imperative to position each patient under the laser carefully and in a manner conducive to fine adjustment

before and during treatment; if a patient's head is placed at the edge of the bed or joystick limits, the surgeon will be unable to compensate for slight changes in patient movement. Fourth, despite eye tracker technology, if a patient's gaze drifts during ablation, the lateral displacement between the limbus or the pupil and the treated cornea can result in an ablation that is decentered. This complication can be prevented if the surgeon actively confirms that the patient continues to fixate on the proper visual target throughout the procedure. Fifth, it is generally recognized that the ablation should be centered on the line of sight to obtain the best visual outcome.<sup>9</sup> Centering the treatment on the visual axis (the corneal apex) instead of the line of sight can result in decentration.

The treatment of a visually significant decentered ablation is difficult at best. It is normally not amenable to a simple spherocylindrical treatment. Correction can be achieved by the placement of a second ablation at 180 degrees opposite the original decentered treatment. However, it is difficult to determine the size and shape of the treatment and to properly place the ablation on the cornea; significant flattening of the cornea can result in a hyperopic shift in refraction. Topographic data can be used selectively to create an ablation profile by the combination of multiple spherocylindrical corrections of various diameters and offset on the cornea to create a more regular corneal shape.<sup>10</sup> Studies that used this technique have shown a reduction of refractive cylinder, improvement in best-corrected and uncorrected visual acuity, and improved corneal regularity. More recently, an aberrometer has been used to compute directly an ablation profile that takes into account not only the residual refractive error but also higher order aberrations, especially coma. Wavefront-guided (WFG) retreatment for decentered ablation has resulted in improvements in best-corrected and uncorrected acuity.<sup>11</sup>

Another important aspect of proper centering of the ablation deals with accurate registration of the ablation on the cornea for the treatment of astigmatism and/or higher order aberrations (WFG LASIK). Unintentional cyclotorsion can occur when a patient lies underneath the excimer laser and can result in a reduction in the efficacy of astigmatic correction or an induction of astigmatism. For WFG treatments, the ablation pattern is determined during the wavefront capture with the patient seated. Even subtle cyclotorsional misalignment between the wavefront treatment pattern and the eye under the laser can result in induced higher-order aberrations. Proper registration of the ablation has been performed typically by the alignment of the treatment to limbal marks placed before surgery. Newer techniques show great promise to improve registration, in particular iris or scleral recognition. Iris or scleral details that are captured during the wavefront capture are aligned to recognition of the same details under the excimer laser.

• **REDUCED QUALITY OF VISION:** Symptoms related to decreased quality of vision after LASIK have been reported in

many clinical studies, such as glare, starburst, and halos.<sup>13-15</sup> Newly developed aberrometers have demonstrated that LASIK can induce optical aberrations that can impair high-quality vision.<sup>17</sup> Pupil size has been correlated to symptoms in the early postoperative time period, presumably because the mesopic pupil would allow light from the untreated cornea to create a halo effect around the viewed image.<sup>17</sup> However, no long-term relationship between the size of the low light pupil and quality of vision symptoms has been observed after LASIK.<sup>18</sup> WFG LASIK appears to result in better quality of vision than conventional LASIK.<sup>19</sup> This is based on changes in BCVA, contrast sensitivity, and patient questionnaires. There is less induction of higher-order aberration with WFG LASIK, especially spheric aberration.

Assessment of quality of vision symptoms after LASIK includes a complete examination that pays attention to the tear film, flap integrity, corneal clarity, crystalline lens, and retina. An evaluation of uncorrected visual acuity, BCVA, and manifest refraction is needed. Topography is useful in the assessment of the regularity of the central cornea and ablation centration. If the preoperative topography is available, a difference map can be used. The usefulness of aberrometry to determine the extent of higher-order aberrations must be balanced against the potential difficulty in interpreting the results, because there are no well-established standards for these aberrations that can be used for comparison; the pupil size used in the aberration analysis can effect the amount and type of aberrations dramatically, and it is not established how these aberrations affect the quality of vision.

Many of these symptoms abate with time as healing and cortical adaptation occur. In lieu of a significant refractive error, observation is often the appropriate management. Spectacles may be useful in guiding a possible retreatment. Slightly over-minused spectacles for suspected night myopia may help abate symptoms. Pharmacologic pupillary constriction can be effective in the reduction of symptoms for patients with both small and large mesopic pupils. Rigid gas permeable (RGP) contact lens can be both diagnostic and therapeutic in symptomatic patients. For example, an RGP trial lens can rule in an early cataract as the cause of symptoms. A well-tolerated, well-fitting lens may also be therapeutic. WFG retreatment holds great promise to address symptoms that are caused by higher-order aberrations.<sup>20</sup>

• **COMPLICATIONS OF HEALING/INFECTION/INFLAMMATION:** The postoperative complications that are perhaps the most perplexing are those that are related to the human healing process. Even with proven equipment, standardized and proper surgical techniques, and adequate postoperative care, the ocular response to surgery can result in an unwanted outcome. In these cases, complications must be recognized and managed appropriately.

• **RECURRENT CORNEAL EROSIONS:** LASIK has been reported to induce or precipitate recurrent corneal erosions (RCE). Symptoms that are suggestive of RCE include sharp



eye pains, the sensation of the eyelid sticking, and soreness of the eyelid to touch. Triggers for RCE after LASIK include epithelial trauma at the time of the LASIK procedure and previously undiagnosed EBMD. Patients with diabetes mellitus who undergo LASIK are at a significantly higher risk of the development of postoperative epithelial complications. This can lead to poorer refractive results when compared with treated eyes of nondiabetic patients. Corneal erosions after LASIK have been associated with a significant increase in DLK, even after re-epithelialization has been completed.<sup>21</sup>

Prevention of epithelial trauma at the time of surgery is the key to the reduction of the incidence of RCE after LASIK. This includes minimization of preoperative eye medications (particularly anesthetic drops), copious irrigation during the keratome pass, and minimization of epithelial desiccation. RCE usually responds to treatment with ocular lubricants, and a bandage contact lens can be considered to speed reepithelialization time and reduce discomfort and irritation. Cases in which loose epithelium is noted after LASIK should be identified as potential RCE cases and followed appropriately, especially if subsequent enhancement procedures are being considered. DLK, if present, should be treated appropriately with topical corticosteroids. For RCE after LASIK that does not respond to conventional therapy, anterior stromal puncture has been reported to be useful and effective.<sup>22</sup>

- **INFECTIOUS KERATITIS:** Infectious keratitis is a well-known, but rare, complication of LASIK. A survey was conducted by the American Society of Cataract and Refractive Surgery in 2003 and, based on 116 infections that were reported by LASIK surgeons who had performed an estimated 338,550 procedures, determined the incidence of post-LASIK microbial keratitis to be 0.03%.<sup>23</sup> Symptoms of pain, discharge, epithelial defects, and anterior chamber reactions within 1 week of surgery are more likely to be associated with Gram-positive infection. Atypical organisms (which include mycobacteria, fungus, and acanthamoeba) have a more delayed onset and result in a prolonged disease course. Flap elevation and culture should be performed when post-LASIK infectious keratitis is suspected. Rapid intervention is correlated with improved visual outcome. Microbial keratitis can mimic DLK in the immediate postoperative time period. Both have inflammation of the flap interface. A discrete infiltrate cells or several focal infiltrates in the anterior chamber, perilimbal injection, and severe eye pain are all indicative of a microbial process. Delayed-onset mycobacterial keratitis after LASIK has been reported up to twenty-four weeks after surgery. A reported outbreak of *Mycobacterium chelonae* infection after LASIK required the removal of the flap in seven of 10 eyes that were involved because of the failure of all conservative measures.<sup>24</sup>

Management of microbial keratitis after LASIK includes topical fortified antibiotic therapy, irrigation of stromal bed with antibiotic solution after lifting the flap, and sending the scraping of the infiltrate for microbiologic evaluation. Oral

antibiotics may be required for those cases that do not respond clinically to topical treatment. Removal of the flap, especially in mycobacterial infections, may be required if antibiotic treatment fails to halt the progression of the disease. When diagnosed and treated appropriately, most sight-threatening microbial keratitis after LASIK heals with minimal scarring and best spectacle-corrected visual acuity of  $\geq 20/40$ .<sup>25</sup>

Endophthalmitis, though rare after LASIK, can occur and requires prompt evaluation and treatment to avoid a permanent visual sequela. Prompt treatment with intravenous, intravitreal, and topical antibiotics can result in successful resolution, although BCVA, and corneal clarity may be reduced.

- **EPITHELIAL INGROWTH:** Epithelial ingrowth describes a population of aberrant epithelial cells within the flap interface after LASIK. Epithelial ingrowth occurs either by contiguous migration of cells from the edge of the flap or by direct implantation of cells in the interface during the LASIK procedure. Defining clinically significant epithelial growth as that which required surgical removal, the incidence is approximately 1%. Risk factors for epithelial ingrowth include poor flap adhesion because of a perioperative epithelial defect, EBMD, DLK after surgery, and possibly thin flaps and diabetes mellitus. Avoidance of epithelial defects after surgery is the most important preventive measure to reduce the occurrence of epithelial ingrowth. Meticulous attention to proper realignment of the flap edges is also an important factor. Other preventative measures may include the irrigation and the wiping of the stromal interface with sponges, the aspiration of irrigation fluid and debris with a suctioning lid speculum, and the use of a bandage contact lens for the first day after surgery.<sup>26</sup>

The decision to treat usually depends on the progression of the epithelial ingrowth and the potential to affect vision. Initial treatment consists of the lifting of the flap and manual removal of the growth of epithelial cells from the stromal surface and the back side of the lifted flap. Replacement of the flap in proper position is important in the reduction of the likelihood of primary or recurrent epithelial ingrowth. Clinically significant epithelial ingrowth recurs in approximately 25% of eyes after the initial surgical removal.<sup>27</sup> The suturing of the flap into position or fibrin glue (Tisseel; Baxter, Baxter Corp, Mississauga, Ontario, Canada) at the flap edge has been used to prevent recurrent epithelial ingrowth after LASIK and epithelial ingrowth removal.<sup>28</sup>

- **DLK:** DLK, also called the “Sands of the Sahara” syndrome, is a post-LASIK inflammatory condition in the interface that appears as a multifocal and/or diffuse inflammation that is confined to the interface and is associated with pain, photophobia, redness, and/or tearing. Inflammation usually appears between two and six days after surgery but may present  $\geq$  six months after surgery. Most surgeons use a threefold strategy of identification, staging, and intervention

for rapid diagnosis and appropriate treatment of DLK. Although epithelial defects are associated strongly with DLK formation, not all cases of epithelial defects result in the appearance of inflammatory cells in the flap interface.

With appropriate diagnosis and treatment, DLK should resolve without sequelae and yield visual outcomes that are comparable with cases with uneventful postoperative courses.<sup>29</sup> Corticosteroids are the mainstay of the treatment of DLK because it is primarily an inflammatory condition. Flap lift and irrigation may be required in cases that are refractory to initial topical medication. Phototherapeutic keratectomy (PTK) has also been reported to be effective in the treatment of DLK that is recalcitrant to conservative measures. In cases of known atopy, patients can be treated with antihistamines before surgery to control the disease and to reduce the risk of DLK and the potential for vision loss. It is essential to measure intraocular pressure in all cases of suspected DLK to rule out pressure-induced post-LASIK interface keratitis because topical corticosteroids are ineffective in this condition and may worsen the process.<sup>30</sup>

- **POST-LASIK DRY EYE:** Up to 48% of patients complain of dryness symptoms during the first six months after surgery; soreness of the eye to touch has been reported in 6.7% of LASIK patients, and sharp pains have been reported in 8.0% of LASIK patients.<sup>31</sup> The risk of refractive regression after LASIK appears to increase in patients with chronic dry eye. Tear secretion and tear film stability are reduced during the early postoperative time period after LASIK.<sup>32</sup> This may be the result of a loss of trophic influence from severed corneal nerve bundles after the creation of the flap with the keratome and may be influenced by hinge position and width. Fortunately, dry eye complaints typically resolve approximately six to twelve months after surgery. The use of artificial tears or punctal plugs in the early postoperative period may help to prevent unwanted symptoms and ocular surface damage.<sup>33</sup> Preoperative screening of patients with mild-to-moderate dry eyes is important for counseling and postsurgical planning. Patients with severe dry eye are generally not good surgical candidates for LASIK.

- **OTHER COMPLICATIONS OF LASIK:** In addition to the myriad of potential complications from the flap, instrumentation, and normal healing processes, there are a number of other issues that are associated with LASIK.

- **INTRAOCULAR PRESSURE MEASUREMENTS AFTER LASIK:** Accurate measurement of intraocular pressure is essential for monitoring patients who are being treated for glaucoma or who are at risk for the development of glaucoma, including corticosteroid-induced glaucoma. Goldmann applanation tonometry (GAT), which is still considered the current "gold standard" for intraocular pressure measurement, assumes a normal central corneal thickness of 520  $\mu\text{m}$ . A thin central corneal thickness, as is often the case after myopic ablation, will result in a falsely low intraocular pressure

measurement with GAT and also noncontact tonometry. Studies that have examined the relationship between central corneal thickness and GAT have reported varying results; some studies concluded a linear relationship exists allowing a simple corrective formula, and others did not. Some clinicians use these corrective formulae to adjust post-LASIK GAT readings.<sup>34,35</sup> Reported underestimation of intraocular pressure after hyperopic LASIK suggests that other post-LASIK changes (such as reduced rigidity, altered corneal microstructure, and changes in corneal curvature) also influence the accuracy of GAT. Contact pneumatonometry may be a more accurate method of intraocular pressure measurement in post-LASIK eyes.<sup>36</sup> Another device, the Pascal dynamic contour tonometer (Swiss Microtechnology AG, Port, Switzerland) may also be less affected than GAT by corneal changes after LASIK.<sup>37</sup> The drawbacks to the use of alternate devices include added cost and a need for more data to support their use. Currently, given that GAT is inaccurate when used to measure intraocular pressure after LASIK, the clinician must use a corrective factor or an alternate method of tonometry (such as contact pneumatonometry or dynamic contour tonometer) until larger, prospective studies verify the accuracy of these methods and provide further guidance.

- **OPTIC NEUROPATHY AND GLAUCOMA:** There have been reports of ischemic optic neuropathy after LASIK that is presumed to be caused by transient ischemia or barotrauma from keratome suction.<sup>38</sup> Corticosteroid-induced glaucoma has been reported after LASIK and may be difficult to identify because of interface fluid or other mechanism.<sup>39</sup> Such reports underscore the importance of evaluation before surgery to identify pre-existing glaucoma or optic neuropathy and to monitor for the development of these conditions after surgery.

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## SUMMARY

OUR PATIENTS BENEFIT BY AN ONGOING EVALUATION OF the surgical complications and events that pose a threat to vision, both in quantity and quality. This is a never-ending pursuit. The advancement of our understanding of the prevention and treatment of complications is an endeavor that must be continued as long as refractive surgery is performed.<sup>12,16</sup>

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### **Biosketch**

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