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"Road to excellence: from RK to LASIK"

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Introduction

Ever since refractive surgery was first devised in Japan in the 1930s, there has been much development and advancement. As quality is a journey, we are still working hard for an even better procedure. The major difference between refractive surgery and other eye operations is that we operate on eyes with normal vision. It is natural for both patients and doctors to have high expectations and demand excellent outcomes in terms of predictability, stability and good safety of the procedure. As all procedures have limitations and risks, the recognition of these is really the first and last principle of refractive surgery. It is important to know the range of limitations for any procedure one uses, as well as have an intimate understanding of their complications and management.

Although radial keratotomy (RK) does not involve the central visual area of the cornea, the issue of long term hyperopic drift is of serious concern in all but the lowest of myopic treatments. The long-term biomechanical stability of the cornea is also compromised. Problems related to surface wound healing present major limitations for photorefractive keratectomy (PRK), restricting its utility to myopia of -6.0 D and below in the opinion of many refractive surgeons. As such, neither PRK nor RK is adequate for high and extreme myopia. Clear lens extraction with intraocular lens implantation is an alternative treatment of very high myopia. Nevertheless, the risk of postoperative retinal detachment (RD) is a major concern. Laser *in situ* keratomileusis (LASIK) has produced very encouraging results for the low, moderate and high myopic groups and has become the focus of attention. Despite problems related to the flap and the interface that can occur, LASIK is gaining rapid acceptance as the keratorefractive surgical procedure of choice for many surgeons and is undergoing very active and rapid development.

Relaxing incisional surgery

Incisional surgery for refractive purposes has opened the minds of modern ophthalmologists to accept the concept of surgical correction of ametropias. Radial keratotomy[1] is one of the early refractive surgical procedures modified from Sato's method, and astigmatic keratotomy from the work of Lans and others in the late 1800s.[2] At the present time, we have not yet found a better way to correct mixed astigmatism than 'arcuate incisions.' The Prospective Evaluation of Radial Keratotomy (PERK) study[3] was designed in 1980-81 for statistical assessment of the procedure. The published results have shown that the number of eyes achieving refractive errors within 1.0 D or 0.5 D of emmetropia actually depends on the patient's age and preoperative refractive error. The PERK study has proven that following RK, refractive predictability and postoperative unaided visual acuity decrease for myopia higher than -4.0 D. There is also evidence of hyperopic drift in 40 to 50% of operated eyes with time, although the magnitude is minimal if smaller numbers of incisions (4-6) and shorter length (outer diameter of 7-8 mm) are employed.[4] In addition, there is always the fear of wound rupture which can happen with blunt trauma, even years afterwards.

World-wide experience with incisional techniques has made the ophthalmic community realize the undeniable limitations and drawbacks of incisional surgery and become interested in more predictable techniques for the whole range of refractive defects.

PRK

PRK is the innovative approach originated by Trokel and co-workers in which a superficial corneal lenticule is ablated to modify corneal refraction.[5] The corneal epithelium is first removed by mechanical, laser or chemical means, then the refractive laser ablation is performed to obtain the desired correction. At the present time, it is estimated that more than a million PRK procedures have been performed all over the world with very good results for low degrees of myopia and myopic compound astigmatism (photoastigmatic refractive keratectomy, or PARK).[6] With new delivery systems and refinements of PRK algorithms, it is now possible to correct up to 12.0 D with accuracy and few adverse effects.[7] Hyperopia is also included in this approach and a number of excimer laser systems now possess such ablation software and clinical trials are underway in many countries world-wide. The adverse effects specific to all modalities of excimer laser surface ablation include postoperative pain, prolonged surface wound healing time with consequent regression of refractive effect, haze, and delayed recovery of best corrected visual acuity.[8]

LASIK

LASIK is the original technique described by Barraquer[9-10] and first applied with the excimer laser by Buratto[11] and Pallikaris.[12] It requires the use of an extra instrument, the microkeratome, to prepare a parallel faced corneal disc with a specific thickness and diameter that includes the epithelium, Bowman's layer and anterior stroma. The corneal disc has no refractive power. It is now a routine to preserve a distal hinge on the disc (forming a flap), with the section perimeter being about 300 - 320.° After lifting and placing the flap with care over the nasal conjunctiva, the refractive ablation is performed on the exposed stromal bed of the cornea. The laser ablation involves only the corneal stroma. This is in contrast to that of PRK in which the Bowman's layer is also ablated and removed. Tens of thousands of such procedures have been performed world-wide, but not yet as many as with PRK. One principal advantage of LASIK over PRK is the ability to correct a much wider range of ametropia.[13-15] LASIK is effective for correction of low, moderate and very high myopia as well as hyperopia up to +9.00 D. Good results were also obtained in astigmatism corrections up to 6.00 D.[16-18] Because of the relatively inert and predictable stromal wound healing and the preservation of the Bowman's layer and corneal epithelium, LASIK offers a rapid, painless and quick visual recovery with reduced risk of stromal haze formation and complications from long-term application of topical steroids. The risk of postoperative infection is also reduced as a result of near total preservation of epithelial integrity and much quicker corneal nerve regeneration.[19-20]

The principal limitation of LASIK is the learning curve that every surgeon has to overcome with the use of the microkeratome. Most LASIK complications are related to either creation of the flap or the newly created interface between the corneal flap and its underlying stromal bed.[17] Corneal flap complications include free cap, thin or perforated flap, irregular flap, corneal striae and even corneal perforation. Interface problems include epithelial ingrowth, talc from powdered gloves, debris or other foreign material deposited in the interface. Epithelial ingrowth is often caused by poor technique resulting in an epithelial defect and poor flap adhesion.[17] The chance of corneal infection increases at the site of epithelial defect, especially at the edge of the flap. Early diagnosis and aggressive treatment with appropriate antibiotics are the keys to rescue.

Complications of corneal photoablation

Major complications of corneal photoablation during LASIK and PRK[21] include:

1. under- or over-corrections;
2. decentration of the optical zone;
3. glare and reduction of contrast sensitivity;
4. induction of astigmatism;
5. central islands (mostly PRK);
6. corneal haze (mostly PRK) and
7. delayed refractive regression (mostly PRK).

Correction of extreme myopia (more than -15.0 D)

The use of LASIK to correct extreme myopia is controversial. The refractive outcome is not as predictable as for lower myopia. Additionally, correction made at the corneal plane does not give the magnification that can be achieved by correcting at the level of the crystalline lens. Moreover, even a slight decentration of the deep ablations required could cause a significant amount of astigmatism, which may lead to substantial decrease in visual acuity, flare, glare and halos. There is also a limitation on the amount of stroma that may be safely ablated. Furthermore, there has been concern on the potential effect of the high intraocular pressure created during the process of flap preparation on the maculae in this group of patients where myopic macular degeneration is relatively common. While subretinal hemorrhage[22] has been reported as a complication of both PRK and LASIK, it is probably quite rare given the vast experience of one of us (CB) that has comprised decades of lamellar refractive surgery without observing such phenomena.

In comparison to LASIK, clear lens extraction with IOL implant for extreme myopia yields better predictability, visual quality outcome and faster visual recovery. In addition, the modern phacoemulsification technique enables surgery to be performed in a closed chamber and allows capsular IOL implantation with a very small limbal or scleral-tunnel wound. The risk of complications arising from the lens extraction and implantation is getting lower.[23-24] However, the incidence of retinal detachment in high myopic patients with aphakia or pseudophakia is related to age, and the procedure should be used very carefully or even avoided in patients under 30 years of age.[25] Last but not least, the retina should be carefully examined by scleral depression and appropriate prophylactic laser or cryotherapy treatments have to be given for any peripheral retinal pathology that might increase the risk of RD following surgery.

Conclusion

While PRK techniques and laser technology will continue to advance and yield improved refractive results, the continued presence of prolonged visual recovery after surgery and the refractive effects of delayed wound healing will continue to limit the utility of this procedure for correction of higher degrees of refractive error. In addition, as LASIK gains popularity it is quite conceivable that the preference of our patients for minimal postoperative pain and rapid visual recovery will drive the demand for laser vision correction away from PRK.

Future advancement of the LASIK procedure will depend on further development of LASIK ablation algorithms for individual lasers, better microkeratome technology and management of microkeratome-related complications. The development of real-time, in-situ corneal topographic measurements will greatly aid our understanding of laser-tissue interactions during surgery and should lead to smoother, more precise stromal photoablation. In addition, the evolution of effective active eye tracking systems and flying spot laser delivery systems (whether excimer or solid state) will greatly enhance our ability to perform "custom" ablations in any configuration necessary to achieve an ideal refractive result, whether treating uncomplicated spherocylindrical errors or irregular corneas.

References

1. *American Academy of Ophthalmology. Ophthalmic Procedures Assessment: Radial keratotomy for myopia. Ophthalmology 1989; 96: 671-87.*
2. *Lan J. Experimentelle Untersuchunqen uber die Entstehung von Astmatismus durch nichtperforirende Cornea wurden Albrecht Von Graefes. Archives of Klin Exp Ophthalmology 1898;45: 117-52.*
3. *Waring GO III, Lynn MJ, Gelender H, et al. Results of the Prospective Evaluation of Radial Keratotomy (PERK) study: one year after surgery. Ophthalmology 1985; 92: 177-98.*
4. *Lindstrom RL Minimally invasive radial keratotomy. J Cataract Refract Surg 1995; 21:27-34.*
5. *Trokel SL, Srinivasan R, Braren B. Excimer laser surgery of the cornea. Am J Ophthalmol 1983; 96: 710-5.*
6. *Slade SG, Machat JJ. Excimer laser refractive surgery, practice and principles. 1st ed. New Jersey: Slack, 1996: 360-8.*
7. *Pop M, Aras M. Multizone/Multipass photorefractive keratectomy: six months results. J Cataract Refract Surg 1995; 21: 633-43.*
8. *Seiler T, Holschbach A, Derse M. Complications of myopic photorefractive keratectomy with the excimer laser. Ophthalmology 1994; 101: 153-60.*
9. *Barraquer JI. Cirugia Refractiva de la Cornea. Tome I. Instituto Barraquer de America Bogota, Columbia. 1989.*
10. *Barraquer C, Gutierrez A. Myopic Keratomileusis: Short-term results. J Refract Corneal Surg 1989; 5: 307-13.*
11. *Buratto L, Ferrari M, Rama P. Excimer laser intrastromal keratomileusis. Am J Ophthalmol 1992; 113: 291-5.*
12. *Pallikaris I, Papatzanaki M, Stathi EZ. Laser in situ keratomileusis. Lasers Surg Med 1990; 10: 463-8.*
13. *Fiander DC, Tayfour F. Excimer laser in situ keratomileusis in 124 myopic eyes. J of Refract Surg 1995; 11: S234-8.*
14. *Salah T, Waring GO, El-Maghraby A. Excimer laser keratomileusis. Corneal laser surgery. 1st ed. St Louis: Mosby. 1995.*
15. *Pallikaris IG, Siganos DS. Excimer laser in situ keratomileusis and photorefractive keratectomy for correction of high myopia. J Refract Corneal Surg 1994; 10: 498-510.*
16. *Waring III GO, Thompson RD Stulting, Carr JD. Laser in-situ keratomileusis (LASIK) for the correction of myopia in 995 consecutive eyes. Invest Ophthalmol Vis Sci 1997; 38: S231.*
17. *Stulting RD, Balch K, Carr JD, Walter K, Thompson KP, Waring III GO. Complications of LASIK. Invest Ophthalmol Vis Sci 1997; 38: S231.*
18. *Lindstrom RL, Hardten DR, Chu YR, Bansal AK. The efficacy, safety and predictability of laser in-situ keratomileusis in the treatment of moderate to high myopia. Invest Ophthalmol Vis Sci 1997; 38: S231.*
19. *Tervo T, Barraquer C, Latvala T. Corneal wound healing and nerve morphology after excimer laser In Situ Keratomileusis (LASIK) in human eyes. Journal of Refractive Surgery 1996; 12: 677.*
20. *Pallikaris I et al. A comparative study of neural regeneration following corneal wounds induced by an argon fluoride excimer laser and mechanical methods. Lasers light Ophthalmol 1990; 3: 89-95.*
21. *Pallikaris IG, Siganos DS. Excimer laser in situ keratomileusis and photorefractive keratectomy for correction of high myopia. J Refract Corneal Surg 1994; 10: 498-510.*
22. *Talamo JG, Krueger RR. The Excimer Manual: A clinicianís guide to excimer laser surgery 1st ed. Boston: Little Brown, 1997: 163 & 241.*
23. *Colin C, Robinet A. Clear lensectomy and implantation of a low-power posterior chamber intraocular lens for correction of high myopia: a four-year follow-up. Ophthalmology 1997; 104: 73-8.*
24. *Lyle WA, Jin GC. Phacoemulsification with intraocular lens implantation in high myopia. J Cataract Refract Surg 1996; 11: 238-42.*
25. *Barraquer C. Incidence of retinal detachment following clear-lens extraction in myopic patients: retrospective analysis. Arch of Ophthalmol 1994; 112: 336-9.*