Refractive Surgery

Keith Kellum, MD, DVM

Hemard & Associates Eye Center, Houma, LA

The concept of surgically altering the eye to correct refractive errors has been considered for hundreds of years, but only in the past 60 years has interest grown considerably due to the development of modern refractive surgery techniques such as astigmatic keratotomies to correct astigmatism induced by cataract surgery and future technologies currently being investigated. Modern refractive surgery is more involved than setting the correct parameters on the laser. Patient selection and examination, proper technique, and postoperative follow-up for potential complications are essential for a successful refractive procedure. Critical evaluation of new techniques is vital to avoid the pitfall of overly exuberant enthusiasm for new and unproven methods of refractive surgery.

Kellum K. Refractive surgery. The Ochsner Journal 2000; 2:164-167.

Early Chinese literature describes various methods of altering the refractive state of the eye including surface treatments and acupuncture, and everything from pressure on the eye to oral medications. One of the first substantial scientific publications on accommodative and refractive errors was written in 1864 by Frans Cornelius Donders. His treatise, "On the Anomalies of Accommodation and Refraction of the Eye," characterized the views of 19th century scientific society. Like the majority of the scientific community, he regarded surgical attempts to correct refractive errors with contempt and referred to these budding refractive surgeons as "rash by ignorance" (1). Such disregard makes it clear why very little descriptive information of refractive surgery was included in his treatise. Interestingly, clear lensectomy, a procedure many ophthalmologists currently consider radical and new, was first described in 1764, more than 100 years before Donders' treatise, by Boerhaave in the Netherlands (2). The first reference to keratotomy was made in 1885 by Hjalmar Schiotz of Norway in a case report of a postoperative cataract patient with 19.5 diopters of astigmatism that was successfully reduced by 12 diopters with a limbal relaxing incision (3). In 1898, Dutch ophthalmologist Leendert Jan Lans investigated the effects of corneal incisions to correct refractive errors. His findings predate the conclusions of Fyodorov of Russia by almost 75 years and are similar to what we now understand about radial keratotomy (4).

The current body of knowledge stems from work begun in the 1950's by Japanese ophthalmologist Tsutomo Sato, who performed anterior and posterior keratotomies to correct myopia (5). Unfortunately, this method caused severe damage to the endothelium and resulted in significant decompensation of the corneas of many patients. Understandably, this dampened enthusiasm for refractive surgery.

In 1960, S.N. Fyodorov attended the Japanese Ophthalmological Society Conference where he became interested in furthering the research begun by Sato. Recognizing that the posterior incisions were not necessary, Fyodorov, along with F.S. Yenaleyev, began varying the size of the optical zone and the number of radial incisions to achieve different amounts of myopic correction (4). From these studies, they developed a nomogram to predict the effects of a given amount of surgery upon the refraction (6).

An explosion of interest in refractive surgery occurred with its introduction into the United States. Leo Bores visited Fyodorov in Moscow in 1976 and there learned how to perform radial keratotomies (RKs) (4). The following year, he was able to reexamine the patients upon whom he had performed RKs, and, finding that the reduction in myopia persisted, he was motivated to introduce the technique into the United States. In 1978, Fyodorov visited the United States to lecture on RK and performed the first one in the US at the Kresge Eye Institute in Detroit (7).

In 1987, the "Prospective Evaluation of Radial Keratotomy" concluded that 65% of RK patients no longer needed spectacle correction or contact lenses (8). We have since learned that a progressive hyperopic drift in some patients can result in significant overcorrection over time (9). Some other criticisms of RK include fluctuating vision, glare, halos, irregular astigmatism, and decreased integrity of the globe.

The imprecision of performing corneal surgery with either steel or diamond knives prompted interest in other methods. The most productive of the new treatment options involve the use of the argon fluoride (AF) and krypton fluoride (KrF) excimer laser beam. Excimer stands for *exci*ted di*mer*, a dimer being two atoms of an inert gas which, when bound together in a highly charged state with halogen atoms, form a temporary, unstable molecule that emits highly energized photons of ultraviolet light as it decays (10). The idea of using the excimer laser on the cornea was first proposed in a 1981 study of the effects of the KF excimer laser upon the corneal epithelium by Taboada et al (11). In 1983, Trokel et al proposed that the excimer laser could be used to flatten or steepen the cornea by either using grooves or ablating large areas of tissue (12). The excimer laser was subsequently used to create astigmatic and radial keratotomies, as well as an incredibly precise corneal trephine for corneal transplants (13-15).

Evaluation of the Refractive Surgery Patient

One of the most important considerations is patient expectation. With the amount of information available over the Internet, as well as the intensive marketing prevalent today, some patients expect to never need glasses again. Some will not be happy with anything less than the 20/15 vision they may achieve with the use of rigid gas permeable contact lenses. It is important to discover and moderate these expectations. The physician needs to explain to patients that the purpose of the procedure is to reduce their dependency upon glasses or contacts and not necessarily to get rid of them completely. It is crucial to advise presbyopic myopic patients that while they can take off their glasses and read prior to refractive surgery, they will not be able to do this afterwards. Some, due to the multi-focal effects of laser refractive surgery, will not have much postoperative difficulty reading without glasses, but these are the exceptions to the rule. A thorough discussion of the informed consent can reduce unrealistic expectations.

As with all patients, a thorough medical history should be obtained since certain conditions may affect the outcome of laser refractive surgery. Collagen vascular diseases as well as other autoimmune disorders can cause serious complications such as corneal melts following laser in situ keratomileusis (LASIK) or photorefractive keratectomy (PRK). The medication history is also important, as various medications can increase scarring and haze formation or retard epithelialization after PRK. A history of herpetic keratitis is also considered by many to be a relative contraindication to PRK because of an increased risk for reactivation of the herpetic keratitis (16, 17). Some ophthalmologists pretreat these patients with oral acyclovir if they have been quiescent for a sufficient time.

Operative Technique

Patient Pr eparation

No preoperative medications are necessary, but a good, thorough preoperative preparation of the patient is essential to a successful surgery. To help reduce anxiety, the patient should know what to expect at every step of the procedure. To allay anxiety, many surgeons advocate a light sedative just prior to the procedure. One of the more useful features of preoperative sedation is that it will help the patient to sleep after the surgery, which can help with the healing process, especially after LASIK. Patients should be instructed to refrain from wearing cologne or perfume (the fumes from which can interfere with the laser beam and decrease the energy reaching the cornea, theoretically resulting in undercorrection or irregular astigmatism) or any eye makeup (such as mascara, which can become trapped under the flap during LASIK or cause a bacterial keratitis).

Procedure

With LASIK, the epithelium is not removed. The cornea is marked with paracentral, nonradial marks to allow proper positioning of the flap should a free cap be formed. A suction ring is fixed to the eye to raise the pressure inside the eye to more than 65 mmHg. This allows the microkeratome to make a controlled and smooth cut across the cornea, shaving a flap of corneal tissue that remains hinged at one edge. After the amount of ablation to be performed and the thickness of the cornea are considered, the microkeratome can be adjusted to vary the thickness of the flap from 130-180 μm. The remaining tissue in the stromal bed should be greater than 200-250 μm thick. Once the flap is created and retracted from the stromal bed, the ablation proceeds the same as for PRK. With broad-beamed lasers, this involves an expanding diaphragm or ablatable mask that allows more laser energy to be delivered in the center of the cornea, causing an overall flattening to correct for myopia.

After ablation, the flap is repositioned and the interface is vigorously irrigated with balanced saline solution to remove any debris. The eye is then medicated with the same medications as with PRK although for a much shorter time. These include a topical antibiotic and corticosteroid or a combination of the two. Topical nonsteroidal drops can be used for pain management, although there is usually very little pain. A bandage contact lens is not necessary unless a free cap has been formed. The eye is kept open for 2-5 minutes to allow the endothelial pumping action to dehydrate the stroma and create a seal between the stroma and cap, which needs to be smoothed to remove any wrinkles or striae.

Results

Early studies showed that PRK had better outcomes for the lower versus the higher ranges of myopia. Most (85-91%) showed an uncorrected visual acuity of 20/40 or better (20/20 or better in 58-79%) 6 months after surgery (18,19). Other studies have shown similar to slightly better results (20-28). It appears that the results are improving as the nomograms become more refined and the lasers are improved.

LASIK shows similar results for myopia at 6 months follow-up with an uncorrected visual acuity of 20/40 or better in 85-100% and 20/20 or better in 45-79% (29,30). One of the main advantages of LASIK is not the final visual acuity but the swiftness with which patients regain clear vision. Many of the previously mentioned articles show that patients have better visual acuity with LASIK early in the postoperative period and later equalize. Also, there is less potential for pain after LASIK than after PRK, although most patients have very little pain with either procedure.

Future Directions

Refractive surgery is developing and progressing very quickly. Many of the future advancements will improve the results of the excimer laser while others will approach refractive surgery in a completely different manner. Some of the most exciting new technologies in the excimer laser field are the customized ablation programs. With wavefront technology, the potential visual outcome can exceed 20/20 and even approach 20/8. This process passes a low-powered laser beam through the cornea, lens, and vitreous to the retina where it is then reflected back and analyzed. All aberrations occurring as the beam traverses the visual media can be corrected for using adaptive optics which can shape or guide the excimer laser beam and perform a customized ablation of the cornea. Other methods of performing customized ablations will use corneal topography linked to the excimer laser to direct the ablation of small areas of irregularity, much like sanding the high points off the cornea.

One of the early concerns about laser refractive surgery was that the laser permanently alters the central cornea. Alternatively, removable intracorneal ring segments are now available which are implanted in the paracentral cornea to flatten the central cornea. These are currently approved for 1-3 diopters of myopia, and trials are currently underway to extend this range and obtain approval for hyperopia. The advantage of these devices is that they do not permanently alter the central cornea and can be removed if the patient desires. However, they are only approved for a limited range and have not been shown to be significantly better than PRK or LASIK. A steep learning curve is also associated with implanting these segments.

One of the disadvantages of PRK and LASIK is that they cannot treat patients with hyperopia or myopia in the extreme ranges--and these are the ones who need refractive surgery more than anyone. One method of approaching this problem is by using phakic intraocular lenses which come in a variety of styles and are implanted in the eye without removing the natural lens, allowing patients to retain their accommodative powers. Some of the disadvantages of the phakic intraocular lenses are that they can cause premature cataracts and endothelial cell loss (31). These are not currently approved for use in the United States, although Phase III trials are currently underway. For patients who are already presbyopic, many surgeons are doing clear lensectomy and implanting multifocal intraocular lenses.

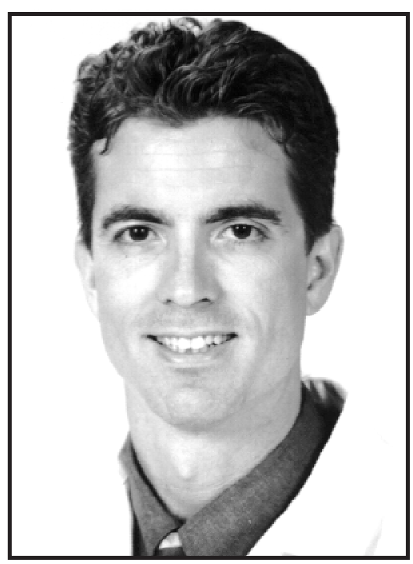
Some of the other emerging technologies include the holmium laser for thermokeratoplasty for hyperopia, the femtosecond laser for intrastromal ablation, and scleral expansion bands to reverse presbyopia.

Conclusion

With such a rapidly changing field, it is an exciting time in refractive surgery. The Cornea and Anterior Segment Section in Ochsner's Department of Ophthalmology is dedicated to staying on the cutting edge of this ever-changing field. As new technologies are developed and proven to provide substantial benefits to our patients, we will continue to adopt these techniques.

References

1. Donders FC. On the Anomalies of Accommodation and Refraction of the Eye [translated by William D. Moore, M.D.]. London: New Sydenham Society, 1864.
2. Boerhaave H. Praelectiones publicae de morbis oculorum. Gottingae: apud a. von den Hoeck, 1764.
3. Schiotz H. Ein Fall von hochgradigem Hornhautastigmatismsmus nach Starextraction. Besserung auf operativem Wege. Arch Augenheilkd 1885; 15:178-181.
4. Thornton SP. Background of incisional refractive surgery. In: Wu HK, Thompson VM, et al, editors. Refractive Surgery. New York: Thieme Medical Publishers, 1999:127-134.
5. Sato T, Akiyama K, Shibata H. A new surgical approach to myopia. Am J Ophthalmol 1953; 36:823-829.
6. Fyodorov SN, Durnev VV. Operation of dosaged dissection of corneal circular ligament in cases of myopia of mild degree. Ann Ophthalmol 1979; 11:1885-1890.
7. Bores LD, Myers, WD, Cowden J. Radial keratotomy: An analysis of the American experience. Ann Ophthalmol 1981; 13:941-948.
8. Waring GO, Lynn MJ, Culbertson W, et al. Three-year results of the Prospective Evaluation of Radial Keratotomy (PERK) Study. Ophthalmology 1987; 94:1339-1354.
9. Waring GO, Lynn MS, Fielding B, et al. Results of the Prospective Evaluation of Radial Keratotomy (PERK) study 4 years after surgery for myopia. JAMA 1990; 263:1083-1091.
10. O'Brart DPS, Marshall J. Background of excimer laser refractive surgery. In: Wu HK, Thompson VM, et al, editors. Refractive Surgery. New York: Thieme Medical Publishers, 1999:217-224.
11. Taboada J, Mikesell GW Jr., Reed RD. Response of the corneal epithelium to KrF excimer laser pulses. Health Phys 1981; 40:677-683.
12. Trokel SL, Srinivasan R, Braren B. Excimer laser surgery of the cornea. Am J Ophthalmol 1983; 96:710-715.
13. Seiler T, Bende T, Wollensak J, Trokel S. Excimer laser keratectomy for the correction of astigmatism. Am J Ophthalmol 1988; 105:117-124.
14. Tenner A, Neuhann T, Schroder E, et al. Excimer laser radial keratotomy in the living human eye: a preliminary report. J Refract Surg 1988; 4:5-8.
15. Serdarevic ON, Hanna K, Gribomont AC, et al. Excimer laser trephination in penetrating keratoplasty. Morphologic features and wound healing. Ophthalmology 1988; 95:493-505.
16. McDonnell PJ, Moreira H, Clapham TN, et al. Photorefractive keratectomy for astigmatism: initial clinical results. Arch Ophthalmol 1991; 109:1370-1373.
17. Vrabec MP, Durrie DS, Chase DS. Recurrence of herpes simplex after excimer laser keratectomy. Am J Ophthalmol 1992; 114:96-97.
18. Thompson KP, Steinert RF, Stulting RD. Photorefractive keratectomy with the Summit excimer laser: the phase III U.S. results. In Salz JJ editor. Corneal Laser Surgery. St. Louis: CV Mosby, 1995:57-63
19. Seiler R, McDonnell PJ. Excimer laser photorefractive keratectomy. Surv Ophthalmol 1995; 40:89-118.
20. Higa H, Liew M, McCarty CA, et al. Predictability of excimer laser treatment of myopia and astigmatism by the VISX Twenty-Twenty. J Cataract Refract Surg 1997; 23:1457-1464.
21. Williams DK. Multizone photorefractive keratectomy for high and very high myopia: Long-term results. J Cataract Refract Surg 1997; 23:1034-1041.
22. McDonald MB, Deitz MR, Frantz JM, et al. Photorefractive keratectomy for low-to-moderate myopia and astigmatism with a small-beam, tracker-directed excimer laser. Ophthalmology 1999; 106:1481-1489.
23. el Danasoury MA, el Maghraby A, Klyce SD, Mehrez K. Comparison of photorefractive keratectomy with excimer laser in situ keratomileusis in correcting low myopia (from -2.00 to -5.50 diopters), a randomized study. Ophthalmology 1999; 106:411-421.
24. Maguen E, Salz JJ, Nesburn AB, et al. Results of excimer laser photorefractive keratectomy for the correction of myopia. Ophthalmology 1994; 101:1548-1557.
25. Talley AR, Hardten DR, Sher NA, et al. Results one year after using the 193 nm excimer laser for photorefractive keratectomy in mild to moderate myopia. Am J Ophthalmol 1994; 118:304-311.
26. Schallhorn SC, Blanton CL, Kaupp SE, et al. Preliminary results of photorefractive keratectomy in active-duty United States Navy personnel. Ophthalmology 1996; 103:5-22.
27. Durrie DS, Lesher MP, Cavanaugh TB. Classification of variable clinical response after photorefractive keratectomy for myopia. J Refract Surg 1995; 11:341-347.
28. Kim JH, Sah WJ, Kim MS, et al. Three-year results of photorefractive keratectomy for myopia. J Refract Surg 1995; 11(suppl.);S248-S252.
29. el-Maghraby A, Salah T, Waring GO, et al. Randomized bilateral comparison of excimer laser in situ keratomileusis and photorefractive keratectomy for 2.50 to 8.00 diopters of myopia. Ophthalmology 1999; 106:447-457.
30. Gimbel HV, van Westenbrugge JA, Penno EE, et al. Simultaneous bilateral laser in situ keratomileusis: safety and efficacy. Ophthalmology 1999; 106:1461-1467.
31. Alio JL, de la Hoz F, Perez-Santonja JJ, et al. Phakic anterior chamber lenses for the correction of myopia: a 7 year cumulative analysis of complications in 263 cases. Ophthalmology 1999; 106:458-466.



Dr. Keith Kellum specializes in refractive surgery and surgery and diseases of the anterior segment of the eye. He is affliated with Terrebonne General Medical Center, Houma, LA.