LASIK Journey

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Professor José I. Barraquer, MD, Father of Refractive Surgery, made initial strides in lamellar refractive surgery, and proposed the theory that adding or removing corneal tissue can modify the refractive power of the eye.[1] Right from beginning he realized the importance of preserving each layer of the cornea, a guiding force in the development of modern lamellar refractive procedures.

Keratomileusis In Situ

Dr. Barraquer's Contribution To The Refractive Surgery

His original technique included the creation of a corneal lamellar disc followed by the removal of stroma, either from the bed (keratomileusis in situ) or the stromal surface of the corneal lamellar disc. The widely used term *keratomileusis* was derived from the Greek root words "keras" (hornlike = cornea) and "smileusis" (carving) to describe lamellar techniques.[2]

While working with Paufique knife, a freehand lamellar dissection to remove the stroma of the anterior half of the cornea, he found it difficult and this led him to focus his research on refining lamellar resection and carving the resected corneal disc.[3] He designed the first manual microkeratome, applanator lenses, and suction rings of various heights. Dr. Barraquer appreciated the importance of maintaining constant contact between the microkeratome and the suction ring during the cut in order to create a smooth, even keratotomy.[4]

Numerous disadvantages of the initial myopic keratomileusis procedure included induced corneal irregular astigmatism, corneal scarring, and complex instrumentation,[4] and ultimately gave rise to the development of alternative techniques, including epikeratophakia,[5-7] incisional keratotomy,[8-10] and IOL implantation.[11]

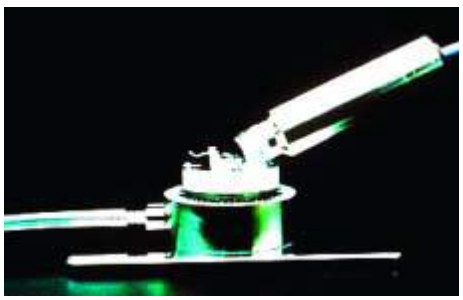

Figure 1. Early microkeratomes, like the Barraquer-Krumeich-
Swinger, utilized a nonfreeze keratomileusis technique.

Chronology Of Corneal Refractive Procedures

In the late 1980s, lamellar refractive surgery evolved in two directions: freezing and non-freezing procedures. According to reports, freezing lamellar procedures were often associated with

corneal haze and induced irregular astigmatism.[12-16] In contrast, the non-freezing techniques offered major advantages, including rapid patient recovery and fewer complications,[12,13,15] but these procedures were technically difficult to perform. They involved the use of a manual keratome to perform a second cut on the stromal side of the resected lamellar disc.[12,13,15] The manually driven microkeratomes had several apparent drawbacks, including a lack of precision and predictability and low levels of safety.[17]

Dr. Luis Ruiz of Bogota, Colombia, developed a nonfreeze procedure based on keratomileusis, known as *automated lamellar keratoplasty* (ALK). This procedure involved a primary keratectomy with an automated microkeratome to create a corneal disc, followed by a second keratectomy on the corneal bed that removed a small central piece of cornea in order to create a flatter central cornea when the corneal disc was replaced. As a result; the procedure was well received in the 1980s. The obvious advantages of this procedure—rapid visual recovery, high levels of efficacy, and stability for the correction of high myopia—were balanced by induced irregular astigmatism and low predictability of the procedure.[18]

Early attempts by Gholam A. Peyman, MD, of New Orleans, Louisiana, to remove corneal tissue using a CO2 laser failed due to major complications, including scarring and tissue coagulation.[19] Dr. Peyman reported the Er:YAG laser to be successful in modifying the corneal curvature, however.[20] In 1983, Stephen L. Trokel, MD, and his group introduced photorefractive keratectomy (PRK).21 When performed with a 193-nm excimer laser, PRK for high myopia often resulted in severe corneal haze, regression of myopia, and poor predictability.[22]

LASIK

The growing need for a safe and predictable corneal refractive procedure motivated the Pallikaris group to design and develop *laser in situ keratomileusis* (LASIK) in 1988 at the University of Crete, Greece. They worked on the original idea of manually creating a corneal cap and removing central tissue from the bed was first described by Nikolai P. Pureskin, Moscow, Russia, in 1967.[25]They combined lamellar refractive corneal surgery with excimer laser photoablation of the cornea under a hinged corneal flap.[23] The first animal studies, which were intended to determine the wound-healing response after LASIK, began in 1987 and involved a Lambda Physik excimer laser (Lambda Physik AG, Göttingen, Germany) and a microkeratome designed to produce a 150-mm corneal flap.[24]

They believed in the hypothesis that a mechanically cut flap would ensure a better tissue alignment after the intrastromal photoablation and along with this type of flap would barely affect the anatomical relations of the corneal layers because it would preserve the Bowman's layer and preserve greater integrity of the superficial nerve plexus of the cornea through the base of the flap. In June 1989, the first LASIK on a blind human eye was performed at the University of Crete, as part of an unofficial blind eye protocol. Human studies began in 1990.[26,27]

Three months after creating the flap, they observed that the cornea remained transparent and noted no

significant irregular astigmatism on corneal topography.

The safety of sutureless LASIK was also suggested by Dr. Ruiz and perhaps others at that time.26 Buratto et al introduced an excimer laser for intrastromal keratomileusis of the corneal button in 1992, and suggested the term *laser intrastromal keratomileusis*.[28] The next year, Stephen Slade, MD, of Houston, Texas, used the automated microkeratome to create a flap. He called the procedure *excimer ALK* (*E-ALK*) or *flap and zap*.[29]

In 1994, Pallikaris group reported the early experience of LASIK on sighted eyes as well as the first study comparing LASIK and PRK.[30,31] LASIK proved superior to PRK in terms of stability and predictability for the correction of myopia greater than 10.00 D. In 1999, the SVS Apex Plus Excimer Laser (Summit Technologies) was FDA approved for LASIK.[32]

Our Prospective

All the progress in the field of LASER refractory surgery motivated us to take an initiative in the unexplored arena of LASIK in the state of Rajasthan as early in 1999. Overcoming the initial financial and social hiccups we were fortunate enough to be party in the journey of LASIK and different variants.

We have witnessed evolution of everything from micro keratomes, Excimer hardware, tracking systems and softwares. Understanding regarding safety of LASIK procedures has increased with time. In the beginning, the initial microkeratomes were to be assembled on the eye and consequently had many assembly related errors; some serious ones like anterior chamber entry were reported. These are now replaced by pre assembled and disposable ones.

Figure 2. Disposable Automatic Microkeratome

Flap thickness was an issue since the initial thickness was around 160 to 180 microns and now it has come down to 90 to 100 microns. Regarding flap construction (nasal or superior), views changed with time. We started with nasal flaps, then some reports came which advocated superior flaps citing risk of nasal flaps dislocating on lid movement. Then due to increased dry eye complaints because of both corneal nerves severing, superior flaps were discouraged and again nasal flaps came in vogue.

We started with broad beam Excimer systems then shifted to high frequency spot lasers. This resulted in reduced total energy delivery into the tissue and also made customized treatment possible. The advent of tracking system and controlled cone atmosphere ensured predictable laser delivery.

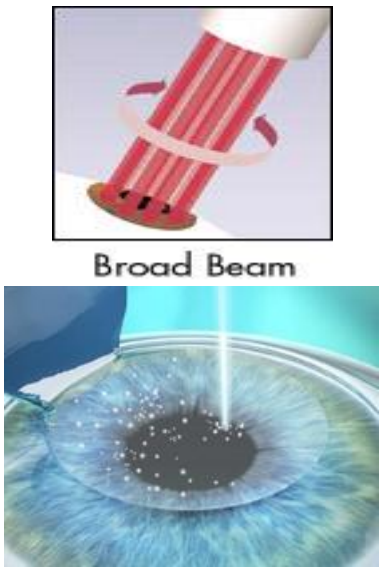

Figure 3. Diagramatic demonstration showing Broad Beam v/s Flying Spot Laser

With the wave front guided technology further higher order customization was made possible. The issues related to asphericity, astigmatism and hyperopic correction were better addressed with small spot scanning laser.

Femto Technology

Now time is again changing with the advent of Femto Technology. Femtosecond lasers produce a different tissue interaction, however, known as photodisruption (Figure 1). The application of many photons of laser energy at the same place and time leads to a nonlinear absorption of femtosecond laser energy. Due to the multiphoton effect, as well as the electron avalanche phenomenon, energy absorption by tissue eventually exceeds the threshold for optical breakdown. This process of photodisruption creates plasma. It also produces an acoustic shockwave, some thermal energy, and then a cavitation bubble, which expands at supersonic speed, slows down, and then implodes. A gas bubble subsequently forms that is composed of carbon dioxide, water, nitrogen, and other elements.

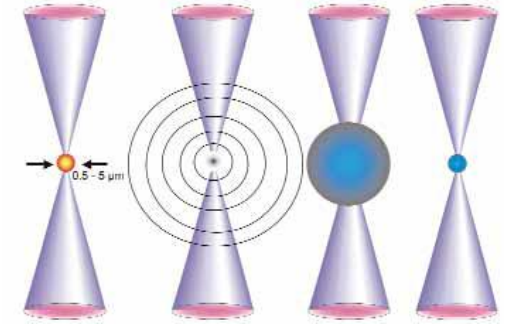

Figure 4. The course of a photodisruptive process is shown. Due to multiphoton absorption in the focus of the laser beam, plasma develops (A).Depending on the laser parameter, the diameter varies between 0.5 µm to several micrometers. The expanding plasma drives as a shock wave, which transforms after a few microns to an acoustic transient (B).In addition to the shock wave's generation, the expanding plasma has pushed the surrounding medium away from its center, which results in a cavitation bubble (C).The maximum diameter of the cavitation bubble can reach 10 to 100 µm .Its lifetime is only a few microseconds. After the collapse of the cavitation bubble,a gas bubble is left behind, containing carbon dioxide and other gas molecules (D).

Femto SMILE

lenticular extraction with the femtosecond laser is the real all LASER procedure. This involves making two lamellar cuts with a femtosecond laser to create an intrastromal lenticle of defined shape, which the surgeon removes. We have used the VisuMax in this fashion for myopic treatments. They create a huge optical zone and a slightly prolate cornea without any need for the excimer laser ablation of tissue.

Our first results with a single small incision lenticule extraction procedure using only a femtosecond laser for the treatment of myopia and myopic astigmatismare very encouraging. In the technique,

a corneal lenticule is cut using a femtosecond laser and is extracted through a single small incision,

without lifting a flap. No excimer laser is used. Our results indicate that the procedure can be done in relatively thin corneas, post LASIK discomfort is minimal with better tear film stability and for a surgeon it is free of nightmares regarding flap. Though the procedure is in infancy, we can say that it is safe, effective, and predictable.

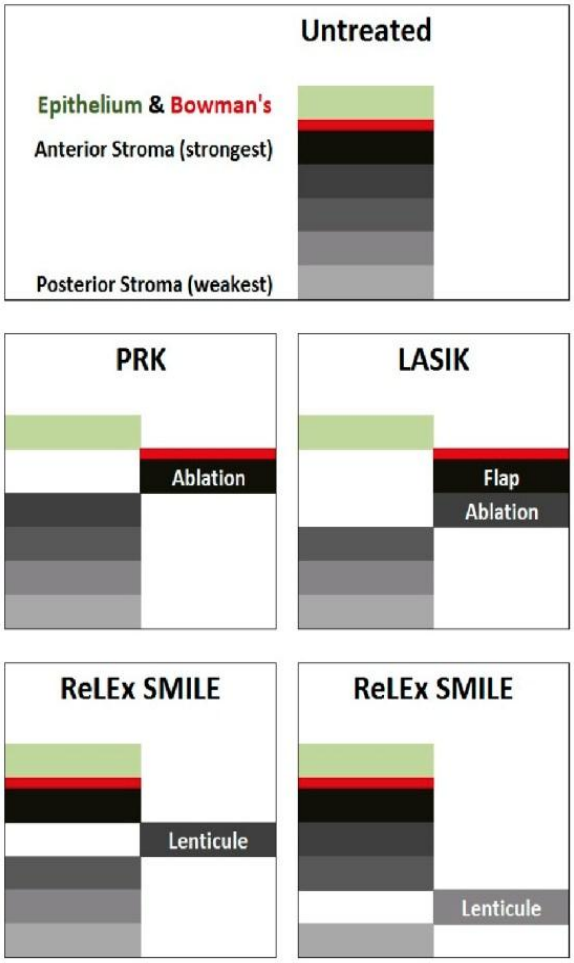

Figure 5[36]
This is a diagrammatic demonstration showing the difference in strength of the remaining stroma after PRK, LASIK, and ReLEx SMILE. These diagrams show that the strength of the stroma remaining after ReLEx SMILE is greater than the equivalent treatment as both PRK and LASIK. The fact that Bowman's layer remains intact will also provide added strength. Finally, the two diagrams for ReLEx SMILE show the even greater strength if the lenticule is removed from deeper within the stroma.

Figure 6. This is a diagrammatic representation showing the difference in incision in smile v/s normal LASIK with flap

The Future of LASIK

Corneal refractive surgery is one of the most evolving procedures in medicine today. Our experience regarding safety, predictability and Long term stability with all LASIK procedures have been excellent. Although the Femto LASERs will replace the Excimer ones in a decade or so, still the traditional LASIK will be the main stay of refractive surgery if performed with all detailed prior work up.

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