

Correcting Astigmatism With the Excimer Laser

Astigmatism is more difficult to manage compared with myopia and hyperopia.

BY GEORGE D. KYMIONIS, MD, PhD

Astigmatism is an optical defect that may lead to shadowing, loss of contrast sensitivity, distortion, blurred vision, and ghosting. There are two types of astigmatism, regular and irregular. Irregular astigmatism is often caused by a corneal scar or scattering in the crystalline lens. It is estimated that astigmatism of more than -0.50 D is present in 44.4% of the population.¹ Astigmatism may be idiopathic or secondary to surgical procedures, including cataract extraction and penetrating keratoplasty (PKP).

Determined by magnitude and orientation, astigmatism is more difficult to manage compared with myopia and hyperopia. Surgical treatment of astigmatism was first attempted with astigmatic keratotomy, in which incisions in the peripheral cornea are made in an attempt to make its shape more spherical. The use of incisional keratotomy has declined in recent years as laser vision correction has gained popularity due to its superior predictability in most cases. The excimer laser corrects astigmatism by removing anterior corneal stromal tissue to alter the curvature of the cornea.

Regular astigmatism is mainly generated by excessive corneal toricity. Corneal toricity can be suppressed either by flattening the steepest meridian to match the curvature of the initially flatter meridian or by steepening the flattest meridian to match the curvature of the initially steeper meridian. Simple myopic and hyperopic astigmatic treatments rely on the use of negative and positive cylinder modes, respectively. Compound and mixed astigmatism are treated by the combination of negative and/or positive cylindrical and spherical modes.

The key to refractive laser correction of myopic and hyperopic astigmatism is the use of an elliptical pattern of ablation applied along the central part of the flat meridian, leading to flattening of the steep axis. Because the treatment zone is elliptical, the effective optical zone is smaller than the treated area.

Numerous surgical techniques and ablation profiles to correct astigmatism have been described. Although many studies have reported good results for the correction of astigmatism with PRK and LASIK,²⁻¹⁶ the ablation

profiles usually cause a hyperopic shift because of the coupling effect in the flattest corneal meridian. Coupling describes the phenomenon by which, for every 1.00 D of cylinder that is corrected, 0.25 D of myopia is treated. Assessing the coupling effect is difficult because it seems to be dependent on many parameters, such as epithelial remodeling, the LASIK flap, differences among excimer lasers, and preoperative corneal curvature.

PRK

Several approaches have been tested and several studies performed to evaluate the safety and efficacy of PRK for the correction of astigmatism, beginning with the description of toric ablation in rabbits by McDonnell et al in 1991.²

In 92 eyes with 1-year follow-up after astigmatic PRK, Kremer et al³ found that the mean reduction in preoperative cylinder was 48%, 68%, and 81% in low, moderate, and high astigmatism groups, respectively. A final distance UCVA of 20/32 or better was achieved in 89% of eyes with low cylinder, 82% of eyes with moderate cylinder, and 85% of eyes with high cylinder.⁴

With 18 months of follow-up in 128 eyes after astigmatic PRK, Zadok et al⁴ reported that mean reduction in preoperative cylinder was 84%, 91%, and 75% in low, moderate, and high astigmatism groups, respectively, with 84% of eyes achieving distance UCVA of 20/40 or better.

Brodovsky et al⁵ evaluated the accuracy of excimer laser

TAKE-HOME MESSAGE

- The excimer laser corrects astigmatism by removing anterior corneal stromal tissue to alter the curvature of the cornea.
- An elliptical ablation pattern applied along the central part of the flat meridian is the key to astigmatic laser correction.
- Good results with PRK and LASIK for the correction of astigmatism have been reported, but ablation profiles tend to cause a hyperopic shift due to the coupling effect.

correction of myopic astigmatism by multipass/multizone treatment in a consecutive series of 332 eyes. They found a mean astigmatic correction of 89% and 98% in the low and high myopic astigmatism groups, respectively. Colin et al⁶ evaluated the precision, accuracy, and safety of three modes of excimer laser surgery for myopic astigmatism in 150 eyes with compound myopic astigmatism and found that results varied among the three platforms. Eggink et al⁷ compared the efficacy, safety, and stability of astigmatic PRK in 41 eyes with myopic astigmatism and found a mean reduction in the astigmatic component of 67% at 12 months postoperatively.

More recently, Spadea et al⁸ evaluated three PRK techniques for mixed astigmatism and reported that PRK is a useful technique in terms of efficacy, safety, and predictability for the correction of mixed astigmatism.

Thomas et al⁹ reported that the prophylactic application of mitomycin-C (MMC) during conventional PRK procedures should be considered for patients with moderate to high levels of astigmatism (approximately at least 1.25 D) because preoperative astigmatism is significantly associated with the development of corneal haze after conventional PRK without MMC.

LASIK

LASIK has been used successfully in the correction of low to moderate myopic astigmatism; there is less documentation regarding its use for correction of high myopic astigmatism. Myopic astigmatic corrections with LASIK are achieved through ablation of the central part of the flat meridian, flattening the steep axis. Hyperopic astigmatism is treated by ablation of the periphery, steepening the flat axis.

According to reviews of the literature by the American Academy of Ophthalmology (AAO),^{10,11} LASIK is effective and predictable for obtaining very good to excellent distance UCVA, and it is safe in terms of minimal loss of BCVA for mild to moderate degrees of astigmatism (less than 2.00 D). Moreover, for correction of low to moderate hyperopic astigmatism, LASIK is effective and predictable in achieving very good distance UCVA and postoperative refractions within 1.00 D of target, and it is safe in terms of minimal loss of BCVA. The postoperative results for both UCVA and safety are less compelling as greater amounts of hyperopia are treated (greater than 4.00 to 5.00 D). Utilizing secondary hyperopic LASIK for the treatment of consecutive hyperopia and astigmatism is also effective, although the ability to reduce hyperopic astigmatism after radial keratotomy is limited.

Barraquer and Gutierrez¹² evaluated the efficacy and safety of steepening the flatter meridian with LASIK to correct hyperopic compound astigmatism in 111 eyes. At 6 months postoperative, mean residual cylinder was -0.61 D,

and 71% of the eyes had a distance UCVA of 0.50 D or better. Chayet et al¹³ evaluated the safety and efficacy of bitoric LASIK for the correction of simple myopic and mixed astigmatism. In that study, 85% of eyes achieved a UCVA of 20/25 or better and a final cylinder of 0.50 D or less. None of the eyes lost lines of BCVA.

Fraunfelder et al¹⁴ retrospectively evaluated the effectiveness of astigmatism correction in eyes treated with LASIK and PRK. Patients with low to moderate myopia with astigmatism ranging from 0.25 to 4.50 D were included in the study. Mean change in distance UCVA (logMAR) was 0.84 ± 0.26 for PRK and 0.89 ± 0.23 for LASIK. There was no significant difference in astigmatism correction between PRK and LASIK at 6 months postoperative.

Payvar and Hashemi¹⁵ studied the efficacy, predictability, and safety of LASIK for moderate to high simple or compound myopic astigmatism in 92 eyes. Six months postoperative, mean astigmatism (vertexed to the corneal plane) was 0.32 D at 7°, and 80% of eyes had a distance UCVA of 20/40 or better. In a retrospective study, Jin G et al¹⁶ reported that LASIK was a safe, effective, and predictable procedure to treat both primary mixed astigmatism and secondary mixed astigmatism after previous refractive surgery, and that nomogram adjustment with spherical and astigmatic components individually may improve refractive outcomes.

HIGHER-ORDER ABERRATIONS AND OTHER EFFECTS

A notable side effect of LASIK is the induction of higher-order aberrations (HOAs), mainly because of the effects of flap formation.¹⁷ Customized ablation protocols were developed to preserve the preoperative level of HOAs.^{18,19} In a recent study, Arbelaez et al²⁰ evaluated the postoperative clinical outcomes and HOAs of LASIK in eyes with moderate to high astigmatism (greater than 2.00 D) that had undergone LASIK using a nonwavefront-guided, aberration-free profile. They reported that 84% of eyes achieved a distance UCVA of 20/20, and preoperative astigmatism was reduced to subclinical values with no clinically relevant induction of HOAs.

Although astigmatic correction can be accomplished with the use of an excimer laser, it is important in any refractive surgical procedure to avoid residual astigmatism due to the laser coupling effect and cyclotorsion errors and to achieve the best primary refractive outcomes.

Throughout the LASIK procedure, cyclotorsion of the globe occurs continually, leading to misalignment of the axis if this effect is not taken into consideration. Cyclotorsion can lead to a decrease in the amount of astigmatism reduction. Mean cyclotorsion of the human eye during laser application in the supine position^{21,22} has been calculated to be $2.670 \pm 1.588^\circ$. With 10° deviation of an astigmatic ablation from the intended axis, approximately one-

third of the astigmatism-correcting effect is lost, and with 20° of axis deviation, approximately two-thirds of the effect is lost. Misalignment greater than 30° produces a net worsening of astigmatism.^{21,22} Bharti et al²³ found that active cyclotorsion compensation during LASIK for myopic astigmatism increases the accuracy of cylinder correction.

LASIK has also been shown to be effective for the treatment of surgically induced astigmatism after PKP. Alio et al²⁴ reported that a two-step technique, in which the lamellar cut and ablation take place in two successive procedures, improved the accuracy of excimer laser correction of astigmatism after penetrating keratoplasty. It seems that the lamellar cut itself is sufficient to produce an effect similar to a relaxing incision, resulting in a reduction of astigmatism. ■

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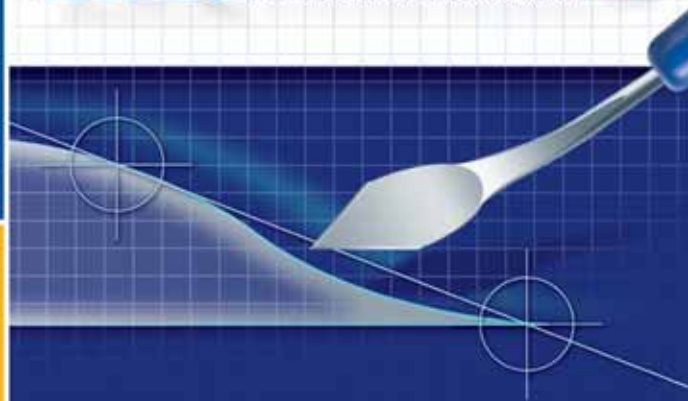
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