CLINICAL PRACTICE

Excimer Laser Correction of Hyperopia

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Abstract. Laser-assisted in situ keratomileusis, photorefractive keratectomy, and laser-assisted subepithelial keratectomy are safe and effective treatments for low to moderate hyperopic spherical and astigmatic refractive errors. These treatments are more challenging than myopic correction because they steepen the cornea centrally by removing tissue in the midperiphery, thus requiring large ablation diameters extending to 9–10 mm. Results have improved greatly over the past 10 years, more closely approaching myopic outcomes for low corrections, but higher refractive ablations still lead to regression, loss of best spectacle corrected visual acuity, tear film instability, and visual disturbances. Wavefront-guided hyperopic corrections are proving effective and may improve the quality of vision. In the future, shorter treatment times, better ablation profiles, iris registration, and torsional eye tracking will all further improve results. **(Comp Ophthalmol Update 5: xx-xx, 2004)**

Key words. adverse effects • excimer laser • hyperopia • laser-assisted in situ keratomileusis (LASIK) • laser-assisted subepithelial keratectomy (LASEK) • photorefractive keratectomy (PRK) • treatment outcome

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Hyperopia, a condition in which parallel rays of light focus behind the retina, is present in 22% of the U.S. population, increasing in frequency from 22.1% (between the ages of 43 and 54 years) up to 68.5% at age 75 years and older.[1] Most hyperopes are between 0.1 diopters (D) and +4 D spherical equivalent with only 1.4% of the U.S. population greater than +4 D spherical equivalent. Hyperopic eyes have shorter axial lengths, more shallow anterior chambers, and flatter corneas. Despite good medical options of correction using spectacles and contact lenses, surgical correction has been attempted for over 100 years and represents a great challenge.

The early results of surgical correction using techniques such as thermokeratoplasty, keratomileusis, hexagonal keratotomy, epikeratoplasty, and automated lamellar keratoplasty had only limited success with many reports of complications including poor predictability and stability as well as sight-threatening

complications. These techniques have been replaced by corneal procedures such as excimer laser correction, intracorneal implants, holmium YAG laser thermokeratoplasty, and conductive keratoplasty, but regression, induced astigmatism, and optical aberrations—especially for higher corrections—still occur. Intraocular surgery consisting of phakic intraocular lenses (IOLs) and clear lensectomy with IOL implantation is gaining in popularity especially for corrections above +4 D and demonstrate good predictability and stability with a low incidence of complications.[2]

The use of the excimer laser for the correction of hyperopia has lagged considerably behind myopia with the earliest treatments being performed by Dausch et al in 1991 with the Aesculap-Meditec MEL60 (Carl Zeiss Meditech, Dublin, CA) utilizing a scanning slit and rotating mask.[3] The ablation profile for the correction of hyperopia had been suggested by L'Esperance et al and aims to create a smoothly transitioned annular ablation in the stroma at the periphery of a defined optical zone that effectively steepens the central visual axis while flattening the periphery.[4] Early results using a 4-mm diameter optical zone, when tapered to 7 mm for corrections under 5 D were more stable and predictable than those above 5 D, but the major problems were regression, decentration, slow recovery, and loss of best spectacle corrected visual acuity. It soon became clear that the best results were obtained with low hyperopia up to 4 D with optical zones 5–7 mm with total ablation area extending to 8.5–9 mm.[5]

Different techniques were used by each laser manufacturer to develop this ablation profile. The Summit Apex Plus Laser (Alcon, Summit Autonomous, Fort Worth, TX) used an axicon lens system to treat the area between 6.5 mm and 9.5 mm. An erodible disk can also be used, which absorbs laser energy to produce a smooth transition zone. Other laser systems use smaller spots or a scanning slit to produce a circular pattern with an optical zone between 5 mm and 6 mm with an ablation zone out to 9.5 mm.

Although PRK for hyperopia was shown to be a relatively safe and effective procedure for refractive errors up to +4 D, it had limitations including discomfort or pain in the first few days because of the large epithelial defect, prolonged wound healing, initial overcorrection with regression over 6 months, and in some cases peripheral haze and induced astigmatism. Laser-assisted subepithelial keratectomy can address many of the shortcomings of PRK with reduced postoperative pain and discomfort and quicker refractive and visual recovery with better efficacy.[6] Laser-assisted in situ keratomileusis has now become the corneal procedure of choice for all but very low hyperopia (conductive keratoplasty shows promise in this group),[7,8] with minimal discomfort, rapid corneal healing, good uncorrected vision within 24 hours, more rapid stabilization of refraction, and little haze.[9,10] However, in the older hyperopic patient, LASIK-induced dry eye combined with a steep cornea can produce fluctuating vision and annoying symptoms.

Patient Selection

Patient selection and evaluation are the most important aspects of elective refractive surgery. Although patients should be at least 18 years of age, the mean age for hyperopic excimer corrections in our series is 49 years old, 10 years older than our myopic cohort. Many presbyopic hyperopes do not realize they will still need reading glasses after the surgery unless treated with monovision[11] or a presbyopic multifocal ablation profile.[12] However, as a group they are often delighted with outcomes that are felt to be less successful than treatment of a myope with a similar refractive error. The most common reasons for hyperopic laser vision correction include contact lens and spectacle intolerance, asthenopia, accommodative strabismus,[13,14] and high near vision requirements.

Preoperative Management

A thorough ocular examination is critical to determine patient eligibility and includes uncorrected and best corrected visual acuity, measurement of pupil size in bright and dim illumination, manifest and cycloplegic refraction, autorefraction, keratometry, pachymetry, intraocular pressure, eye dominance, and dilated fundus examination. Young hyperopes have good accommodation ranges so the difference between the manifest and cycloplegic refraction must be considered to avoid inducing myopia associated with the excess of accommodation. Corneal topography is essential in all cases to rule out contact lens-induced corneal warpage, asymmetric and irregular astigmatism, and early keratoconus. Wavefront aberrometry is quickly becoming an important tool to measure the refractive error, identify higher order aberrations, and determine preoperative quality of vision and point spread function.

A slit-lamp examination is critical to rule out any significant corneal abnormalities such as scarring, corneal vascularization, or the presence of a cataract. Careful attention must be paid to detect the presence of ocular rosacea, anterior or posterior blepharitis, atopic appearing conjunctiva, and tear film abnormalities. Since PRK and LASIK can cause a symptomatic decrease in tear flow and tear film stability,[15] a Schirmer test and tear break-up time should be documented in any patient with a history of dry eye or contact lens wear.[16] Hyperopic patients with

dry eyes and steep corneas may develop persistent epithelial keratitis and corneal scarring due to poor lubrication.[15,17] Patients with symptomatic blepharitis should be treated with good lid hygiene and topical antibiotics, such as erythromycin. Meibomitis associated with ocular rosacea and dry eye often improve on oral doxycycline 100 mg twice daily and frequent artificial tears. Ocular surface disease, not responding to copious lubrication, or poor compliance should be treated with punctal plugs preoperatively and refractive surgery should be delayed until the cornea is free of any fluorescein or rose bengal staining.

Although the depth of the ablation should be calculated and compared with the preoperative pachymetry readings, the risk of progressive corneal ectasia is very low, but it has been reported[18] because the ablation is performed more in the periphery, leaving the central cornea relatively untouched. However, careful attention must be paid to preoperative keratometry values anticipating 1 D corneal change for every D of attempted correction at the spectacle plane. Keratometry readings greater than 50 D should be avoided because of corneal apical scarring, iron deposition lines, poor optical quality, and a pseudokeratoconus.

Surgical Technique

SURFACE ABLATION (HYPEROPIC PRK AND LASEK)

Before the patient is positioned in the laser chair, the 3 and 9 or 6 and 12 o'clock meridians may be marked at the limbus with a gentian violet pen at the slit-lamp and then used for precise alignment prior to stromal ablation.

The complete and rapid removal of all the corneal epithelium, leaving a smooth, undamaged Bowman's membrane within the 9.5-mm area, is critical to maintain consistent hydration of the bed and avoid uneven stromal ablation, minimize keratocyte apoptosis, and promote rapid re-epithelialization. The original technique of epithelial removal was scraping using a Paton spatula, scalpel blade, Desmarres blade, or blunt #67 blade. Experience is required to achieve consistent results with even hydration; therefore, many found the introduction of a motorized brush, such as the Amoils Epithelial Scrubber (Innovative Excimer Solutions, Inc., Toronto, Canada), helpful in removing the epithelium.[19]

An 18–20% ethanol solution applied to the corneal epithelium for 20 seconds in a well or on a corneal light shield and thoroughly irrigated with balanced saline solution will allow easy debridement with a spatula or microsponge.[20] Less postoperative discomfort,[21] corneal haze,[20] and quicker visual rehabilitation,[22] have been reported with this method. Laser-assisted subepithelial keratectomy is an extension of this technique. A 9.0-mm corneal marker is used to trephine through the epithelium and 20% alcohol solution prepared in balanced saline solution is applied for 20–40 seconds to loosen the epithelium. An epithelial flap is then raised, hinged at the 12 o'clock meridian.[6]

The reticle is centered on the pupil center, and the eye tracker is engaged. Miotics should be avoided as they can shift the pupil superonasally.[23] Despite an eye tracker, it is important that the patient maintain fixation throughout the procedure; therefore, excessive illumination should be avoided. Because of the small central optical zone associated with high hyperopic treatment, small decentrations can have a significant effect on vision. Although most surgeons focus on the pupillary center, some feel that moving toward the light reflex, especially with a large-angle kappa, may avoid decentration of the optical zone with better results.[24] Improved results can be obtained with nomogram adjustments based on an analysis of the refractive center's data.

Wavefront customized laser ablations promise to improve results and eliminate much of the need for customization.[25] Nonetheless, small nomogram adjustments will be needed depending on the laser epithelial removal technique, environmental conditions, patient's age, and targeted refractive outcome.

A cross-cylinder ablation has proven successful for myopic or hyperopic eyes with high or mixed astigmatism. With this technique, the refraction is converted into two cross cylinders, resulting in the steepening of the flat axis and flattening of the steep axis. Vinciguerra et al has reported a modification of this technique in which the astigmatism is corrected first—half the amount of cylinder in diopters is ablated along the steepest meridian and the other half is next ablated along the flattest meridian followed by the spherical equivalent.[26] The use of wavefront-customized treatments has the potential to improve the visual results in these difficult cases without the limitation of defined spheres, slits, and ellipses.

Hyperopic epithelial defects will

> **Focus Point #1**
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> Laser-assisted in situ keratomileusis has become the preferred technique for laser correction of hyperopia over surface ablation but is more challenging than when performed in myopics because of the necessity for large flaps with a risk of bleeding, dry eyes in the older population, and increased risk of epithelial defects.

heal in 4–5 days.[27] Disadvantages of a bandage contact lens include sterile infiltrates and an increased risk of infectious keratitis. In a small percentage of patients (less than 5%), especially those who are intolerant of a contact lens, an occlusive patch with an antibiotic steroid ointment is used. Re-epithelialization after hyperopic PRK is faster with a thicker appearing but rougher epithelium.[27]

A broad spectrum antibiotic, such as fluoroquinolone, 0.3% ofloxacin (Ocuflox®, Allergan, Irvine, CA), or 0.3% ciprofloxacin HCl (Ciloxan®, Alcon, Ft. Worth, TX), should be instilled four times a day until the epithelium is healed and the contact lens is removed. A topical nonsteroidal anti-inflammatory drug (e.g., ketorolac tromethamine, diclofenac, fluriprofen) is used four times a day for the first 24–48 hours to control pain, which is often notably less than with myopic ablations.[28] A topical steroid, such as fluoromethalone 0.1% (FML®, Allergan, Irvine, CA) is used four times a day for a few weeks to 3 months. It is important that the patient be followed closely as there is a very small risk of steroid-induced cataract[29] and increased intraocular pressure,[30] which is lower postoperatively,[31,32] following both myopic and hyperopic treatment. For those few patients experiencing considerable discomfort 0.5–1% tetracaine or 0.05% topical proparacaine[33] can be used safely for a few days. A few drops of tetracaine can be placed into artificial tears and when used frequently can alleviate any discomfort. Oral analgesics for the first 48–72 hours and the application of ice packs or cold compresses help relieve discomfort. For the first 6 months postoperatively, non-preserved or minimally preserved artificial tears should be used frequently to re-establish a smooth ocular surface. Punctal plugs may be inserted postoperatively if not done prior to surgery to ensure a good tear film and to avoid fluctuations in vision and epithelial keratitis.

LASIK

Laser-assisted in situ keratomileusis has become the preferred technique over PRK for laser correction of hyperopia, but it is more challenging than for correction of myopia because of the flatter keratometry, small corneal diamerer, necessity for large flaps with a risk of bleeding, older population who may have dry eyes, and increased risk for epithelial defects. The risk of epithelial ingrowth is higher after hyperopic LASIK especially when the ablation strikes the edge of the flap cut, and in the presence of large flaps and epithelial defects. Newer microkeratomes allow for bigger diameter flaps, bigger optical zones, and smoother transition zones. During the ablation the flap should be protected. Postoperatively, there is minimal discomfort with quite rapid return of good uncorrected vision. An antibiotic and steroid are used for 1 week, along with copious artificial tears, which should be continued for at least 6 months.

Results of Hyperopic Laser Vision Correction

HYPEROPIC PRK

Following epithelial healing there is an initial overcorrection of 1–1.5 D, which drifts toward plano over 3–6 months and stability of refraction and vision takes 6–12 months. Uncorrected visual acuity at 1 year varies from 46–70%, 20/20 or better, depending upon the refractive mean spherical equivalent. A one-line loss of best spectacle corrected visual acuity is seen in upward of 30% but is rarely appreciated by the patient. With higher corrections, the results are not as encouraging, with more regression, loss of contrast acuity and best spectacle corrected visual acuity, and daytime as well as night-driving visual problems.[34,37]

Our most recent data on patients treated at the University of Ottawa Eye Institute for hyperopic PRK using the VISX STAR™ S2 and S3 laser (VISX, Santa Clara, CA) in 82 eyes followed for 24 months with a mean preoperative spherical equivalent of +2.36 (1–4 D) achieved 20/20, 20/25, and 20/40 uncorrected visual acuity in 65%, 84%, and 98% of eyes, respectively. There was a one-line loss of best spectacle corrected visual acuity in 26% and a retreatment rate of 3.5%. For higher correction from +4 D to +6 D with a mean of +5.17 D we followed 19 eyes for 24 months and uncorrected visual acuity was 21%, 42%, and 63% for 20/20, 20/25, and 20/40, respectively. We had an 11% one-line and a 5% two-line loss of best spectacle corrected visual acuity with a retreatment rate of 7%.

In 2002, Stevens et al published a study on the safety, efficacy, and predictability of PRK for hyperopia of +1.75 D to +5.00 D manifest refractive sphere and up to -2.50 D manifest refractive astigmatism using the VISX Star™ excimer laser system with version 2.5 software.

Stevens et al concluded that PRK for hyperopia using the VISX Star™ excimer laser system was effective in the treatment of hyperopic astigmatism. They could not conclusively demonstrate any advantage of using a 6-mm optical zone compared to a 5-mm zone. Although no patient lost two or more lines of high-contrast best spectacle corrected visual acuity 1 year after treatment, there was a significant decrease in Pelli-Robson contrast acuity.

In the study, corneal epithelial healing was complete between days 4 and 10. Twelve months after treatment, 93% achieved 20/40 or better uncorrected visual acuity and 19 eyes (70%) achieved 20/20. The

mean spherical equivalent refraction was reduced from +2.90 D at baseline to +0.10 D at 1 year and +0.40 D at 2 years; 65% of eyes had a refraction within ±0.50 D.

Nagy and coauthors have published the largest series of hyperopic PRK results using the Meditec MEL 60 and the Meditec MEL 70 G-scan (Carl Zeiss Meditec, Dublin, CA).[34,37] The results of the first study in 800 eyes revealed that with preoperative refractive error of +3.50 D or less, 20/20 uncorrected visual acuity could be achieved in 76% at 1 year with 2.1% losing two lines of best spectacle corrected visual acuity and 11% noting glare and ghost images in daytime and 18% noting problems with night driving. However, in their second group, with a refractive error of +3.75 D or more preoperatively, 20/20 was achieved in only 34% and 19% lost two lines of best spectacle corrected visual acuity and 12% lost three lines. Optical symptoms were seen in 22% during the day and 41% had night-driving problems. Using the MEL 70, a flying-spot laser, Nagy et al achieved 89% with 20/20 in spherical hyperopia, 77% with hyperopia up to +3.50, and astigmatism of +1.00 or more, 79% with 20/20 over +3.50 with low astigmatism, and 61% with astigmatism over +1.00 at 12 months.[34] They concluded that flying-spot technology was more promising in eyes with a refractive error greater than 3.75 D than obtained with the previous scanning technique.

The treatment of spherical hyperopia does better in both low- and high-hyperopia groups compared to eyes with a high hyperopic astigmatic component.[34] Alessio et al reported good results with flying-spot technology in eyes with irregular hyperopic astigmatism in the case of topography-driven PRK treat-ments.[38] We have noted peripheral segmental haze to be more prominent with astigmatic treatments than with spherical treatments where haze is annular sparing the corneal center and is minimal. Surgically induced astigmatism was no more frequent with hyperopic than with myopic treatments.[39]

Overall, hyperopic patients are extremely pleased with the results of their surgery with many achieving a multifocal cornea and being able to read much better than expected.[35] Despite undercorrections that may result from the surgery, regression over 6 to 12 months, or progression of hyperopia, very few patients request retreatments. Significant peripheral haze can occur and is seen more frequently with higher corrections and with hyperopic astigmatic treatments. In addition, some ablation profiles and lasers are more prone to cause haze, scarring, and induced regular and irregular astigmatism because of abrupt transition zones. Small optical zones with high refractive corrections and decentrations are the main causes of more loss of best spectacle corrected visual acuity than seen with myopic corrections combined with a minified image. Complications unique to hyperopic PRK include an iron-ring,[40] central nodule formation with scarring,[17,41] and acute corneal necrosis.[42] It is not unexpected that these patients may experience symptoms and signs of dry eye because of the older age of the hyperopic population and the steepening of the central cornea.[43]

Hyperopic PRK has been used successfully to treat postradial keratectomy hyperopic shift with 72% achieving uncorrected visual acuity of 20/25 without serious complications, including haze.[44] Purely refractive accommodative esotropia in young adults associated with mild to moderate hyperopia has been shown to successfully respond to hyperopic PRK with a reduction of the mean preoperative esotropic deviation of 10.75 prism D to orthophoria in all 16 eyes of eight patients.[13] The authors caution that these results should not be applied widely to children with accommodative esotropia. A few cases of hyperopic anisometropia with amybyopia have been treated successfully between the ages of 3 and 10 years with hyperopic PRK.[14]

HYPEROPIC LASEK

In 2003, Autrata and Rehurek reported the first results of hyperopic LASEK in a prospective single-surgeon trial in 216 eyes of 108 patients in which one eye received PRK and the other LASEK.[6] The Nidek EC-5000 laser (Nidek, Gamagori, Japan) was used in all eyes with a similar surgical technique in each group except the epithelium was removed using alcohol-assisted debridement in the PRK eye but replaced in the contralateral LASEK eye. The mean preoperative spherical equivalent cycloplegic refraction was +3.67 D (+2 D to +5 D) with astigmatism less than 1.00 D.

The uncorrected visual acuity in the PRK and LASEK eyes at 1 week was 20/40 or better in 58% and 85% of eyes, respectively, and 81% and 91% at 2 years. Seventy-three percent of the PRK and 67% of the LASEK eyes achieved 20/20 uncorrected visual acuity at 2 years while 73% and

Focus Point #2

Laser-assisted subepithelial keratectomy is a better alternative than PRK when microkeratome and flap complications of LASIK are to be avoided.

Focus Point #3

Hyperopic patients with dry eyes and steep corneas may develop fluctuating vision, persistent epithelial keratitis, and corneal scarring due to poor lubrication.

89%, respectively, achieved N8 uncorrected near visual acuity. Although both groups showed an initial overcorrection, the spherical equivalent refraction achieved stability at 9 months in PRK eyes and 6 months in LASEK eyes. The predictability was better at 2 years in the LASEK group with 78% compared to 57% in PRK eyes within ±0.5 D.

Both procedures were safe with no eye losing two or more Snellen lines of best spectacle corrected visual acuity. There was statistically significantly less corneal haze at 1, 3, and 6 months as well as less postoperative pain and discomfort at days 1, 2, and 3 in the LASEK-treated eyes. Eighty-five percent of patients preferred the LASEK procedure.

HYPEROPIC LASIK

Results for hyperopic LASIK are very similar to those for hyperopic PRK and LASEK but refractive stability occurs sooner with less myopic overcorrection and subsequent regression, and less discomfort and follow-up.[7] It is for these reasons that hyperopic LASIK is the current preferred procedure.

A review of the literature by Nagy et al led them to conclude that the refractive results, efficacy, and predictability depend more on the type of excimer laser beam delivery system than on the refractive procedure used (PRK or LASIK).[34]

In 1998, Ditzen et al reported his results on LASIK for hyperopia postulating that with LASIK one could prevent strong epithelial regression with an overlying flap and be able to do higher corrections.[45] They treated from +1 D to +8 D with a total ablation zone of 7.5 mm using the Aesculap-Meditec MEL 60. At 1 year, 95% with a refractive error up to +4 D and 90% from +4.25 D to +8.00 D achieved uncorrected visual acuity of 20/40. Ten percent of eyes lost best spectacle corrected visual acuity due to flap problems mainly epithelial ingrowth. Ditzen et al concluded that LASIK for hyperopia resulted in less regression, minimal haze, and better predictability and stability than surface PRK, especially in eyes with more than 3 D of hyperopia. They also noted that preoperative corneal radius appeared to be an important factor in eyes with high hyperopia. Davidorf also noted loss of best spectacle corrected visual acuity in high hyperopia and astigmatism due to tear film instability and decentered ablations.[46]

Two-year results reported by Esquenazi and Mendoza on 100 eyes with a preoperative mean spherical equivalent of +4.50 D revealed 37% saw 20/20 and 82% saw 20/40. Undercorrections were more common with keratometric power of more than 45.00 D, when ablation zones were less than six and when higher amounts of corrections were attempted.[47] Better reading vision than expected was noted in his patients, which might be explained by areas of multifocality.

Over the last 6 years, numerous studies have been published on hyperopic LASIK using different lasers, beam profiles, and ablation zone parameters, achieving fairly similar results. These studies conclude that the treatment is reasonably effective and safe up to 4 D or 5 D, but less effective for hyperopic astigmatism. Stability occurs in most cases by 3 months but with the loss of best spectacle corrected visual acuity above 5 D or 6 D other procedures such as refractive IOLs may be a better choice.[48-50] Retreatment after hyperopic LASIK was reported in up to 25% because of undercorrection of 0.50 D or more seen with low hyperopia but to a greater extent with moderate hyperopia.[49] Improved nomograms helped to reduce the amount of undercorrections.[51,52]

A study by Salz and Stevens supported the safety and effectiveness of the LASIK correction of spherical hyperopia, hyperopic astigmatism, and mixed astigmatism using the LADARVision® (Alcon, Ft. Worth, TX) excimer laser system with active tracking. They achieved 20/20 or better in 46% of eyes with mixed astigmatism, 49% in spherical hyperopia, but only 37% in hyperopic astigmatic eyes. An average of 4% lost two lines of best spectacle corrected visual acuity with 6% in the hyperopic astigmatism group.[52]

Carones et al reported the results of performing hyperopic LASIK using a 7-mm optical zone diameter with a 3-mm transition zone for a total ablation diameter of 10 mm using the LADARVision® 4000.[53] A 10-mm flap was created with the SKBM® microkeratome (Alcon, Irvine, CA). In the 53 eyes treated mainly for compound hyperopic astigmatism, there was an early overcorrection that decreased slightly by 6 months. Fifty-three percent had 20/20 uncorrected acuity at 6 months and all eyes had 20/63 or better. There were no eyes that lost more than one line. There appeared to be faster refractive stability with less early overcorrection, better predictability, and more positive visual outcomes with larger diameter ablations. There were epithelial defects associated with the microkeratome pass in 9% of eyes and epithelial ingrowth in 15%, in part due to the large flaps.

Hyperopic LASIK has been used to treat under- or overcorrected hyperopic PRK with good results.[35]

> **Focus Point #4**
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> Overall, hyperopic patients are extremely pleased with the results of their surgery with many achieving a multifocal cornea, and they are able to read much better than expected.

Consecutive hyperopia following myopic LASIK and radial keratectomy can be treated with hyperopic LASIK with good results, but in one case following radial keratectomy corneal ectasia developed.[54] Refractive accommodative esotropia in young adults has been treated successfully with hyperopic LASIK.[55]

WAVEFRONT-GUIDED PRK AND LASIK

The limited data available for wavefront-guided treatments suggest that PRK may give better outcomes than LASIK by avoiding some of the challenges associated with the LASIK flap.[56] Standard hyperopic treatment can achieve 20/20 or better in 70% or more of cases at 1 or 2 years.[6,35,37] It is yet to be determined whether we can consistently increase this percentage and for how long these patients will maintain better than 20/20 uncorrected visual acuity.[57] Retreatment based on aberration sensing and wavefront-guided ablation does hold significant promise for not only correcting defocus but also higher order aberrations, thereby reducing subjective complaints of glare, halos, doubling, and night-vision disturbances.[58]

Studies using wavefront-guided PRK or LASIK for treatment of hyperopia have shown early encouraging results. In 2002, Nagy et al conducted a study to compare the results of traditional laser photoablation and wavefront-supported customized ablation in hyperopic PRK.[25] They concluded that wavefront-supported customized ablation-guided hyperopic PRK treatment was safe and predictable. The results were slightly superior to traditional PRK for hyperopia in terms of uncorrected visual acuity and best spectacle corrected visual acuity, although additional studies with longer follow-up and more patients are needed. However, wavefront-guided hyperopic PRK resulted in less day- and nighttime glare and halos when compared to patients treated with traditional PRK. Nagy et al also noted that with wavefront-guided PRK, patients had not lost contrast sensitivity after 6 months' follow-up as seen with traditional PRK. Loss of best spectacle corrected visual acuity in 25–30% of eyes still occurred in both groups. Wavefront-guided treatments still increase the root mean square value for higher order aberrations postoperatively despite the improvement in uncorrected visual acuity, which raises the possibility that a decrease in higher order aberrations is not a prerequisite for improvement in subjective visual acuity.[25]

My associates and I reported at the American Society of Cataract and Refractive Surgery 2003 (Jackson WB, Mintsioulis G, Lafontaine M, et al: WaveScan-Guided LASIK Treatment of Hyperopia Using the VISX WavePrint System. American Society of Cataract and Refractive Surgery, San Francisco, 2003, p 51) the results of the first cohort of hyperopic patients treated with wavefront-guided LASIK using the CustomVue™ System (VISX, Santa Clara, CA). There were 16 eyes of eight patients who were treated for up to 3 D of spherical hyperopia and up to 2.5 D of cylinder. The mean age was 50.9 years and preoperatively the mean refractive spherical equivalent was 1.98 D. All patients were measured on the WaveScan® (VISX, Santa Clara, CA) and the planned ablation was verified with the PreVue® lens (VISX, Santa Clara, CA) with each patient achieving 20/20+3 with the lens. The Amadeus™ microkeratome (Advanced Medical Optics, Santa Ana, CA) was used in all cases. All ablations were targeted for plano and treatment was performed on the VISX Star S4 ActiveTrak. There were no nomogram adjustments. Follow-up at 6 months showed 40% at 20/16, 69% at 20/20, and 100% at 20/40. The refractive outcomes showed good accuracy and stability. The mean refractive spherical equivalent at 1, 3, and 6 months was +0.09, +0.13 D, and +0.24 D. The change in mean refractive spherical equivalent between 3 and 6 months was 0.50 D or less in 94% of eyes. No eye lost more than two lines of best spectacle corrected visual acuity with 100% at 20/20 or better and 81% at 20/16, or better at 6 months. The wavefront results showed no significant increase in mean higher order root mean square compared to baseline. Longer follow-up studies with more patients and higher refractive errors are currently being evaluated.[59]

HYPEROPIC MULTIFOCAL PRESBYOIC TREATMENTS

Over the past 2 years, my colleagues and I at the University of Ottawa Eye Institute have been conducting trials using the VISX STAR S4™ excimer laser for the treatment of hyperopic presbyopia. The ablation pattern used in these studies was patented by VISX and created using the Variable Spot Scanning (VISX, Santa Clara, CA) technology. The central zone is

Focus Point #5

Wavefront-guided treatments show encouraging outcomes and result in less day- and nighttime halos and glare.

Focus Point #6

Wavefront-guided bilateral multifocal LASIK may provide an effective and safe treatment option for presbyopic hyperopic patients.

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