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Surgical management of astigmatism

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Toric IOL surgery: Success starts with accurate biometry

Fam Han Bor, MD

Optimizing refractive outcomes begins with good patient selection. This is followed by good refraction, surgical planning with patients to establish targets, achieving those targets with proper surgical technique, and using the outcomes to personalize and so further optimize a surgeon's nomograms. According to **Fam Han Bor, MD**, when it comes to refractive surgery, this process is clear cut.

Not so much with cataract surgery, though the process should, by rights, be the same, Dr. Fam said. Cataract surgeons tend to dwell on technique, he said, but they should take a step back and look at the similarity between cataract and refractive surgery.

Dr. Fam described the equivalences as follows: In both refractive and cataract surgery, topography or preferably tomography is performed to determine suitability. The importance of good biometry in cataract surgery is equivalent to accurate refraction in refractive surgery. This is followed by the execution of the surgical plan in both refractive and cataract surgery. Finally, while the outcomes are used to personalize nomograms with refractive surgery, they are used to personalize intraocular lens (IOL) constants with cataract surgery. Done right, this means that surgeons—both cataract and refractive—can achieve better and better outcomes with each succeeding procedure.

Clearly, cataract surgery—where less than optimal refractive outcomes result in unhappy patients—is refractive surgery. This fact gains particular significance with toric IOL surgery.

Biometry

Candidates for toric IOL implantation are patients who have regular corneal astigmatism—the lenses are not recommended for irregular astigmatism—with stable keratometry over months. Ideally, they should have intact capsular bags with appropriately sized and shaped continuous curvilinear capsulotomies.

After identifying these candidates, good biometry that includes keratometry, topography or tomography, axial measurement, and IOL power calculation is essential, said Dr. Fam.

Patients should have stopped contact lens wear, which can affect keratometry readings significantly. Dr. Fam recommends having patients stop using contact lenses at least one week for soft contact lenses and at least two weeks for hard contact lenses.

Keratometry should also be performed before any contact investigation such as contact tonometry. Excessive eye drops before keratometry should be avoided. If necessary and especially if dry, the cornea should be lubricated during keratometry. The patient's head should be in an appropriate upright position during the procedure.

The keratometer itself can be manual, automated, the IOLMaster (Carl Zeiss Meditec, Jena, Germany), or LENSTAR (Haag-Streit, Koeniz, Switzerland); what matters is that the surgeon is familiar with the machine and knows how it behaves. If initial measurements are in doubt, repeat the measurements, with or without application of tear lubricants. Keratometry can be followed by topography to screen for irregular astigmatism and/or tomography to measure total corneal astigmatism (combined anterior and posterior corneal astigmatism), and intraoperative aberrometry can be useful if available.

An important thing to remember, said Dr. Fam, is that manifest refraction should not be used for toric IOL calculation. Manifest refraction is a summation of corneal and lenticular components; since the surgeon will be removing the lens, only the corneal component is left for the procedure to compensate.

According to Dr. Fam, optical biometers provide the best biometry results. Dr. Fam recommends performing an immersion A-scan at the very least, if optical biometry is not possible or available. Avoid using applanation A-scans, as the results can have an unacceptably wide standard deviation.

IOL power calculation

The next step is IOL power calculation. First, calculate the spherical equivalent, then determine the toric power and the axis using the online tool provided for the specific lens model.

At this point, it is important for surgeons to identify their patients' visual goals and match their expectations. Not all patients want emmetropia, said Dr. Fam; some may want to see better at near/reading distances.

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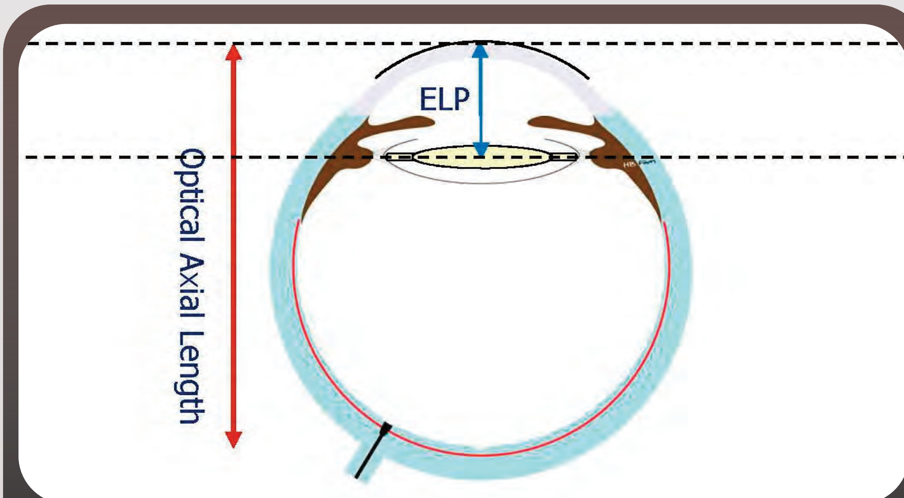

Figure 1: Effective lens position

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An important factor for the IOL is effective lens position (ELP)—essentially, where the IOL will sit in the eye. ELP is a function of three parameters: the design of the IOL, including the IOL's angulation and where it sits in the eye after implantation; the eye's axial length; and the radius of curvature of the cornea.

To illustrate the effect of ELP on IOL power calculation and, ultimately, refractive outcome, Dr. Fam said that varying ELP in eyes with the same axial length can result in a significantly different IOL power (Figure 1).

Fixed ratio vs. ELP

In calculating toric IOL power, most calculators rely on an approximation that involves a constant for the ratio of the required IOL toricity to corneal astigmatism—a constant Dr. Fam referred to as the fixed ratio. Using this approximation rather than the theoretical vergence formula itself is less precise. The more a specific patient varies from normal—for instance, as the lens sits farther into the posterior of the eye—the more error is introduced as the actual ratio can be quite different from the fixed ratio (Figure 2).

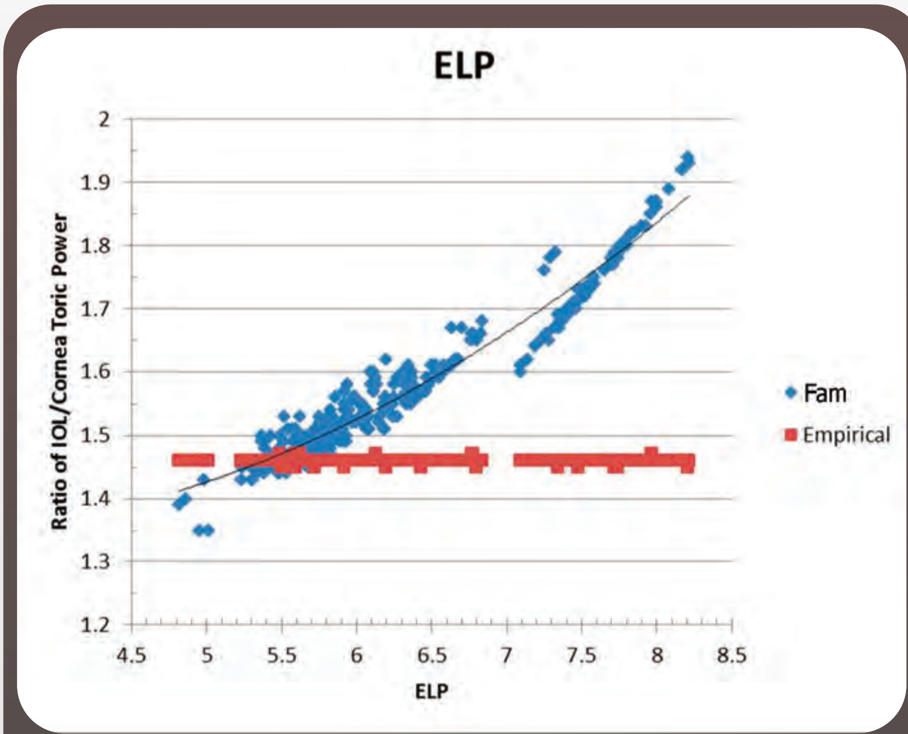

Figure 2: The ratio increases as the lens sits farther into the posterior of the eye.

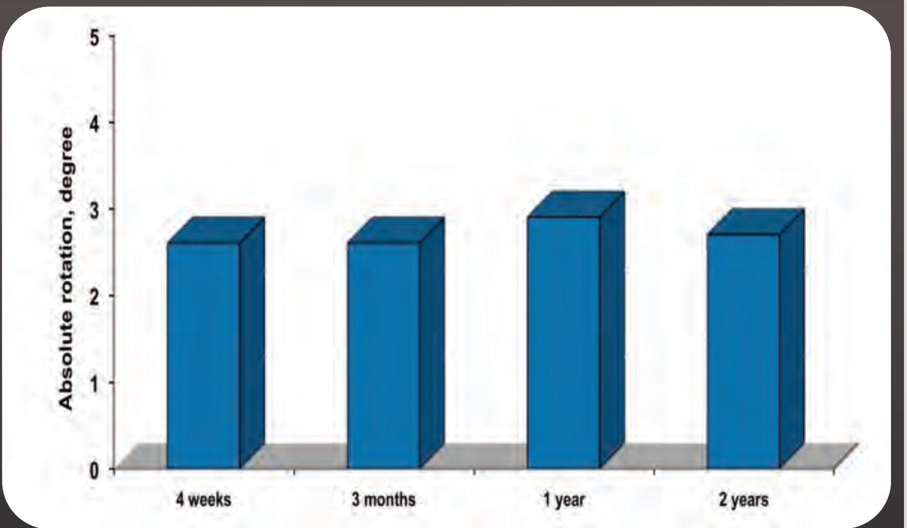

Figure 3: Rotational stability with less than 3 degrees of change up to two years after surgery

Rather than relying on this fixed-ratio approximation, the toric IOL calculator from Abbott Medical Optics (AMO, Santa Ana, Calif., U.S.) utilizes ELP-based calculation for more precise calculation of the cylinder.[1] The AMO toric calculator, said Dr. Fam, thus requires a little more information than other calculators—in addition to surgically induced astigmatism (SIA), preop Ks, and IOL power, IOL constant and the axial length are required—but in return the surgeon is assured of a more accurate calculation.

Controlling induced astigmatism

Astigmatism is a vector—it has both magnitude and direction; correcting it, said Dr. Fam, is therefore comparable to crossing a stream, in which you have to account for the current in order to arrive at a particular point on the opposite side, rather than finding yourself further downstream.

In the case of cataract surgery, SIA—astigmatism induced by the surgical incisions—stands in for the current. These days, there are techniques and technologies that allow incisions smaller than 2.2 mm, which induce minimal amounts of astigmatism of perhaps 0.25 D or less. Larger incisions are, of course, more likely to induce more astigmatism.

Each surgeon should determine his or her own SIA with his or her preferred technique and incision size to input into the AMO toric calculator.

IOL design considerations

The stability of the IOL design platform is important. The Tecnis Toric IOL Tri-Fix three-point fixation design (AMO), he said, has been found to provide excellent stability, with less than 3 degrees of rotation up to two years after implantation[2] (Figure 3).

For successful outcomes with toric IOLs, said Dr. Fam, selecting the right patient through accurate biometry, correctly aligning the lens, and using a rotationally stable IOL are essential.

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Optical synergy in toric IOLs

Daniel Black, MD

Blurry vision isn't the sole complaint of most patients presenting for cataract surgery, said **Daniel Black, MD**. Rather, he said, his patients complain of needing to go out into sunlight to read, of losing their golf ball as it goes up into the sky, of being disabled by glare during the day and halos at night. These particular complaints might not be typical of all patients, but they demonstrate reduced visual quality and need to be addressed by cataract surgery.

Patients judge the success of a cataract operation by how much the quality of their vision is improved, and the most important aspect in determining the patient's quality of vision postoperatively is the choice of intraocular lens (IOL).

When choosing an IOL, the lens must maximize visual quality; it should not induce dysphotopsias and introduce a new problem to the patient. Also, since some of the problems caused by cataracts—particularly nuclear sclerosis cataracts—result from filtering out of blue light, the IOL should allow full light transmission.

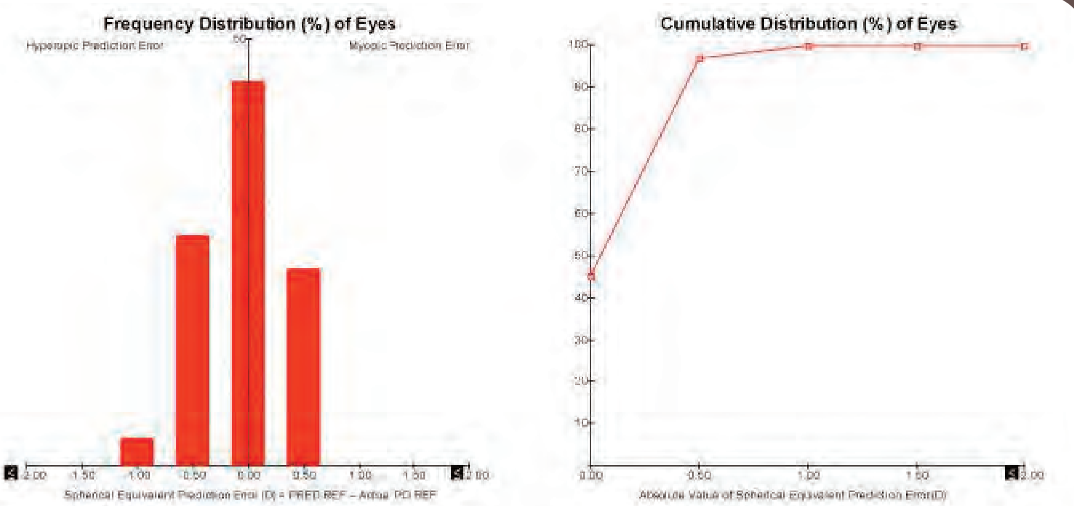
IOL selection should also consider other conditions patients in the cataract age group will develop or may already have. Macular degeneration and glaucoma, for instance, will reduce a patient's contrast sensitivity, so it's imperative that the IOL implanted maximizes visual quality. Visual quality is measured by contrast sensitivity and maximized by minimizing aberrations.

Correcting aberrations

The widespread use of PRK and LASIK in the 1990s revealed the unwanted effect of aberrations in the form of patients with excellent Snellen acuity who were nonetheless very unhappy. Surgeons thus recognize the need to correct higher order aberrations.

Of the higher order aberrations, spherical aberration is the most significant. In 2002, **Jack T. Holladay, MD**, published a paper in the *Journal of Refractive Surgery* in which he described the cornea as having a positive spherical aberration of +0.27 microns that is neutralized by negative spherical aberration in the crystalline lens—resulting in zero total ocular spherical aberration.[1] However, as patients grow older, the crystalline lens loses its compensatory negative spherical aberration and develops positive spherical aberration. Patients over 40 may thus have good Snellen acuity even as their visual quality begins to decline.

Dr. Holladay further recommended that the positive corneal spherical aberration should be corrected by IOL implantation during cataract surgery, and the following year, **Ulrich Mester, MD**, publishing in the *Journal of Cataract & Refractive Surgery*, measured an improvement in visual quality by implanting an IOL with a modified



Formula	Number of Cases	Personalized ACD (mm)	Eqv. Form Constant	Current Form.	Mean Rx Err (D)	Mean Abs Rx Err (D)	Std Dev Rx Err (D)	Max Rx Err (D)	% Cases > +/- 2D Rx
Holladay II	270	5.807 +/-0.017	ACD: 5.807	5.807	-0.032	0.315	0.388	1.18	0.0%
Holladay I	270	5.892 +/-0.017	SF: 2.123	2.123	-0.045	0.312	0.391	1.78	0.0%
Hoffer-Q	270	5.920 +/-0.018	ACD: 5.920	5.920	-0.030	0.341	0.428	1.41	0.0%
SRK-T	270	5.921 +/-0.016	ACst119.638	119.638	-0.002	0.306	0.391	1.78	0.0%
Holladay R	270	0.000 +/-0.000	ACD: 0.000	5.397	-0.412	0.434	0.565	-3.25	2.6%

Figure 1: Spherical correction in 270 consecutive patients

Mean rotation	Follow-up period	Reference
2.74°	6 months	Data on file (Abbott Medical Optics)
<3°	2 years	Findl, presented at ESCRS 2012
3.15°	2 months	Ferreira TB, Alemeida A, JRS, 2012;28(8):551-555
3.4°	2 months	Sheppard et al, JCRS, 2013; 39:41-7
2.1°	2 weeks	Assaf A, presented at the ESCRS 2012, Milan, Italy
2.6°	2 months	Assaf A, presented at the ESCRS 2012, Milan, Italy

Figure 2: Various studies demonstrating rotational stability

surface designed to compensate for the positive spherical aberration in the cornea described by Dr. Holladay.[2]

In Dr. Mester's study, the aspheric IOL, compared to a standard spherical IOL, improved contrast sensitivity in low light and in photopic conditions. This is of real practical benefit. Night driving simulations showed that patients were better, safer drivers with correction of spherical aberration through a Tecnis IOL implant (Abbott Medical Optics, AMO, Santa Ana, Calif., U.S.). This was recognized by the U.S. Food and Drug Administration, and AMO was allowed to publish and state that improving visual quality is not just a laboratory exercise but has real-world benefits.

Corneal aberration is particularly significant in Asian populations. In 2009, **Fam Han Bor, MD**, showed that higher order aberrations tended to be higher in Southeast Asian Chinese eyes—at –0.30±0.22 microns.[3]

There are other forms of aberration as well. In 2007, Norberto Lopez-Gil, PhD, and Robert Montes-Mico, PhD, demonstrated the benefits of correcting chromatic aberration,[4] while **Alessandro Franchini, MD**, published that correcting both spherical aberration and chromatic aberration resulted in synergy that maximized image sharpness.[5]

Ideal IOL characteristics

Because the ideal IOL should not introduce more visual symptoms such as glare or reflections, it is important to look at low refractive index materials. The ideal material should be free from optical imperfections that might cause light scatter and further degrade the image.

Full light transmission is also important. Filtering blue light reduces scotopic sensitivity, and blue-blocking IOLs have been shown to reduce visual performance on short wavelength automated perimetry. Cataract patients already complain of poor vision in low light conditions during which retinal sensitivity shifts to the left, requiring short wavelength light; therefore full light transmission is necessary to allow optimum results in vision.

These are all characteristics of the Tecnis Toric IOL (AMO) and are the reasons why the Tecnis Toric is Dr. Black's IOL of choice. The IOL comes in the Tecnis one-piece platform—a single-piece, hydrophobic acrylic IOL that allows full light transmission. The toric lens corrects both higher (spherical and chromatic aberration) and lower order aberrations—sphere and cylinder—to realize the full benefit of aberration correction.

Clinical results

Dr. Black examined the outcomes of 270 consecutive patients implanted with the Tecnis Toric IOL. In these cases, Dr. Black has personalized his A constant at 119.6 (optical) versus the manufacturer setting of 118.8 (ultrasound) or 119.3 (optical).

In 270 cases, Dr. Black achieved a mean absolute refractive error of about one third of a diopter (0.306–0.434 D) with a standard deviation of about a third (0.388–0.565 D), none more than 1.2 D off the mark, varying with the IOL formula, across a wide range of axial lengths (20.85 mm–27.80 mm) and dioptric power (8.5–30.0) (Figure 1).

Cylinder was corrected from a preop mean of 1.33±0.81 (0.7–3.7) to a postop mean of 0.15±0.28 (0.0–2.0).

Out of 270 patients, Dr. Black had two outliers with deviations from targeted outcome greater than 1.0 D. Both had reduced astigmatism postop and were uncomplicated cases with correctly aligned lenses, illustrating that about 1% of patients presenting for cataract surgery have some element of internal astigmatism, perhaps from the posterior cornea or on the retina.

Significantly for a toric IOL platform, the Tecnis has been demonstrated to have excellent rotational stability with various studies showing less than 5 degrees of rotation up to two years after implantation (Figure 2). At less than 5 degrees of rotation, patients will lose no more than 3% effectiveness, as published by **Noel A. Alpins, MD**, in 1997.[6]

Optimizing outcomes

In order to ensure optimal outcomes, Dr. Black recommended performing biometry on virgin corneas, marking the steep axis, using any technique to ensure a central and consistently sized continuous curvilinear capsulorhexis, and making sure that all viscoelastic has been removed from behind the IOL at the end of implantation.

Beyond these surgical pearls, he said, maximizing visual quality is a synergy. The surgeon should choose an IOL that will correct both lower and higher order aberrations (sphere, cylinder, spherical and chromatic aberration), that is glistening free and allows full light transmission.

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High definition astigmatism treatment with the laser

Con Moshegov, MD

In treating refractive errors such as corneal astigmatism, an accurate and reliable laser system is invaluable. The VISX STAR S4 Excimer Laser System is the laser component of the iLASIK suite (Abbott Medical Optics, AMO, Santa Ana, Calif., U.S.). It is the system **Con Moshegov, MD**, has been using for more than 10 years. In that time, he said, the system has undergone several refinements.

What initially attracted Dr. Moshegov to the system was its variable spot size. The VISX STAR S4 Excimer Laser System combines the advantages of large and small beam diameters—something he says no other flying spot laser can do—and has a variable repetition rate, which is necessary when applying different spot sizes to avoid the risk of thermal damage on the stroma of the cornea.

Iris registration

The system also has iris registration capabilities. It detects cyclotorsion by comparing landmarks on the intraoperative image with preoperative photographs of the iris. It then compensates for the rotation to ensure that the laser treatment is on the correct axis of the cornea.

Iris registration thus allows the system to correct for the cyclotorsion, which occurs when the patient goes from the upright to the supine position, thereby optimizing astigmatic outcomes as well as minimizing higher order aberrations.

With its iris registration capabilities augmented by Fourier waveform analysis, the VISX STAR S4 Excimer Laser System has been shown effective in treating low to moderate myopia, with data published for 32,569 eyes from the Optical Express group in the United Kingdom.[1]

Now AMO have given its laser a new brain. The iDesign Advanced WaveScan Studio is a multipurpose instrument with a high-definition sensor to maximize capture rates, giving it the ability to capture very highly aberrated eyes.

The brain of LVC surgery

A single capture sequence with the iDesign takes five measurements: wavefront aberrometry, pupillometry, autorefraction, keratometry, and topography. But the most significant difference between the iDesign and its predecessor, the WaveScan system, is an improvement in spot quality.

Spot quality affects the ability of the aberrometer to analyze said spots; the aberrometer cannot analyze poor quality spots and simply ignores the information those spots might otherwise provide.

Improved spot quality means the system can detect even highly aberrated eyes, and thus has the ability to capture more eyes—for instance, eyes with keratoconus, post-radial keratotomy or astigmatic keratotomy and post-graft eyes.

The iDesign system's high-definition Hartmann-Shack wavefront sensor has five times the resolution of the WaveScan, with the Fourier reconstruction algorithms used to analyze 1,257 microrefractions as opposed to only 250 over a 7-mm diameter wavefront. This increased resolution allows the system to capture more eyes, with a reduction in spot crossover effect from poor spot quality and greater detection of higher order aberrations.

The system detects between –16.0 D and +12.0 D of spherical error, up to +8.0 D of cylinder error, and up to 8 microns of higher order aberration.

Topography vs. wavefront-guided

Topography-guided treatments can correlate well with wavefront-guided treatments, but at other times they can be completely different. In Dr.

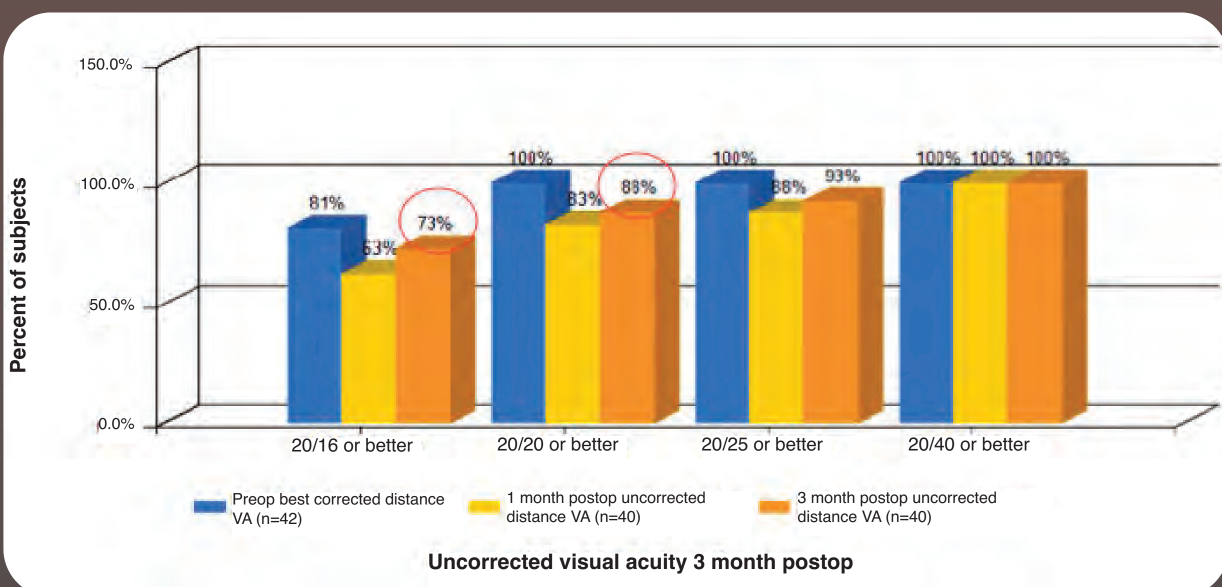

Figure 1: Efficiency of iDesign in patients with up to –9 D of myopia and 4 D of astigmatism

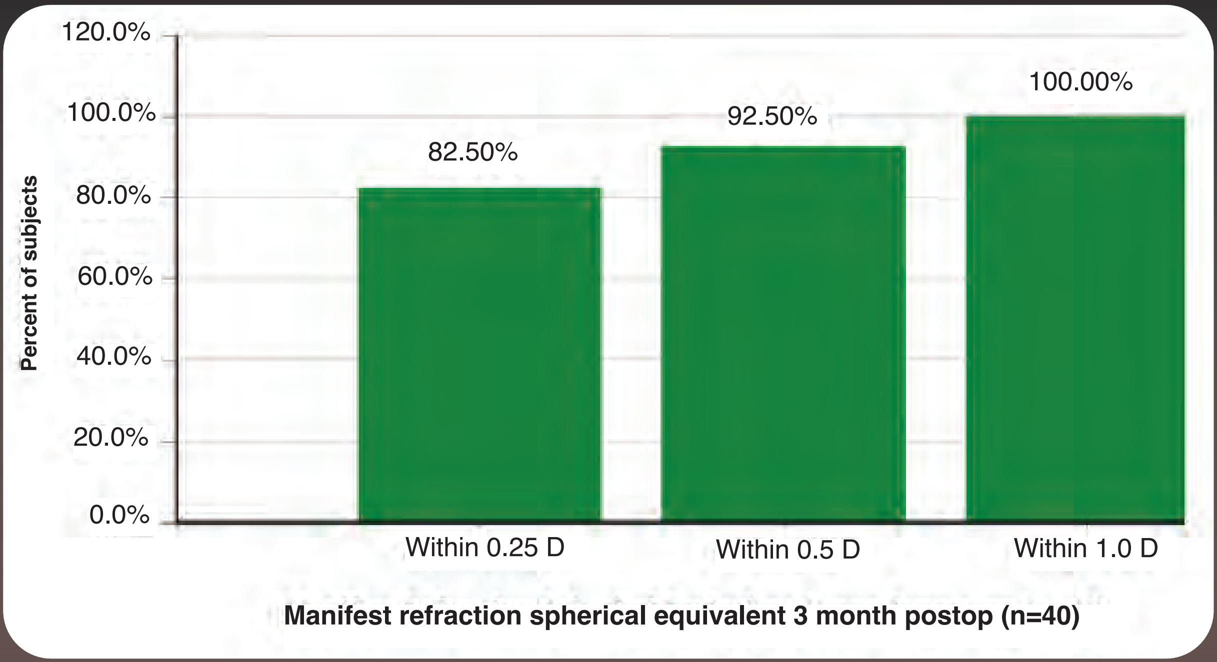

Figure 2: Predictability of iDesign

Moshegov's experience, the corneas can look better on corneal topography, but the quality of the vision remains suboptimal. He thus believes that aberrometry on eyes that are very sick and have a lot of irregularities is the preferable approach.

However, the iDesign system allows measurements of full-gradient topography. This Hartmann-Shack system reduces sensitivity to misalignment, and the topography is integrated on the same measurement axis as the aberrometer. It analyzes an area of more than 8.3 mm in diameter including a thorough examination of the central region—not available with Placido disc systems. The system also measures the pupil under controlled scotopic and photopic conditions.

Keratometry is calculated from the system's corneal topography data, and the algorithm used is one that has good correlation with manual and autokeratometers, designed to reduce errors that are common to Placido disc systems such as the missing central data.

Again, all this information is obtained in a single capture.

Clinical results

Various studies have shown the efficacy of the iDesign Advanced CustomVue treatment in myopia of up to –9.5 D with astigmatism of up to 5.25 D and hyperopia of up to +3.75 D with astigmatism of up to +2.0 D. Dr. Moshegov has examined the outcomes of his patients with myopia of up to –9.0 D and astigmatism of up to 4.0 D who underwent the treatment.

At one month, 83% of Dr. Moshegov's patients achieved 20/20 or better and 63% achieved 20/16 or better uncorrected visual acuity, with the percentages increasing to 88% and 73%, respectively, at three months. In terms of predictability, 92.5% of his patients were within 0.5 D of emmetropia, and all were within 1.0 D of emmetropia (Figures 1 and 2).

Dr. Moshegov emphasized that unaided visual acuity is where the "ultimate degree of satisfaction" for patients is achieved.

In Dr. Moshegov's experience, the iDesign system's autorefraction is more accurate than with any other machine at his disposal. To date, he said, there has been none of the underestimation of the myopic sphere that he had seen with the WaveScan, while the cylindrical estimate remains as perfect as it had been with the older system. In addition, he said, there is no doubt that this high definition Hartmann-Shack aberrometer is able to capture many more eyes with complex corneas—that increases the pool of eyes that surgeons can treat with wavefront-guided technology without having to concern themselves with the alternative of a topographically driven treatment. Finally, iris registration is much improved, with a virtually 100% capture rate.

The VISX STAR S4 Excimer Laser System already has a superb record of precision and reliability, but the iDesign system, said Dr. Moshegov, represents a genuine advance in wavefront-guided laser treatment technology.

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