Refractive Laser Surgery: an in-depth look at LASIK and brief overview of PRK, Epi-LASIK, and LASEK

A Science Writer’s Guide
I. Introduction
Refractive surgery was developed so that people could enjoy good vision with no or reduced dependence on glasses or contact lenses. LASIK, or laser-assisted in situ keratomileusis, is the surgical procedure most often used in the United States to treat nearsightedness, farsightedness and astigmatism. These are forms of “refractive error,” problems with the ability of the eye to bend light in order to focus images clearly on the retina.

Ophthalmologists, or Eye MDs, have known for more than a century that surgically modifying the shape of the cornea, the clear outer layer of the eye, could correct refractive error. Advances such as the microkeratome, a blade device (around 1950), excimer laser (1968) and application of the excimer laser to refractive surgery (1980s) made possible the development of LASIK. In 1990, Dr. Ioannis Pallikaris, a Greek ophthalmologist, performed the first LASIK procedure. The new procedure was a melding and improvement upon two earlier techniques, keratomileusis and photorefractive keratectomy (PRK).

LASIK quickly gained acceptance and widespread use because of its high precision and low complication rate. In 1998 the Food and Drug Administration approved the excimer laser for LASIK, and subsequent innovations like advanced microkeratome and bladeless cornea flap incisions, improved lasers, and wavefront-optimization have significantly increased LASIK’s efficacy and reliability. Other laser surgeries performed today include an updated version of PRK that includes advanced surface ablation (ASA) techniques, Epi-LASIK, and Laser epithelial keratomileusis (LASEK); these are appropriate when the patient’s cornea is too thin for LASIK or for other specific treatment reasons.

In LASIK and other refractive surgery laser procedures, the surgeon uses an excimer laser to reshape the cornea’s central, or stromal, layer; the procedures vary in how the epithelial (top) layer, is managed. The excimer laser, filled with argon-fluoride gas, is a cold laser that can precisely etch tissue without causing significant thermal damage to the surrounding area. The laser’s high-energy pulses of ultraviolet light break molecular bonds in the protein of the stroma and vaporize microscopic amounts of tissue in a highly precise pattern. A single pulse of the laser removes 0.25 microns of tissue; for comparison, a typical human hair is 70 microns thick. The two excimer laser types approved by the FDA for refractive surgery are broad-beam and scanning with slit or spot sub-types. Each laser type has pros and cons, but the variations in outcomes for each type are so subtle that most patients would not be concerned. (See this guide’s Sources: Eye Surgery Education Council web site for further details on excimer laser technology.)

Approximately 700,000 LASIK procedures are performed annually, making it one of the most common surgeries in the United States. More than 90 percent of people who have LASIK achieve 20/20 to 20/40 vision and are able to perform all or most of their daily activities without glasses or contact lenses. Sometimes, especially in patients with more severe refractive error, a second treatment is needed for optimum results. LASIK is described in detail in this guide, along with basic information on PRK, Epi-LASIK and LASEK. Also covered are criteria to determine good candidates for LASIK and other procedures, and side effects, risks and benefits.
II. How the Cornea Works
The eye’s cornea, the transparent tissue that covers the front of the eye, refracts, or bends, light to focus images on the retina at the back of the eye. People with refractive error have irregularities in the cornea and/or shape of the eyeball that cause light to focus too far in front of the retina (nearsightedness, or myopia) or too far behind it (farsightedness, or hyperopia). Myopia causes near objects to appear clear while distant objects appear blurry; hyperopia makes far objects appear clear and near ones blurry. Another refractive error, astigmatism, prevents light from converging on a single point and forming clear images on the retina, so objects appear blurry; types of astigmatism include regular, irregular, and mixed and can occur in combination with myopia or hyperopia. Refractive error is calculated in diopters, units of measurement that designate the degree of light convergence or divergence. Emmetropia is the term for the state of no refractive error.

Laser refractive surgery reshapes the corneal curvature, making it flatter or steeper as required to counterbalance the patient’s refractive error. When wavefront-guided technology (described in detail in the LASIK Procedure section) is used, it is also possible to address very subtle corneal irregularities.

Another condition that makes it difficult to see close-up objects clearly is presbyopia (literally “aging eye”). This occurs when the natural crystalline lens behind the eye’s pupil gradually loses elasticity, which begins for most people in their 40s and eventually affects everyone as part of the normal aging process. Currently, laser surgery does not correct presbyopia; ophthalmic researchers are exploring approaches that may make this possible in the future.

III. The LASIK Procedure

A. Mapping the Cornea and Programming the Excimer Laser: In the pre-surgery evaluation exam, the surgeon may use computerized technology to measure and “map” the patient’s corneal measurements. The excimer laser is then programmed with this data (or, if computerized mapping is not used, with the patient’s refractive error prescription), which is the basis for the individualized sculpting of the cornea during LASIK.

Wavefront, an advanced technology, creates a three-dimensional topographical image, like a “fingerprint” of each unique cornea’s subtle variations and irregularities. The device generates light that travels into the eye in a series of flat “sheets,” known as wavefronts. As these wavefronts pass through the eye, they wrinkle or distort when they encounter irregularities in the cornea. These wrinkles and distortions (as well as normal areas) are then displayed as a color image that resembles a three-dimensional map. This image can be used to guide correction of irregularities during LASIK. Wavefront is a relatively new technology, approved by the FDA in 2001.

Approximately 10 to 17 percent of optical errors are termed “higher order aberrations.” Conventional LASIK may increase these aberrations, but this undesirable result can be minimized with “wavefront sensing,” an emerging use of wavefront technology. Wavefront sensing also appears to effectively correct certain naturally occurring higher order aberrations.

Wavefront technology improves LASIK results for vision qualities such as “image contrast” and “special detail.” One study found that wavefront-treated patients reported better visual acuity, compared with conventional LASIK patients. Undesirable LASIK outcomes such as poor night vision, glare, halos and blurry vision were also reduced in these wavefront-treated patients.
Drawbacks of wavefront-optimized LASIK include:

- The range of correctable refractive error is narrower than for conventional LASIK
- Removal of 18 to 30 percent more corneal tissue is required
- It is more expensive.

B. LASIK Step by Step:

- The patient lies on a reclined chair; the eye is drapped and numbed with topical anesthetic. The surgeon marks the cornea with water-soluble ink to guide later replacement of the corneal flap. An eyelid holder is put between the upper and lower lids to keep them open. The eye is moistened and a suction ring is placed to appropriately pressurize the eye, stabilize the cornea, and keep the eye from moving during surgery. The patient’s vision goes dim or black until the ring is removed.
- Next, the corneal flap is created from the outermost 20 percent of the thickness of the cornea, using either a laser keratome or microkeratome blade. This part of the procedure is termed a keratectomy. When a laser keratome is used, the cornea is first flattened with a clear plastic plate; the laser pulses through the top cornea layers and creates bubbles at a specific depth. The surgeon creates the flap by gently separating the tissue where the bubbles have formed, then folding back the flap. When a microkeratome is used, it is attached to the suction ring and moves across the cornea, stopping at a preset point to leave a hinged flap of thin corneal tissue. The blade and ring are then removed and the flap folded back.
- The exposed cornea is dried and the excimer laser is positioned over the eye; the surgeon tests the alignment. The surgeon asks the patient to stare at a blinking light (called “fixation”) and talks him or her through the process. In less than 60 seconds the laser sculpts the cornea based on preprogrammed information obtained in the evaluation exam. The patient may be aware of a ticking sound.
- The surgeon places the corneal flap back in position and smoothes the edges, then observes the eye for three to five minutes to ensure bonding. The flap adheres to the main cornea, and stitches are not required. A clear eye shield may be provided to protect the eye from being accidentally hit or poked. The surgeon may advise that the shield be worn during sleep for four weeks to protect against pressure and prevent accidental rubbing.
- LASIK is generally painless, but there may be discomfort or pressure when the speculum or suction ring is placed on the eye. Anesthetic drops are administered to minimize this discomfort.
- Very rarely a surgical device may malfunction or another error may occur that causes the surgeon to discontinue the surgery. Eye damage may occur, and/or the problem may make a future attempt to complete the LASIK unadvisable. Often an excimer laser treatment performed on the surface of the cornea can improve vision in these patients.

IV. LASIK Criteria: Factors Considered by the Potential Patient and Eye MD

A. Health Status Requirements: The patient should discuss his or her specific eye health challenges and vision criteria as well as general health status with the Eye MD. LASIK surgeons in the United States commonly report that they decline approximately 10 to 25 percent of patient requests for LASIK because the candidate is not suited for the surgery due to medical reasons or unreasonable expectations. For some of the health factors noted below, if the condition changes or is treated or resolved the patient may then be approved for LASIK

- The refractive error must be within the range that can be treated by FDA-approved excimer lasers, defined as: for myopia to -14.0 D (diopter); astigmatism to -6.0 D; and hyperopia to +6 D. Because techniques and technology are evolving rapidly, doctors may be able to treat more severe...
errors in the future. Also, lasers are currently approved for use with regular and mixed astigmatism; new procedures may soon be approved to include irregular astigmatism. If a patient’s refractive error or other health factors rule out LASIK, another procedure may be recommended.

- The eyes must be relatively stable and unlikely to change in the foreseeable future, as confirmed by a contact lens or glasses prescription that has remained within certain parameters (determined by the Eye MD for the individual patient) for a year or more. LASIK candidates who fall outside this guideline should discuss their specific circumstances with their Eye MDs.

- The following conditions, until changed or resolved, may make a patient ineligible for LASIK, because they involve fluctuations in the eye:
  - Pregnancy or breastfeeding
  - Diabetes or other illness with hormonal fluctuations that affect the eye
  - Under age 21 (laser surgery is not approved by the FDA below age 18); eyes usually stabilize by the mid-twenties
  - Patient use of medications that cause vision fluctuations

  **Eye conditions** that in some cases exclude patients from consideration for LASIK, temporarily or permanently, are:
  - Glaucoma, suspected glaucoma or ocular hypertension
  - Some eye diseases, such as uveitis (inflammation of the eye)
  - Eye injuries or previous eye surgeries
  - Keratoconus, a degenerative corneal disease, or pre-keratoconus
  - Cataract
  - Retinal disease

- The person must be free of diseases or medications that would affect wound healing, such as: autoimmune diseases (rheumatoid arthritis, lupus, and others), immunodeficiency states (HIV and others), diabetes, and certain medications, including steroids, retinoic acid, and other compounds.

- The person must not have had ocular herpes within a year of the potential surgery date.

**B. The Evaluation Exam:** If the LASIK candidate wears contact lenses, she or he may be asked to switch to glasses days to weeks before the baseline exam; contacts can change the shape of the cornea for several weeks after they are last worn, depending on the type of contact lens. This can be an important variable in the Eye MD’s ability to take the accurate measurements of the cornea that are key to a good LASIK outcome. Hard lenses (PMMA) and rigid gas permeable (RGP) lenses may need to be discontinued several weeks or months before the exam and toric soft lenses and soft contacts days to weeks before. These are general guidelines and may be modified for individual patients.

The patient should make sure the Eye MD has received his or her complete medical history and current medication use, including over-the-counter medicines. In addition to examining the patient and checking the medical history for the health requirements listed above, the Eye MD will screen the patient for the following LASIK risk factors:

- **Thin corneas.** Tissue thickness levels associated with successful LASIK have been determined through extensive research. If a person’s corneas are too thin for LASIK, he or she may be a candidate for PRK, Epi-LASIK, or LASEK.

- **Dry eye.** In this eye disorder, tear production is disrupted or insufficient. This disorder is on the rise in the United States, and is more common in women especially after menopause. It can cause mild to severe discomfort, including burning, a sense of a foreign object in the eye, stringy mucus, and blurry vision. LASIK sometimes intensifies dry eye, or dry eye may be a factor in LASIK side effects. If the disorder is treated prior to surgery this potential problem
may be avoided, so it is particularly important that the patient and surgeon discuss this topic and plan treatment as appropriate.

- **Previous refractive surgery.** This may not rule out LASIK but needs to be carefully considered by surgeon and patient.
- **Blepharitis,** an inflammation of the eyelids. If not treated before LASIK, this condition increases the risk of infection or inflammation of the cornea. The doctor will also look for other infections, eyelid abnormalities, or tear duct problems.
- **Corneal scarring**
  - Significant asymmetry between the eyes’ refractive errors may indicate impending keratoconus, a degenerative disease of the cornea, or other abnormality which could rule out LASIK.

**Corneal measurements:**

- The cornea is measured via computerized technology to create precise, topographical maps that can then be used to program the excimer laser for the LASIK procedure (see LASIK Step-by-Step and Wavefront information, above.)
- The corneal topography is analyzed, since abnormal results can rule out LASIK. The surgeon looks for patterns that may indicate impending keratoconus or pellucid marginal degeneration, a thinning of the lower cornea that may create one form of astigmatism.
- The curvature of the cornea is measured with a keratometer and thickness with a pachymeter; the corneal tissue must meet LASIK thickness standards.

Also, the dominant eye is identified, since this may influence which eye is treated first and how much each eye is treated; patient and surgeon determine together whether LASIK should be performed on both eyes at once (bilateral simultaneous treatment, described below) or one eye should be allowed to fully recover before proceeding with the other.

**C. The Patient’s Lifestyle and Personal Choices:** People from all walks of life have had successful LASIK surgery. LASIK candidates consider this elective procedure for a variety of personal reasons; most are motivated by the idea that their quality of life will be significantly improved. A recent meta-review of 19 peer-reviewed studies found that more than 95 percent of the 2,000 patients involved were satisfied with their LASIK results. The decision may be part of a person’s plan to pursue new career goals or enhance his or her enjoyment of sports or hobbies. Convenience and safety can factor strongly into the decision for frequent travelers, young parents, or others concerned about misplacing glasses or being without their contact lenses at the wrong moment.

Wearing glasses or contact lenses can be hazardous in occupations such as law enforcement or firefighting, and for those who work in toxic chemicals or dusty environments. In 2007 the National Aeronautics and Space Administration (NASA) approved LASIK for astronauts. But certain occupations may not accept applicants who have had refractive surgery for safety reasons, so prospective LASIK candidates need to research vision correction requirements for their current and prospective career choices.

Some athletes pursue refractive surgery to enhance their performance, others for convenience or comfort. Professional golfer Tiger Woods is a well-known LASIK success story; before surgery he was so nearsighted that without glasses or contacts he could not see the ball on the tee. However, athletes involved in contact sports such as boxing, wrestling, or martial arts may be advised not to have refractive surgery. (Note: for many sports---and especially basketball, soccer, and hockey---protective eyewear is advisable whether or not a person has had LASIK.)

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People considering refractive surgery should discuss their current and anticipated work and lifestyle choices with their Eye MDs. Also, since most insurers do not cover elective surgery, the candidate must be able to cover the cost of refractive surgery and potential additional costs, such as an enhancement procedure.

D. Potential Outcomes: While LASIK improves vision and reduces or eliminates reliance on glasses or contact lenses for virtually all patients, as with any surgical or medical procedure, it cannot promise perfection. A prospective patient should study several sources of information on the vision correction procedure recommended by his/her Eye MD and determine whether he/she is willing to accept the related uncertainties and risks, as would be appropriate when considering any form of elective surgery.

- **Contrast Sensitivity and LASIK 20/20:** For many people, 20/20 vision after LASIK can be different from the 20/20 they experienced with contact lenses, especially the gas permeable type. Following conventional LASIK, people often say that what they see appears less "crisp" than when they used glasses or contacts. This condition is termed "loss of contrast sensitivity" in the ophthalmic literature. It does not affect acuity as measured on an eye chart, but the visual experience is different enough that a new term has been coined: LASIK 20/20. Most people adjust to this change following LASIK, but those whose work involves visual detail, such as artists, architects, draftsmen, are cautioned to weigh LASIK’s benefits against a potential loss of contrast sensitivity. Wavefront-guided and wavefront-optimized LASIK are more likely to preserve (or enhance) contrast sensitivity.

- **Results for Myopia (nearsightedness):** According to studies used by the FDA, 93 percent of patients with mild to moderate levels of myopia and myopia with astigmatism (up to -14 diopter of myopic error and 6 diopter of astigmatism) achieve 20/40 or better vision and about 56 percent achieve 20/20 vision within six months after LASIK surgery. In most areas of the U.S., 20/40 is good enough to drive without having to wear contact or glasses. In general, people with higher degrees of myopia may need to have a different set of expectations regarding outcomes. Several studies have demonstrated that LASIK for higher degrees of myopia can be effective, however sometimes the goal is simply to reduce the patient’s glasses or contact lens prescription rather than eliminate all refractive error. Also there is a slightly higher incidence of regression to the former refractive error and slightly higher risk of complications. People with myopia are better able to focus on close-up tasks like reading and computer work even when their eyes become presbyopic (sometime after age 40), but if they have LASIK to correct myopia they may lose this advantage.

- **Correcting Hyperopia (farsightedness):** The visual recovery of hyperopic patients is typically not as quick as that of myopic patients, and the surgeon may suggest an interval of a few days to (rarely) several weeks between LASIK for each eye. Studies presented to the FDA have shown that the six month post-LASIK results are similar to those for myopia (see above); there is a slightly higher incidence of regression, however. Patients with less severe hyperopia experienced slightly better overall results than those who required the highest degrees of correction. For more information on lasers approved by the FDA for treatment of hyperopia and hyperopia in conjunction with astigmatism, visit [http://www.fda.gov/cdrh/lasik/lasers.htm](http://www.fda.gov/cdrh/lasik/lasers.htm).

- **Retreatment:** After original refractive surgery, approximately 10.5 percent of patients need an additional procedure, termed a retreatment or enhancement. (For more information, see “Considering Retreatment,” below.) The need for retreatment can arise from several causes:
  - When a high degree of correction is required, the surgeon may purposefully under-correct the cornea and perform a retreatment procedure at a later date. This plan should be discussed prior to surgery with the patient.
Results successfully attained from the original surgery may regress over time, depending on the pre-LASIK severity of refractive error, the patient’s healing pattern and other factors. After the first retreatment, problems with over- or undercorrection or regression may occur again. If there is sufficient corneal tissue available, and after the eye has stabilized, an additional retreatment surgery may be performed.

E. Monovision LASIK: This procedure can delay or prevent the need for reading glasses (and counteract the effects of presbyopia) in appropriate candidates. The monovision concept, first used in contact lenses, corrects one eye for near vision and the other for far vision; the brain selects the clear image and disregards the blurry one transmitted from each eye, thus improving vision at all distances. People considering this option are advised to try monovision contacts before going ahead with surgery, as it is not well tolerated by everyone. A person should see whether he or she can pass the driver’s license tests using monovision contact lenses. Vision may not be adequate in dim lighting or when very clear, precise vision is needed. Patients should ask their physicians to estimate how long monovision LASIK results would remain effective before glasses or an enhancement procedure might be needed.

F. Bilateral Simultaneous Treatment: The obvious pluses of opting for bilateral simultaneous treatment are the convenience of having surgery on one rather than two separate occasions, including less time away from work and simplified arrangements for transportation and help; also a combined surgery day is less expensive. Simultaneous treatment allows the eyes to adjust together to their corrected status which reduces the risk of anisometropia, a condition that may include eyestrain, headaches, and reduced depth and distance perception. But in some cases there may be advantages to having separate surgeries, especially the opportunity to see how the first eye responds and to have a functional second eye while the first recovers. If the reaction to the first LASIK is adverse, the patient may decline the second surgery.

- Although the risk is very low, if one eye becomes infected or severely inflamed following bilateral LASIK---or develops delayed corneal clouding or scarring, internal bleeding or retinal damage---both eyes may become involved and a potentially devastating loss of vision may result.
- Response to the first surgery may indicate that the second eye should be corrected more or less than originally determined.
- If undesirable side effects such as poor night vision, glare, or dry eye arise, it is preferable to have them occur in only one eye and to learn whether the problems resolve over time.
- People contemplating monovision have the opportunity to experience the change in their near vision after the correction of one eye, and better decide whether to go ahead with monovision.

G. Informed Consent: After the LASIK evaluation exam, the Eye MD will discuss all results with the patient as well as potential benefits, risks, outcomes, and lifestyle considerations (these points are outlined above). The patient should feel free to ask questions, receive resources for further research, and have a sense of ease and trust in providing information to and receiving information from the physician. The physician should be able to verify how many LASIK procedures he or she has performed and whether the laser to be used is FDA-approved. Only when the patient’s concerns have been addressed, including questions that arise from reviewing the form, should he or she sign the informed consent. This may take place days or weeks after the evaluation exam.

V. The Patient’s Experience Before and After LASIK Surgery
A. Before Surgery
- Before the surgery, the patient stops using creams, lotions, makeup and perfumes to insure that no debris collects on the eyelashes that might increase the risk of infection. The doctor may ask the
person to scrub their eyelashes for a period of time before the surgery to get rid of residues and debris.

- The patient makes arrangements to be driven to and from the surgery and the first follow-up visit. Medication for relaxation taken the day of surgery makes driving unsafe, and after surgery vision will be blurry.

### B. After Surgery

- Mild burning or itching, or a sensation of having something in the eye, may continue for a few hours after LASIK. Pain medications may be prescribed. Eye drops to prevent infection and inflammation must be applied daily for several days.
- Vision will often be blurry the first day and improve considerably by the time the patient returns for the post-operative exam the next day. Most people report much clearer vision the day after surgery. (One should not resume use of contact lenses, even if vision is blurry, during this period.) Many patients can drive without glasses the day after surgery.
- The patient may be instructed to wait several days before resuming a normal work schedule.
- Eye makeup and lotions should be avoided for some period after surgery, as advised by the surgeon.
- All sports should be avoided for three days and strenuous or contract sports for four weeks.
- Swimming, whirlpools and hot tubs should be avoided for at least one week or up to eight weeks if the most cautious approach is preferred.
- The patient should not drive until his or her vision is clear.
- For the first few months (up to six months) visual acuity may fluctuate and side effects (detailed below) may persist. The usual period for healing and vision stabilization is one to three months. Patients who experience problems beyond six months should consult their ophthalmologist about potential retreatment procedures or other treatments.
- After LASIK the eye may be more susceptible to trauma from impact, because the corneal flap site is not as strong as the original cornea. Patients are advised to wear protective eyewear during sports and activities where balls, projectiles, elbows, fists, or other potentially traumatizing objects are involved. (This is excellent advice for any individual, LASIK patient or not.)

### VI. Side Effects, Minor and Major Complications

#### Side Effects and Minor Complications

- Reduced low-light vision, sensitivity to light, and/or visual distortion such as glare, haloes, or starbursts around light sources may be bothersome or make driving at night difficult. For most patients these problems resolve within six months of LASIK. Wavefront-guided and wavefront-optimized LASIK can reduce these side effects and in many cases improve night vision as compared with the patient’s prior vision corrected by contacts or glasses.\(^9\)
- Dry eye may be a temporary side effect or become long-term and highly problematic. The corneal surface becomes drier for some period of time following LASIK. Ongoing application of artificial tears and, for severe problems, closure of the tear duct may be required.
- Minor complications occur in 1.0 to 2.0 percent of cases\(^5\) and can slow recovery, lead to minor visual disturbances, possibly delay LASIK on the second eye, or require additional, enhancement surgery.
- Epithelial ingrowth (in which cells from the epithelial layer on the surface of the cornea migrate and grow under the corneal flap) may occur and require surgical removal.
Corneal inflammation may be caused by post-LASIK healing and/or medications. It may take the form of diffuse lamellar keratitis, also known as “Sands of the Sahara,” which can include corneal haze, blurred vision, farsightedness, astigmatism, or permanent corneal irregularities. This complication may be minor and dissipate early in the postoperative period. Treatment includes topical steroids or further surgery which may or may not fully restore vision.

Eyelids tend to droop with age, and this may be hastened in those who have LASIK.

The vision correction that the patient hoped to get from LASIK may not be realized, as discussed in several sections above. Overcorrection or undercorrection may occur, causing the patient to become hyperopic, myopic, or have increased astigmatism. These problems may be permanent or may be correctable through a retreatment. Over- and undercorrection may be more likely in people over 40 years old.

Major Complications
The overall risk of a major complication that might permanently reduce correctable vision is 0.2 to 0.4 percent. The following complications are very rare.

- Rarely, the microkeratome malfunctions during surgery. It may excise an entire portion of the central cornea, which the surgeon would reattach to the eye after laser treatment. Or the flap incision could result in an incomplete flap, or one that is too thin, which could necessitate halting the procedure and completing laser shaping at a later time after corneal healing.
- Irregular healing of the flap could result in a distorted cornea with the potential result that glasses or contact lenses could not correct vision to the pre-LASIK level. If vision distortion is severe, wearing rigid contact lenses or a partial or complete corneal transplant might be necessary.
- Very rarely the laser treatment is delivered to the stroma (the central layer of the cornea) off-center or irregularly, which could compromise the visual result.
- Perforation of the cornea could occur from the surgery and result in partial or total vision loss. An internal or external infection that could not be controlled by antibiotics could lead to this result as well.
- Severe infection, even if successfully treated with antibiotics, could lead to permanent scarring that could necessitate further surgery or, in severe cases, a corneal transplant.
- Keratoconus, a degenerative corneal disease, could develop. This could be corrected by contacts or glasses if mild, but would require a corneal transplant if severe.
- Other very rare complications may include: corneal swelling, corneal thinning (ectasia), “floaters” and retinal detachment, hemorrhage, venous and arterial blockage, cataract formation, total blindness, or loss of an eye.

VII. Considerations for Retreatment
Further LASIK surgery is only one option if the initial LASIK surgery result is not what the patient expected. Visual correction could also be achieved through use of glasses or contact lenses. PRK is another option. In any case, the LASIK surgeon and patient will wait until eye refraction measurements are consistent---indicating the eye has stabilized---before planning a retreatment procedure or prescribing contacts or glasses. The eye usually stabilizes within one to six months after LASIK. Typically, the higher the attempted correction in the LASIK procedure, the longer it will take the eye to heal. Most surgeons prefer to wait three months before performing a retreatment, but if little correction is needed and other factors are favorable, it may be done after one or two months.

The ophthalmologist will determine whether:
- Any of the risk factors noted above for original LASIK surgery now apply to the patient, and if so, whether the factor can be resolved so that retreatment surgery would be advisable.
• To do the retreatment by lifting the original corneal flap or creating a new flap. Surgeons prefer using the original flap, which can often be lifted two or more years after the original LASIK. In some cases the flap re-adheres after only a few months, however.
• It is likely that a new flap can be safely created. The danger would be that an incompletely healed piece of tissue from the original flap may form a wedge in the center or side of the flap. This could make the cornea irregular or lead to scarring and/or epithelial ingrowth, which would compromise vision
• There is enough corneal tissue remaining to safely perform the laser retreatment, which can be determined by measurement after the flap is lifted during surgery; this is an important consideration.

The surgeon may opt to perform PRK, where the surface rather than the stroma of the cornea is corrected, if he or she determines that this would provide the best outcome for a particular patient.

The Procedure
• The original flap is lifted, or the microkeratome or laser keratome creates a new flap, and the flap is folded back.
• The laser correction (pre-programmed as described in the LASIK procedure section) is performed on the stroma, then the flap is replaced and in most cases re-adheres with no need for a stitch. The epithelial layer usually reintegrates the flap with the main cornea within days of surgery. If a stitch is required, it is done below the surface and removed within several days.
• A soft contact lens may be used as a “bandage” to protect the eye surface for several days.

Post-Surgery: Recovery and Potential Complications from Retreatments
Side effects and minor and major complications as described above for original LASIK surgery may occur after retreatments. In addition, some differences in recovery and complications are possible. These include:
• A sensation of having a foreign object in the eye, sensitivity to bright lights, blurred vision, dry eyes, tearing or fluctuation in vision are common early in the postoperative period.
• Discomfort is more common following enhancement procedures than with original LASIK, but persistent pain is uncommon. If it occurs, it may indicate displacement of the corneal flap or an infection, and the patient should report persistent pain immediately to his or her surgeon.
• Complications may be more likely in patients who had more severe refractive error originally and those who have retreatments due to over- or under-correction in the original LASIK.
• Complications that can arise from retreatment in relation to the corneal flap include:
  o Corneal perforation: repair may include corneal stitches or sutures and usually the need for an intraocular lens implant, because the natural lens is usually lost or damaged. Corneal perforation can also lead to an infection with could necessitate a corneal transplant or result in blindness.
  o Displacement and wrinkling of the flap and epithelial ingrowth (with either the original or newly created flap
  o Flap displacement: care needs to be taken to protect the eye from trauma and from rubbing for several weeks after the procedure. Partial displacement can result in striae, or wrinkles, in the cornea that blur vision; this problem can usually be treated. Full displacement is usually painful and requires urgent treatment.
  o Epithelial ingrowth: produced when cells of the type that normally grow on the surface of the epithelium (top layer of the cornea) grow underneath the corneal flap during healing. This response is common following any breakdown or trauma to the epithelium and therefore is more common following an enhancement than original LASIK. It may be
treated by lifting the flap and clearing away cells. Untreated larger areas may distort vision and damage the flap integrity if severe and progressive.

VIII. Other Refractive Laser Surgery Techniques: PRK, Epi-LASIK, and LASEK
For these three procedures, screening, risk factor, lifestyle, outcomes, side effects and minor and major complications are substantially the same as for LASIK, with the exceptions noted below. Also, corneal haze or scarring may be more likely with these procedures than with LASIK (when wavefront technology is used, this problem may be greatly reduced; see information in the PRK section). The information in the LASIK Procedure section, above, regarding the patient’s decision-making process, including the bilateral simultaneous treatment option and informed consent, applies to these refractive laser surgeries as well.

A. PRK, photorefractive keratectomy: This was the first corneal laser surgery developed, and recent innovations have improved patient comfort during and after PRK. Results are similar to LASIK within three to six months post-surgery. PRK may be recommended for original or retreatment surgery when the cornea is considered too thin for LASIK, when there are concerns about creating a corneal flap, or when the surgeon considers it safer and more effective for a particular patient for other reasons. PRK can correct myopia, hyperopia and astigmatism.

The procedure: The difference from LASIK is that a corneal flap is not created, but instead the top, or epithelial, layer is removed (or moved aside) before treating the stromal layer with the excimer laser. Many surgeons use a blunt, gently vibrating microkeratome to remove the epithelium.

Wavefront-guided PRK offers additional vision correction, similar to wavefront-guided LASIK. Though thousands of wavefront-guided PRK procedures have been safely and effectively performed in the United States, the FDA approval process has not yet taken place, so wavefront-guided PRK is considered an “off-label” use of the technology. Professional medical standards permit Eye MDs to use this and other “off-label” procedures and medications.

Advanced surface ablation (ASA) techniques, including cooling the cornea before or after surgery, help reduce PRK patient discomfort. After surgery the patient may be given topical antibiotics and anti-inflammatory medications and oral pain medications. A soft contact lens “bandage” is usually applied to the eye to promote epithelial healing, which takes about four days.

Post-operative healing usually takes a few days longer than for LASIK, and the patient may experience more discomfort (usually within 48 hours post-surgery) during healing. Also, stabilization of visual acuity and full healing of the eye may take up to six months. Between one and nine percent of PRK patients may have persistent scarring of the cornea; wavefront-guided PRK greatly reduces this problem. An increase in intraocular pressure (IOP) may result from post-treatment medications; this can usually be resolved through discontinuing these medications or treatment with other drugs.

Epi-LASIK and LASEK are essentially variations of PRK and would be recommended to patients for the same reasons as PRK.

B. Epi-LASIK: A special microkeratome, the Epi-keratome, is used to precisely separate the thin epithelial sheet from the rest of the cornea. Once separated, this thin sheet is lifted to the side, the stromal layer is treated with the excimer laser, and then the thin sheet may be moved back into place to re-adhere to the cornea, or removed. Post-surgery treatment is similar to PRK.

C. LASEK: A microsurgical instrument called a trephine is used to create a flap of epithelial corneal tissue, and an alcohol solution is used to loosen the epithelial cells. Once the epithelial flap is created and moved aside, the procedure is the same as PRK. After corneal sculpting, the epithelial flap is repositioned and smoothed with a small spatula, then secured with a “bandage” soft contact lens to promote epithelial
healing, which takes about four days. Several recent studies found that LASEK results were comparable to LASIK or PRK; additional long-term studies are needed to confirm these results. LASEK is a relatively new procedure that does not yet have specific FDA-approval for this use of the excimer laser.

**SOURCES for the information in this guide:**