

Refractive eye surgery is any eye surgery used to improve the refractive state of the eye and decrease or eliminate dependency on glasses or contact lenses. This can include various methods of surgical remodeling of the cornea or cataract surgery. The most common methods today use excimer lasers to reshape curvature of the cornea. Successful refractive eye surgery can reduce or cure common vision disorders such as myopia, hyperopia and astigmatism. According to surveys of members of the American Society of Cataract and Refractive Surgery, approximately 948,266 refractive surgery procedures were performed in the United States during 2004 and 928,737 in 2005. ⁽¹⁾

The goal of refractive surgery is to bring light rays to a focus on the retina by adjusting the refractive power of the cornea. Refractive surgical procedures achieve this goal by reshaping the anterior corneal surface, which accounts for the greater part of the corneal refractive power. However, different types of laser refractive surgery have been reported to induce a forward shift of the cornea, and their effect on the posterior cornea has been of great concern. ⁽²⁾

LASIK is a type of laser surgery of the cornea to correct refractive errors, during which a slice of the patient's cornea is removed, shaped to the desired curvature with an excimer laser, and then sewn back to the remaining cornea. In recent years,

LASIK surgery has become the procedure of choice for treating moderate to high levels of myopia, with or without astigmatism. Physicians then began using these lasers for LASIK surgery as well and to treat refractive disorders other than myopia. The laser emits an ultraviolet beam that is able to reshape the cornea. Refractive errors are minimized with the aid of a programmed computer that, using a patient's refraction and corneal topography, controls the laser beam to precisely remove corneal tissue. ⁽³⁾

The procedure itself consists of different surgical steps. One of the important parts of this surgery is the flap creation. Many complications can occur during the preparation of the corneal flap, resulting in costly retreatments. A meta-analysis of 30 trials reported an incidence of 31% for intraoperative complications, of which 19% were microkeratome associated. ⁽⁴⁾

Preoperative evaluation for refractive surgery follows a structured sequence that includes patient interview followed by a complete ophthalmologic examination. The aim of preoperative evaluation is to answer three broad questions in addition to generating specific refractive data for the actual treatment: 1) Is it possible to safely perform refractive surgery in the patient; 2) What is the risk of possible complications, given the patient specifics; and 3) Is it possible to meet the expectations that the patient has from the surgery? ⁽⁵⁾

Computerized corneal topography examination is an important part of the preoperative evaluation. It can detect irregular astigmatism, whether from contact lens wearing or other causes, which, if significant, is a contraindication to LASIK. The average Simulated K. (SimK) is noted. The central keratometry number is used to choose the diameter of the flap cut (9.5 mm if 41 D or less and 8.5 mm if 48 D or more). Flat corneas are associated with small microkeratome flaps and free caps, and steep corneas are associated with flap buttonholes. Central keratometry flatter than 35 or 36 D or steeper than 50 D after LASIK is said to be associated with a decrease in quality of vision. ⁽³⁾

The Orbscan corneal topography system uses a scanning optical slit design that is fundamentally different from the corneal topography that analyzes the reflected images from the anterior corneal surface. The high-resolution video camera captures 40 light slits at the 45° angle projected through the cornea similarly as seen during slit lamp examination. The instrument's software analyzes 240 data points per slit and calculates the corneal thickness and posterior surface of the entire cornea. The anterior surface of the cornea initially was calculated in this manner; however, since the calculation from the reflected images used by corneal topography is more precise, the current version of Orbscan is using the latter

method and is a combination of reflective corneal topography and optical slit design. ⁽⁶⁾

The Pentacam (Oculus, Lynnwood, Wash) uses a different method to image the cornea: Scheimpflug imaging is based on the Scheimpflug principle, which occurs when a planar subject is not parallel to the image plane. In this scenario, an oblique tangent can be drawn from the image, object and lens planes, and the point of intersection is the Scheimpflug intersection, where the image is in best focus. With a rotating Scheimpflug camera, the Pentacam can obtain 50 Scheimpflug images in less than 2 seconds. Each image has 500 true elevation points for a total of 25,000 true elevation points for the surface of the cornea. ⁽⁷⁾

Contrast sensitivity testing was introduced in 1956 by Schade (**Schade et al., 1956**) who found that it provides much more information about vision than Snellen acuity testing. visual acuity measured using standard clinical tests is useful but is an incomplete description of visual ability. Although visual acuity tests determine the ability to resolve small details (i.e., resolution of high spatial frequencies) at high contrast, the visual environment is composed of objects with variety of spatial frequencies and contrasts. Therefore, to determine how well one can function in complex environment, it is necessary to measure sensitivity to contrast as a function of spatial frequency. ⁽⁸⁾

- The word keratomileusis is derived from the Greek keratos, which means "cornea", and Mileusis, which means, "carving". Literally, it is carving of the cornea. It is a procedure which aims to change the refractive power of the cornea, i.e., to reduce or eliminate myopic, hyperopic or astigmatic defects.⁽⁹⁾

History of keratomileusis:

- The first experimental studies about refractive surgery were published in **1896** by **Lendeer Jans Lans**,⁽¹⁰⁾ an ophthalmology teacher in Holland, where he developed a theoretical work proposing penetrating corneal cuts to correct astigmatism.
- In **1930**, the Japanese ophthalmologist **Tsutomu Sato**,⁽¹⁰⁾ made the first practical attempt to perform such surgery in military pilots. He practiced radial cuts in the in the cornea to correct effects by up to 6 diopters, but this procedure was soon rejected by the medical community because of the high rate of corneal degeneration.⁽¹⁰⁾
- **Dr. Jose Ignatio Barraquer of Bogota, Colombia** conceived the idea of carving the cornea to correct refractive error, in **1949**, he coined the term "refractive keratoplasty" that is, plastic surgery for refractive reasons. Thirteen years of experimentation in animals followed, during which time he formulated the

"Thickness Law" and elucidated the principles of many of today's lamellar refractive surgery techniques.⁽¹¹⁾

- In **1958, Barraquer** performed the first resection in situ following the removal of a corneal disk and created human positive and negative lenticles from donor corneas through a planar cut and freeze techniques.
- In **1962, Barraquer** started using a microkeratome with a 26° cutting angle, pneumatic (suction) ring and track, the applanation tonometer and the first intraoperative keratometer and invited the first cryolathe and its algorithm. In 1964, the cryolathe was modified (automatic computerized cryolathe)⁽¹²⁾.
- Meanwhile, experiments in **1970** using a xenon dimer and in **1975** using noble gas halides resulted in the invention of a type of laser called an excimer laser. While excimer lasers were initially used for industrial purposes.⁽¹³⁾
- In **1980, Srinivasan**, a scientist of IBM who was using an excimer laser to make microscopic circuits in microchips for informatics equipment, discovered that the excimer could also be used to cut organic tissues with high accuracy without significant thermal damage. The discovery of an effective biological cutting laser, along with the development of computers to control it, allowed

new refractive techniques which were previously unavailable.⁽¹³⁾

- In the period **1983-1986**, **Luis Ruiz** proposed in situ keratomileusis, which involved two superimposed parallel keratectomies using a microkeratome. In **1983**, **Trokel** performed the first corneal application of excimer laser to perform the refractive incisions and the corneal resection.⁽¹⁴⁾
- In **1989**, **Buratto** presented the technique of intrastromal keratomileusis using the (excimer laser intrastromal keratomileusis) {ELISK} on the cap or in situ).⁽¹⁵⁾
- Between **1990** and **1991**, **Pallikaris** presented the concept nasal corneal hinge. In **1991**, **Gullermo Avalos and Riccardo Guimaraes** developed sutureless technique for keratomileusis.⁽¹⁵⁾
- **1996**, **Buratto** modified the LASIK technique, performing the cut vertically ie, from below upword as opposed to horizontally. The technique called "Down - up LASIK" (Superior Hinge Technique or Top Hinge LASIK).⁽¹⁵⁾

Technique:

- LASIK is performed by surgically making a lamellar corneal dissection, followed by excimer laser ablation of the stroma and then replacement of the dissected cornea. It is used in attempts to correct myopia, hyperopia, and astigmatism. LASIK has evolved as the alternative to PRK for several reasons.⁽¹⁶⁾
- LASIK offers more rapid visual recovery and much less pain and irritation immediately postoperatively. After LASIK, one does not see the occasional stromal haze or scarring that is seen with PRK. Higher refractive errors can be corrected with LASIK than with PRK. LASIK, when performed properly, offers a very high percentage of success.⁽¹⁶⁾
- The microkeratome is used to make a 130 or 160 μm thick section of corneal stroma and its covering epithelium. It travels approximately 80% across the cornea to a stop, creating nasally or superiorly located "hinge" flap.
- This flap is folded away so that photorefractive laser keratectomy may be performed in the stromal bed. The corneal flap is replaced and the interface is irrigated with sterile balanced salt solution. One usually waits a period of 1 to 4 minutes for the stromal flap to "stick" in position.⁽¹⁶⁾

- Comparison studies are still being conducted comparing laser devices and mechanical microkeratomes. The laser devices have been found to be as good as or better than mechanical microkeratomes , but long term results are still needed ⁽⁴⁾.
- Therefore, refinement of cutting quality with regard to morphology of cutting surfaces and edges is ongoing .A smooth cutting surface is considered to be one of the main quality markers in LASIK. Surface irregularities can cause haze and result in lower visual outcome. ⁽⁴⁾
- Sharp cut edges are relevant for the reduction of postoperative epithelial ingrowth, less flap dislocations, and less postoperative inflammation ⁽⁴⁾.
- Today, different instruments can be used for corneal preparation such as occurs in LASIK. One recent option is use of an fs-laser system,⁽¹⁷⁾ which is however, a very expensive surgical tool for lamellar keratotomies. Despite the increasing use of fs-lasers, microkeratomes are still common for cutting flaps.⁽⁴⁾
- As long as fs-lasers do not offer a main advantage in terms of visual outcome or complications, microkeratomes can continue to be regarded as a cost-saving alternative. Hence it is also necessary to refine the technical parameters of mechanical microkeratomes.⁽¹⁸⁾

- The procedure generally is performed as follows: Topical anesthesia is instilled in the conjunctival gutters, and the eyelids are propped with Betadine Solution. Plastic drapes are placed on the upper and lower eyelids. Alignment marks are made on the cornea with gentian violet.⁽¹⁹⁾
- A pneumatic suction ring is suited on the eye at the corneal limbus. The intraocular pressure is checked with a Barraquer tonometer⁽¹⁹⁾
- A microkeratome is inserted into a track on the suction ring. It is advanced across the cornea, making a tissue flap of 130 or 160 um in thickness. The microkeratome and suction ring are removed, and the corneal flap is opened and laid back over its hinge of tissue. The corneal stroma is ablated with the excimer laser, and the corneal flap is irrigated and then closed.⁽¹⁹⁾
- The interface is irrigated with balanced saline solution between the corneal flap and the stromal bed for a few seconds to remove debris, and the corneal flap is wiped into alignment with a wet surgical spear. A 2 to 3 minute waiting period is observed to allow the corneal flap to adhere to the stromal bed.⁽²⁰⁾
- Antibiotic eye drops and steroid eye drops are instilled onto the cornea. The patient is returned to the slit lamp

for a final recheck of corneal flap alignment before being discharged.⁽²¹⁾

- One reason LASIK is so popular with patients is because there is usually minimal irritation during and after the procedure. Most patients have blurry vision immediately after the surgery. They often describe it as if they had entered a "steam room" or had been "swimming with their eyes open," but vision improves rapidly. Many patients will have uncorrected visual acuities of 20/40 or even 20/20 by their 24-hour follow-up visit.⁽²⁰⁾
- The cut edge of the corneal Flap is usually almost undetectable by the next day, being already healed over with epithelium.⁽²⁰⁾
- Antibiotic and steroid eye drops are used four times daily for 1 week and then discontinued. Lubricant eye drops are often helpful for at least 6 months. The patient should be seen postoperatively at 1 day, 1 week, and 1, 3, and 6 months.⁽²¹⁾
- Although there appears to be fewer complications with LASIK than with other refractive procedures, the complications that can occur are usually much more severe. Irregular astigmatism, epithelial in-growth, displaced flaps, stromal melts, and poorly cut flaps can be very hard to manage.⁽²¹⁾

- Since the complications that occur can be difficult to correct, prevention is the order of the day. This can be accomplished by obtaining the best possible training for oneself and the surgical staff and by paying meticulous attention to the details of laser calibration, setup, and surgical performance.⁽²¹⁾

Corneal wound healing:

- Corneal wound healing is a major contributor to the success of traditional excimer laser ablation procedures and custom Q-linked or wavefront-guided corneal ablations used to optimize visual outcomes⁽²²⁾. Biological differences in wound healing responses are thought to be a major factor limiting the predictability of refractive surgery in some patients (overcorrection, undercorrection and regression, and induction of irregular astigmatism).⁽²³⁾
- In addition, wound healing may contribute to some of the complications of PRK, LASEK, or LASIK, including haze formation,^{1,2} which are more common after surface ablation than LASIK, particularly in deeper ablations for higher degrees of myopia.⁽²³⁾

Corneal biomechanics:

- It is evident from incisional refractive surgery that the cornea is not mechanically inert. The role of biomechanics is therefore important to consider in routine LASIK or surface ablation procedures and in special cases where the biomechanical status of the cornea is abnormal (for example, after any previous refractive surgery or after penetrating keratoplasty).⁽²⁴⁾

- Biomechanical changes can manifest clinically as immediate corneal shape changes, shape instability over time and increased sensitivity to shape changes from stimuli such as altered hydration, hypoxia and subsequent injury or surgery. The relative impact of biomechanics and wound healing increases when wavefront-guided treatments of higher-order aberrations are attempted. Figure (1) describes an approach to biomechanical problems in the cornea that illustrates a relationship between the corneal structure, its material properties, the nature of the mechanical injury and the structural and optical responses.⁽²⁴⁾

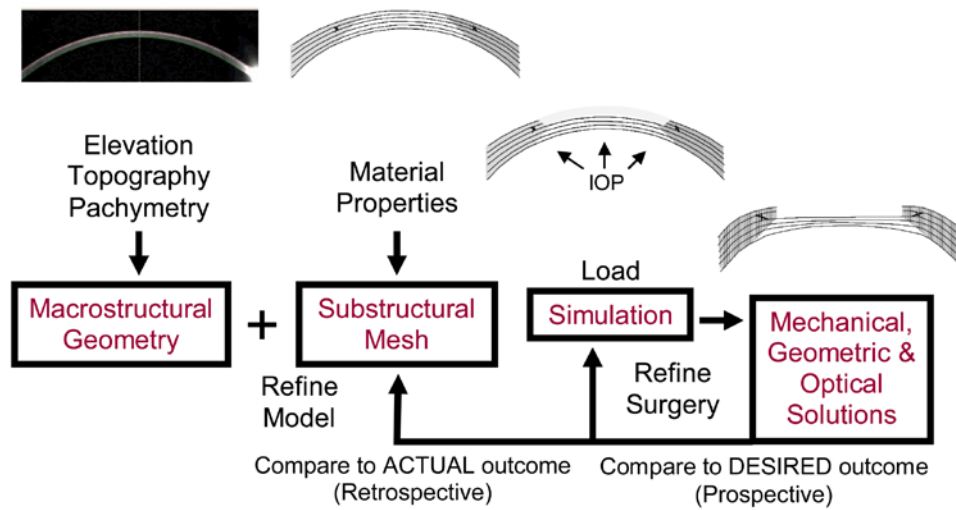


Figure (1): An approach to biomechanical modeling of surgery and disease in the cornea. Disease is simulated by alteration of the substructural components or their material properties. Surgery is simulated by imposing an ablation profile or incisions. The model is optimized retrospectively by comparing model simulations to analogous experiments in tissue or clinical models. A model optimized with clinical data can then be used prospectively to design and evaluate patient-specific treatment algorithms. ⁽²⁴⁾

Corneal Shape After Wound Healing:

- Evaluation of corneal shape is an important, if not essential, component of the preoperative assessment of refractive surgery candidates. The development of automated corneal topographic analysis has made a considerable difference to the assessment of patients and planning of their surgery, and such measurements on