

Vision Correction Surgeries: Past Techniques, Present Trends and Future Technologies

Arun C. Gulani, MD

Editor's Note: Due to space and color constraints, Figures 1,2,3, 5B,6,7,10 & 11 of this article are not printed in the journal. These figures are available online at dcmsonline.org. In the text, the online figures are denoted with an asterisk (*).

Abstract: *Since its inception, refractive surgery has undergone radical and revolutionary refinement with technological advancement catapulting it into the 21st century as one of the most sought-after elective procedures. Recent advances in both diagnostic and therapeutic technologies are responsible for its unprecedented success and popularity. Blades, stitches, and patches are now a thing of the past. There is now the comfort and safety of lasers, plastics, and glued-sutureless techniques. Advances in diagnostic technologies allow ophthalmologists to better select candidates, provide more predictable precision in treatment and aim for an attractive goal of "SuperVision."^{1,2}*

Early History

The pursuit to make people see without glasses has been an ongoing endeavor for centuries. The techniques that evolved from this desire signify the ongoing improvement in technology as well as progressive understanding of the visual system of the human eye. Numerous procedures were born, marketed and performed. Some stood the test of time while others withered away when compared in outcomes, safety and or philosophy.³

Over the last century, the cornea (shape of the cornea) did emerge as the main platform for vision corrective surgeries. In order to reshape this cornea, various surgical techniques came about. Radial keratotomy, first introduced by Tsutomu Sato in the early 1930s gained worldwide acceptance when Russian ophthalmologist, Dr. Slatoslav Fyodorov (*Figure 1) taught his technique (Russian technique: Periphery to Center Cuts) for the correction of Myopia (nearsightedness) by making radial, diamond incisions into the cornea thus flattening its shape.⁴ He turned Moscow into a pilgrimage site for eye surgeons from the United States who traveled to learn this new and promising cure. This turned out to be the most documented and studied refractive surgery in the United States of America (Prospective Evaluation of Radial Keratotomy Study) and the American technique (Center to Periphery Cuts) became widely accepted.^{5,6}

Dr. José Barraquer (*Figure 2) in Columbia, South America discovered that changing the shape of the cornea by Lamellar or flap-based corneal surgery could correct refractive error. He

altered the shape by removing a layer of the anterior cornea with an instrument called a Microkeratome, froze the tissue, and reconstructed its shape with a mechanical lathe called the Cryolathe. Dr. Barraquer's concepts of Lamellar Refractive surgical approach to the cornea made sense as the cornea is lamellar in anatomy.⁷ Also, his desire for higher accuracy for the shape determining cut was eventually realized. Rightly so, Dr. Jose I. Barraquer is called the father of Laser Assisted in Situ Keratomileusis (LASIK surgery). He invented LASIK surgery nearly half a century ago. Only the technology and tools have changed to make this the most popular surgery of the 21st century.

Arrival of the Excimer Laser

In 1987 the 193 nm Excimer Laser (originally designed to work on computer chips) was introduced to achieve precise, non-thermal corneal reshaping.⁸ This laser works on the principle of Photo-Ablation wherein inter-molecular bonds are broken and the molecules ejected while the cornea is sculpted to the desired shape. This surgery was introduced as Photo Refractive Keratectomy (PRK). It was only a matter of time when the precision of the Excimer Laser (over the cryolathe) and the flap based, lamellar concept of Dr. Barraquer (Automated Lamellar Keratoplasty - ALK) were combined (A hinged corneal flap made first followed by Excimer Laser reshaping of the cornea underneath and then replacing the flap back like a page of a book without stitches) to evolve into LASIK.⁹ (*Figure 3)

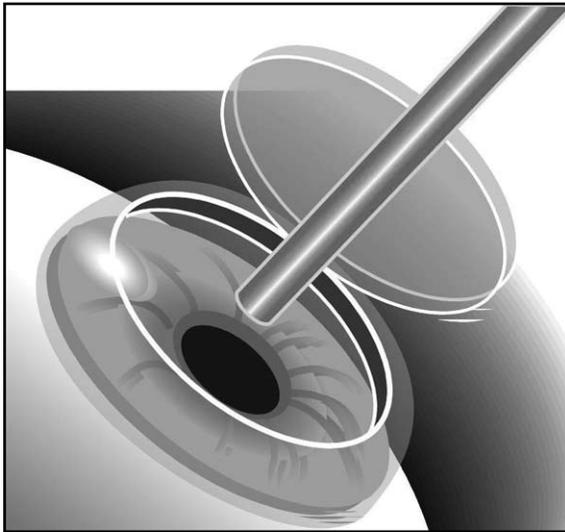
LASIK received a head start in Europe and Asia. Initial clinical trials of LASIK began in the United States in 1996 with the FDA granting approval of the procedure in 1999. With acceptance of LASIK, new instruments were invented and protocols were outlined.¹⁰⁻²²

In late 2001 IntraLase Corporation in Irvine, CA developed Femtosecond Laser technology to provide a laser activated corneal flap in LASIK. The advantage of this technique (usually known as bladeless or all laser LASIK) as opposed to the new generation microkeratome flaps in LASIK is still a matter of debate, but this laser has now found a wider scope in the field of blinding corneal pathologies for corneal transplants.²³ (Figure 4, p.42)

In 2002 the FDA approved LASIK with Wavefront-guided Excimer Laser Ablation. Using waves of light to map higher and lower order aberrations in the eye, Wavefront technology now allows surgeons to go beyond the capabilities of traditional refraction (Sphere and cylinder) to identify vision errors that affect image quality, especially in dim light. Incorporating

Address Correspondence to: Arun C. Gulani, MD. Gulani Vision Institute, 8075 Gate Parkway (W), Suites 102-103, Jacksonville, FL 32216. Email: gulanivision@gulani.com. Website: www.gulanivision.com

Figure 4 Lasik Surgery



Lasik Surgery with raised corneal flap and laser beam reshaping

readings from Wavefront analyzers or “aberrometers” into Excimer Laser systems has opened the floodgates for patients seeking individualized vision corrective surgery.²⁴⁻²⁷

As technologies to refine flap making and corneal re-shaping improved, concepts for safety and outcomes moved surgery to the very superficial layers of the cornea. LASIK and Epi-LASIK are techniques that combine certain elements of both PRK (superficial and precise corneal shaping) and LASIK (Flap based surgery for faster visual rehabilitation and comfort) thus enabling patients with corneas too thin for LASIK to avail of the laser precision surgeries.²⁸⁻³⁰

PRK, the first approved Excimer Laser technique (even before LASIK) shall see a resurgence in the form of Advanced Surface Ablation.²⁹ The safety of this technique along with the blade free approach is welcomed by patients with the only downside being a longer recovery to vision (5 days) when compared to LASIK surgery (1 day). (Figure 5A. *Figure 5B) This is also the only presently approved procedure for the United States Armed Forces.

Figure 5A Gulani Lasik Marker



The Gulani Lasik Marker is one of six instruments in the Gulani Lasik Set. Figure 5B of the web illustrations shows the entire set.

Alternative Approaches

Certain conditions of the cornea are considered to be contraindications for LASIK surgery due to their unstable pathologies inclusive of very thin corneas and extreme abnormality in shape. One such very important condition is Keratoconus (ectatic condition of the cornea resulting in very

high and irregular astigmatism wherein patients cannot wear contact lenses anymore and are relegated to a lifetime of poor vision). The recently approved Intrastromal Corneal Ring Segment Inserts (INTACS) are placed in micro channels in the cornea to reduce irregular steepening (irregular astigmatism) by flattening and have revolutionized this relentless condition by providing a reversible and safe corneal molding surgery.²³ (*Figure 6) A procedure that may prove complementary to this approach is presently under investigation for using Riboflavin collagen cross-linking to prevent the cornea from protruding and becoming increasingly steep and irregular.²⁹

Intraocular Lenses (IOLs)

In 1948 Dr. Harold Ridley, a physician to Royal Air Force pilots in World War II, observed the non-reactive nature of retained cockpit “glass” in the eyes of pilots who suffered this injury following bombings. He began experimenting with plastic lens designs, giving birth to the modern era of intraocular lens implantation. No longer were patients required to wear “Coke bottle” glasses after cataract surgery.

In the 1970s Intraocular lenses were designed to replace the extracted cataract and to provide refractive power. Taking this to the next level we now have a plethora of choices of lens implants that can correct Presbyopia - the scourge of every patient who crosses that age of 40. The new Presbyopia-correcting lens technology enables surgeons to offer more options to patients who desire the ability to see well at distance and near without glasses. (*Figure 7) Whereas cataract surgery previously meant restoration of visual clarity with spectacle correction, now it means restoration of visual quality both at distance and near without visual aids.³¹

Phakic IOLs

Until recently, refractive surgery for some people with very high degrees of refractive errors (nearsighted or farsighted) had not been an option. The amount of correction needed could not be achieved safely through LASIK and other laser surgical procedures involving reshaping the cornea. The Phakic IOLs are artificial lenses which are implanted inside the eye in front of the eye’s natural lens.³¹⁻³³ (Figure 8, p.43) BIOPTIC is a combination of Phakic implant technology and LASIK surgery, so the Phakic implant will correct the majority of the very high refractive error while the laser will reshape the cornea to correct co-existing astigmatism and or residual refractive error.

Present and Future Diagnostic Technologies

The diagnostic arena is also growing at an unprecedented rate to include topography (Corneal shape studies) and Wavefront Aberrometry that aid not only in precise pre-operative determination of surgical candidates, but also in the diagnosis of post-operative complications. Starting with mere Placido’s discs which reflected the corneal shape mires, slit-scanning topography evolved as the Orbscan™ (Bausch & Lomb, New York, NY) which derives the curvature and elevation of both the front and back surfaces of the cornea from a series of slit-beam images.²⁸ (Figure 9, p.43)

Figure 8 Phakic Implant



Phakic Implant (Contact lens in the eye)

Figure 9 Pentacam Scheimpflug Technology



Pentacam Scheimpflug Technology for Lasik.

Topography and imaging for LASIK patient screenings were further advanced with the development of the Pentacam (Oculus, Inc., Lynnwood, Wash., USA). This technology provides 3-dimensional images of the cornea and entire anterior segment of the eye captured by a rotating Scheimpflug camera along with software analysis.³⁴⁻³⁷

Potential Complications from Lasik Surgery

Like any surgery, refractive surgery too can have side effects and complications. Careful preoperative patient selection along with advanced diagnostics like the Pentacam technology and surgeon experience with the full range of vision corrective surgeries can minimize these adverse events.^{17,18,20,22,23,38} (*Figures 10 & 11) Surprisingly, most of the LASIK surgeons throughout the country are not corneal surgeons (even though LASIK surgery is performed on the cornea). This along with their inability to perform the full spectrum of refractive surgeries (not just LASIK) can, in many cases, be a handicap for the LASIK surgeon resulting in providing “cookie-cutter” LASIK. There is also the concern the LASIK surgeon will not be able to handle complications from their own surgery if they were

to arise. In a majority of cases though, the complications can be addressed successfully without permanent blindness.

Conclusion

We have techniques and technologies to suit practically any individual patient today. A holistic approach to Lasik and Laser Vision Surgery, named Corneoplastique™ has been introduced as a possible super specialty of the future³⁹⁻⁴¹ wherein eye surgery itself is being performed in brief, topical, aesthetically pleasing and visually promising techniques to provide a system of vision correction and repair as well as continued enhancement hand in hand with ongoing technological advances.

Therefore, not only can we currently address practically any eye condition to help decrease a patients’ dependence on glasses, we can also provide techniques to help those patients who have had surgeries in the past to have their eyes fine tuned or corrected to present day expectations. Vision Corrective Surgeries such as Corneoplastique™ will provide the best choice of surgery or even combination surgeries based on age, profession, lifestyle, previous eye surgery and personality tailored to the individual.

As non-ophthalmic physicians, the above detailed choices of refractive surgery options necessitate a dialogue with virtually every patient. These choices provide a wide selection for each and every patient whether he/she is contemplating a glass-free lifestyle or looking for improving previous eye surgery (ie Radial Keratotomy (RK), Astigmatic keratotomy, LASIK, PRK, cataract surgery, corneal transplant, keratoconus, etc.).

LASIK, the mainstay refractive surgery, can be used in all its various forms of laser vision surgeries and even combined if needed with Phakic implants, cataract surgery and Presbyopia correction. Patients who are not good candidates because of pathology like Keratoconus or corneal scars also now have excellent options. The confidence of correcting even complex or complicated cases and the choice of procedures with above mentioned criteria will raise the comfort of patients and surgeons alike.^{40,41} Even age is not a barrier for Laser vision surgery. Patients at 90 can have successful outcomes.

In the future, eye surgeons will have to provide the whole spectrum of surgical choices for patients in order to meet their needs as they age and their lifestyles change.⁴² With Super Vision as a final frontier, one day a patient may well walk into the eye doctor’s office and say “Doctor, I see 20/20”. The eye doctor will stand up with a solemn look on his/her face and say “I can help you”.

Acknowledgements: Advanced Lasik Program Team: Gulani Vision Institute: Dr. Rajesh Dalvi (University of Mumbai- India) , Fellow in Advanced LASIK Surgery at Gulani Vision Institute; Dr. Shaily Batki (Michigan State University), Medical Student at Gulani Vision Institute; and Chuong Dao (University of North Florida), Extern at Gulani Vision Institute.

References

1. Gulani AC. "A New Concept for Laser Refractive Surgery". *Ophthalmology Management*. 2006;10 (4):57-63.
2. Gulani AC. Corneoplastique. *Techniques in Ophthalmology* 5(1):11-20, 2007.
3. Rich L: History of Refractive Surgery: Principles and Practice of Refractive Surgery. Saunders WB (1997); 3-7.
4. Fyodorov SN, Durnev VV: Operation of dosaged dissection of corneal circular ligament in cases of myopia of mild degree: *Ann Ophthalmol*. 1979;11:1185-1190.
5. Bores LD, Myers W, Cowden J: Radial Keratotomy: An Analysis of the American experience. *Ann Ophthalmol*. 1981;13:941-948.
6. Waring GO, Lynn MJ, Gelender H, Laibson PR, Lindstrom RL, Myers WD, Obstbaum SA, Rowsey JJ, McDonald MB, Schanzlin DJ, Sperduto RD, Bourque LB: Results of the Prospective Evaluation of Radial Keratotomy (PERK) study one year after surgery. *Ophthalmology*. 92:177-198, 307, 1985.
7. Barraquer JI: basis of Refractive Keratoplasty. *Arch Soc Am Ofial Optom*. 1964;5:27-48.
8. L'Esperance FA Jr, Taylor DM, Warner JW: Human Excimer Laser Keratotomy: Short Term Histopathology. *J Refract Surg*. 1988;4:118.
9. Pallikaris IG, Papatzanaki ME, Stathi EZ, et al: Laser in situ keratomileusis. *Lasers Surg med*. 1990;10:463-468.
10. Gulani AC. Innovation in LASIK for Farsightedness, Text book of E-medicine (1999), <http://www.emedicine.com/oph/topic659.htm>.
11. Gulani AC. Experience with Ten Refractive Surgical Techniques for Farsightedness (Abstract) International Society of Ocular Toxicology Congress, Kiawah Islands, South Carolina. October 2000.
12. Gulani AC. "New Flap Instruments Created as Lasik goes Mainstream". *Eyeworld*. 1999;4: 48-49.
13. Gulani AC. "Innovative multi-function instrument for Lasik in cases with Nystagmus" European Society of Cataract and Refractive Surgery XIX (Abstract). Amsterdam, The Netherlands. Sept 2001; 21:229.
14. Gulani AC. "New Instrument for Revision Lamellar Refractive Surgery". *Journal of Cataract & Refractive Surgery*. (JCRC), 1998; 24: 595.
15. Gulani AC. "New Triple Benefit Intra-Ablative Invention for Hyperopic LASIK" *Contactologica*. 1999;21:107.
16. Gulani AC. "Lasik Corneal Complications: A New Stratified Classification". *Ophthalmology* 1999; 106:1457-58
17. Gulani AC. "A New Classification and Management Guide for Corneal Complications of Lasik ". *Journal Canadien D' Ophtalmologie*. 2000; 35 (2). 103-105.
18. Gulani AC: Excimer Laser Beam Profile Topography. *Corneal Topography*. Slack Inc (2005). 10; 149-153.
19. Gulani AC. "Lamellar Corneal Procedure Useful for Reparative Surgery" *Ophthalmology Times*. April 2003; 28 (7) 1,12.
20. Gulani AC. "Take a closer look at Lasik candidates"- Review of *Ophthalmology*. 2003; X (2), 76-77.
21. Gulani AC. "Epithelial Ingrowth Protocol Guides Intervention, Therapy" *Ophthalmology Times*. 2002; 27: No.23, 1, 24-25.
22. Gulani AC. Complex Lasik & Complications: Avoidance & Management. University of Pisa, Italy. 2000. KMSG Conference.
23. Gulani AC. "How to put logic into action after Lasik"- Review of *Ophthalmology*. 2006; XIII (9), 60-64.
24. Gulani AC. Wavefront in Full Spectrum Laser Vision Surgery. Clinical Instructional Course. European Society of Cataract & Refractive Surgery (Abstract), Sept 2003, Paris. France.
25. Gulani AC, Probst L, Cox I, Veith R. "Wavefront and Custom Lasik": The Zyoptix. Platform. *Ophthalmol Clin N Am*. 17 (2004). 173-181.
26. Gulani AC, Hersh P, Kornmehl E. "Lasik Refractive Surgery Developments: Wavefront Technology" *Ophthalmology Times*. Dec 2003; 22 (14). 20-21.
27. Gulani AC. "Wavefront Guided- Asisted Lasik Surgery" *Ocular Surgery News*. 2003; 21: No.7. 1 & 6-12.
28. Gulani AC, Mertens E, Karpecki P: Indices for Corneal Ectasia in LASIK surgery. *Textbook of Ophthalmology*. Slack Inc (2005).15; 209-220.
29. Gulani AC. Advanced Eye Surgery. *Informacion Oftalmologica (Madrid, Spain)* June 2006; 13 (3). 30-31.
30. Gulani AC. "Gulani Systems in Lasik surgery". 2002. *Eye News*. 3(1), 6-12.
31. Gulani AC: What's new in refractive surgery? *Review of Ophthalmology*. 1997; 79-81.
32. Gulani AC. Mackool R: Refractive Lensectomy in Refractive Surgery: South African Society of Cataract & Refractive Surgery (Abstract) – Durban, SA– Aug 2005.
33. Gulani AC, Neumann AC, Fyodorov S. "Phakic implants for high myopia- Six years follow up" (ARVO abstract), *Invest Ophthalmol Vis Sci*. 1997; 38: S539.
34. Gulani AC et al: Post-Lasik Corneal Ectasia. *International textbook of Corneal Topography (In Press)*.
35. Wang M, Schwartz T, Gulani AC. Complex Lasik Cases & Topography. *Corneal Topography*. Slack Inc (2005). 9; 131-146.
36. Gulani AC, Alio J et al: "Abnormal Preoperative Topography in Refractive Surgery Complications: Cataract and Refractive Surgery Today Journal. 2007; 7(2) 37-42.
37. Gulani AC, Wang M: Future of Corneal Topography. *Textbook of Corneal Topography in the Wavefront Era*. Slack Inc. 2006; 26: 303-304.
38. Gulani AC. "Como manejar logicamente a los pacientes post-lasik" *Review of ophthalmology en Espanol.*, 2007; Edicion. #19, 14-17.
39. Gulani AC. Corneoplastique: Art of Vision Surgery (Abstract). *Journal of American Society of Laser Medicine and Surgery*. 2007; 19: 40.
40. Gulani AC. "Corneoplastique: Art of Laser Vision Surgery". *Ophthalmology Times. (Asian Edition)* 2006; 2 (7). 36-39.
41. Gulani AC. "Corneoplastique" *Video Journal of Cataract and Refractive Surgery*. Vol XXII. Issue 3, 2006.
42. Gulani AC. Gulani 5S Classification System. *Ophthalmology Times*. 2007; 32 (1).