Merging Cataract and Refractive Surgery

Improving Visual Quality and Acuity with Advanced Corneal and Lenticular Technologies

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By Baha Toygar, MD

At a private eye hospital in Turkey, my colleagues and I have performed approximately 300 Tecnis Multifocal IOL implantations. The Tecnis Multifocal is a silicone lens with an aspheric modified prolate anterior surface (just like the Tecnis monofocal), and a diffractive posterior surface. The optics diffract incoming light to two focal points for near and distance vision, with about half the light distributed to each. It is available in a wide dioptric range of 5 D to 34 D.

We recently presented long-term (12-month) data on 37 eyes of 19 patients with this IOL. The mean age was 48.4, with a fairly wide range (22-77 years). Twenty-five eyes were hyperopic, 6 myopic, and 6 plano presbyopes.

**Study Results**

In the hyperopic eyes, the mean spherical equivalent (SE) improved from 3.43 ± 2.25 D to 0.44 ± 0.42 D at 12 months. In the myopic eyes, the mean SE improved from -8.02 ± 5.83 D to 0.52 ± 0.42 D.

At 1 year, mean monocular uncorrected distance visual acuity improved from 0.29 (20/69) preop to 0.64 (20/31) postop. Best-corrected acuity was unchanged at 0.85 (20/23).

Uncorrected near visual acuity was considerably enhanced, with 89% of eyes achieving J3 or better and 81% of eyes reading J2. With distance correction, 95% of eyes could read J2 or better, including 76% achieving J1 or better. About half the patients were tested binocularly at 12 months, and all of them could read at least J2 with both eyes.

We also tested intermediate vision at 60 cm in a subset of about half the patients. Seventy-eight percent of these patients achieved at least J2 intermediate vision with both eyes open. Monocularly, 63% were J3 or better and nearly a third were J2 or better. This is reassuring. I had been concerned that the design of the Tecnis Multifocal might not provide sufficient intermediate vision, but the acuity results were quite good and we had no complaints from the patients in this study about difficulty with computers or other intermediate tasks.

Visual acuity after Tecnis Multifocal implantation is stable and predictable. There were no surgical complications in the study and no problems with centration. Two eyes underwent Nd:YAG capsulotomy postop. One patient had an IOL exchange (both eyes). This patient, a dental technician who was a plano presbyope, had good distance acuity and J1 near vision postop but complained of reflections off his dental instruments. We implanted Tecnis monofocal lenses instead and he is happy now.

Patient satisfaction in this study has been high. Ninety-five percent of patients told us they never wear spectacles, and almost all were satisfied or very satisfied with the results.

“Ninety-five percent of patients told us they never wear spectacles, and almost all were satisfied or very satisfied with the results”

Our study demonstrates that the Tecnis Multifocal IOL effectively corrects far, intermediate, and near vision, reducing patient dependency on glasses. With appropriate patient selection and preoperative biometry and IOL power calculations, outcomes are comparable to LASIK. This is an excellent modality for refractive correction, especially in hyperopes and higher myopes who may not be good candidates for laser refractive surgery.

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**Multifocal IOL Pearls**

- Avoid plano presbyopes and low myopes for initial cases
- Counsel patients appropriately
- Use IOLMaster or immersion biometry
- Use appropriate IOL power calculation formula
- Make a careful capsulorrhexis

**Table 1: 12-Month Near and Intermediate Vision Results with Tecnis Multifocal**

<table>
<thead>
<tr>
<th></th>
<th>≥ J5</th>
<th>≥ J3</th>
<th>≥ J2</th>
<th>≥ J1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monocular DCNVA</td>
<td>100%</td>
<td>94.6%</td>
<td>94.6%</td>
<td>75.7%</td>
</tr>
<tr>
<td>Monocular UCNVA</td>
<td>97.3%</td>
<td>89.2%</td>
<td>81.1%</td>
<td>51.4%</td>
</tr>
<tr>
<td>Binocular UCNVA (n=9)</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>66.6%</td>
</tr>
<tr>
<td>Monocular UCIVA (n=19)</td>
<td>73.7%</td>
<td>63.2%</td>
<td>31.6%</td>
<td>0</td>
</tr>
<tr>
<td>Binocular UCIVA (n=9)</td>
<td>100%</td>
<td>78%</td>
<td>78%</td>
<td>0</td>
</tr>
</tbody>
</table>

Patients reported experiencing some glare and halos around lights. The vast majority ranked these symptoms as mild (1-2 on a scale of 1 to 6). Three patients complained of more severe glare and halo (5-6). However, 94% said they had little or no difficulty seeing at night.
By Frank Goes, MD

Patients can achieve excellent near and distance vision and spectacle independence across a range of distances with a diffractive lens, such as the Tecnis ZM900 Multifocal IOL. Recent studies show that patients can have good reading vision at short distances and also have excellent intermediate vision without compromising distance vision.

**The Technology**

The Tecnis Multifocal lens has a prolate surface that is designed to compensate for spherical aberrations of the cornea and improve contrast sensitivity.

The multifocal lens is indicated for cataract patients and visual correction of presbyopia.

Careful patient selection remains important. Patients can read at short distances while maintaining excellent intermediate vision. This is achieved without compromising distance vision. Multifocality is independent of pupil size.

**Patient Selection**

By determining the patients’ desires for their vision and lifestyle, we can best determine their needs. I ask all my patients how important is it if they are spectacle free? I then discuss their lifestyle and occupational activities. I make sure to ask them several key questions, such as: Do they play sports or do a great deal of reading? Do they do a lot of night driving or computer work? I also consider their personalities, are they an obsessive person?

It is important to discuss the possibility of postoperative glare and halos with each patient. Also, I never promise a patient that they will be “free of spectacles.” Instead, I advise them that they will be “more independent with multifocals” and often say that in more than 90% of cases, they will be spectacle-free for both far and near.

**Recent Studies**

In an average cornea eye model (with a 4-mm or 5-mm pupil), visual quality at near and far with the Tecnis™ ZM900 lens with a modified prolate surface was better than the ReSTOR multifocal lens with a spheric surface.

We conducted a study of 114 eyes of refractive lensectomy patients for correction of presbyopia and hyperopia (range +1.5D to +8D). The mean patient age at the time of surgery was 55 years. Eighty-four eyes of 42 patients were reviewed at three-month follow-up. Patients had a simultaneous bilateral outpatient surgery with topical anesthesia. These patients presented with refractive problems, and some only had reading problems.

**Results**

The mean spherical equivalent (SE) before surgery was 4.21 D and postop SE improved to 0.29 D. At three months, 40 out of the 42 patients in the study indicated that they never used spectacles afterwards. Only two patients needed spectacles for hobby or personal computer work at intermediate distances (-1.25 D glasses).

“At three months, 40 out of the 42 patients in the study indicated that they never used spectacles afterwards”

At three months, the distance uncorrected vision was a mean of 20/25 monocular. Distance best corrected vision had a mean of 20/20 monocular, but 14/84 eyes had LASIK as an enhancement. The possible need of LASIK enhancement should be discussed prior to treatment.

For near uncorrected vision, 95% of patients achieved Jaeger 1 uncorrected monocular. For near with distance correction, 98% of patients reached Jaeger 1 distance corrected monocular.

Intermediate vision required for PC work is critical for many patients today. In this study, intermediate PC vision was excellent. Also at 50 cm binocular and eventually distance corrected, 40% of patients could read Jaeger 2 and another 52% could read Jaeger 3.

**Patient Feedback**

Amazingly, patients did not have any complaints at all concerning their distance vision. However, some patients did indicate that they experienced some side effects, which decreased over time.

A review of the six month follow-up data shows that some patients still mention seeing rings from time to time; but they are no longer disturbed by the occurrence any more.

Concerning the three-month data, 16% of patient indicated minor subjective complaints when asked, while 7% reported major subjective complaints. Two patients noted significant driving problems at night, but felt they could still drive.

All patients said they would recommend the lens and not one patient considered explantation.

**Future Outlook**

The overall acceptance and patient satisfaction for this combination procedure was excellent. I performed simultaneous bilateral surgery and topical anesthesia on an outpatient basis and the recuperation time was extremely short.

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The combination of the Tecnis MF and ReZoom multifocal lenses offers a full range of vision that appears to be a good solution for patients. With this combination, patients can achieve good bilateral near vision in lower light situations. The typical reading distance is a more comfortable one and there is greater bilateral contrast sensitivity than when ReStor and ReZoom are combined. Additionally, having a Tecnis MF IOL in at least one eye reduces spherical aberration.

**Lens Selection**
For the mix and match procedure, I do not take into consideration the dominant or recessive eyes. For the first eye, I select the IOL according to the patient's characteristics and individual needs. For example, if the patient is a heavy computer user, I select a refractive IOL. Other patients who also rely heavily on intermediate vision will benefit from these lenses. Refractive lenses, such as the AMO ReZoom, also are ideal for light-to-moderate readers who drive mostly during the day. If the patient is a compulsive reader, I select a diffractive IOL. Diffractive IOLs, such as AMO's Tecnis Multifocal IOL, offer excellent near and distance vision with good reading speed.

**Recent Study**
Because not all patients fit neatly into one category or the other, my colleague Pedro Paulo Fabri, MD, and I decided to compare the results of bilateral implants of the same IOL to a mix-and-match diffractive/refractive approach. Four groups of patients were compared: 100 patients with bilateral ReStor implants; 100 patients with bilateral ReZoom implants; 88 patients with ReStor in the nondominant eye and ReZoom in the dominant eye; and 15 patients with a Tecnis multifocal implant in one eye and ReZoom in the other.

We compared refractive outcomes, reading speed, spectacle independence, and quality of vision using various multifocal IOL approaches.

Patients in both of the mixed lens groups achieved 100% spectacle independence, compared to 75%-89% in the bilateral implant groups.

Distance acuity was weakest in the bilateral ReStor patients, but very good across all of the study groups. Intermediate vision was best with the ReZoom/Tecnis MF combination, but was also excellent in the bilateral ReZoom group. Average near vision in the patients with at least one ReStor lens was J 1.40-1.50. However, the ReZoom/Tecnis MF group achieved even better near visual acuity of J 1.10.

Reading speed is not something ophthalmologists typically measure. However, we measured the number of words per minute (wpm) patients could read with a 3.5-mm pupil because we have found reading speed to be an important component of patient satisfaction with their near vision abilities. Reading speed varied from 125 wpm with bilateral ReZoom implants to 185 wpm with the ReZoom/Tecnis MF combination.

**Patient Satisfaction**
Most of my patients are very satisfied with the results when they receive a refractive IOL in one eye and a diffractive in the other. However, 15 days after the first surgery, I ask the patient about any complaints or visual problems they might be experiencing. If the patient has limitations because of one of the IOLs, I propose that we replace it with the complementary type of IOL (refractive or diffractive) to fulfill the patient's expectations and increase their satisfaction.

In addition to considering individual characteristics and needs, surgeons want to carefully explain to their candidates the procedure and how resulting vision will work. Patients will be more satisfied if they are orientated to see with both eyes and instructed not to compare their vision in each eye. Also surgeons should prepare patients to expect more haloes in the refractive eye and explain that after six months the haloes will decrease or the patient's vision will adjust.

**Future Outlook**
At this time we have performed relatively few ReZoom/Tecnis MF pairs. We plan to continue using this approach and look forward to reporting more results as they become available. Our initial impression is that this combination of IOL technologies provides better near and intermediate vision, faster reading speed, and less glare and halo than the ReStor/ReZoom combination without sacrificing distance acuity.

As such, we believe that the mix-and-match approach is well worth considering.

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**Expanding the Range of Vision by Combining Multifocals**

Mixing and matching refractive and diffractive IOL styles can offer patients binocular vision that is excellent at all distances.
Presbyopia Treatment

Key Considerations for Successful Mixing and Matching

The differing IOLs' designs allow some patients to achieve better distance and near vision, which increases range of vision in different light conditions.

By Ángel López Castro, MD

Mixing and matching the Tecnis Multifocal (MF) and ReZoom IOLs can maximize patient vision at both near and far distances.

I am implanting this combination in all cataract surgery or clear lens extraction patients who are interested in discharging the uses of glasses for distance and near vision. To date, I have implanted 40 patients with this combination. The majority of these patients are clear lens exchange patients.

My first mixed implants have achieved excellent distance vision. The ReZoom provides improved distance vision compared with the Tecnis MF. Also, because of the optical design of both lenses, patients achieve better distance and near vision with different pupil sizes. Therefore, patients maximize the range of vision in different light condition. The Tecnis MF is a superb IOL for reading with good light, but not as good in dim condition. Conversely, ReZoom is wonderful for distance in bright light and better for reading in dim light.

In my experience, it is better to implant the Tecnis MF first because near vision rehabilitation is faster than with ReZoom. To date, no patient regrets doing the second eye because the result of the first. I always implant the ReZoom in the dominant eye.

Results

Patients are reporting high levels of satisfaction with their vision. I will perform a LASIK enhancement if there is any residual distance refraction. Therefore, for far vision there are no patients using correction, unless there is a reason not to recommend a laser procedure.

Patient Selection

First and foremost, patients must be interested in near vision without glasses. Also, patients who are eager to be spectacle-independent usually are more willing to accept the potential visual side effects of the IOLs. In cataract patients, good candidates are those with a quiet lifestyle, interested in near vision without glasses, but who do not want to lose the sharpness of the monofocal IOLs for distance.

The ideal patient for PRELEX mix and match is a presbyopic or prepresbyopic hyperope (45 years or older), especially high hyperopes. Second best are high myopes (more than -6.00D), followed by emmetropic presbyopes, and then the least likely candidates are low myopes.

PRELEX should be done with extreme caution in emmetropes and patients with minor refractive errors because of a high incidence of intolerable halos and secondary procedures. Informed consent should clearly state the frequency of secondary procedure, in particular IOL exchange, and excimer laser touch up.

Photic Phenomena

All my patients are advised about halos and glare. I explain that photic phenomena are normal and usually resolve way or decline within about three months. I note that they could persist and be uncomfortable. However, no patients have asked for explantation of the IOL.

I carefully explain realistic expectations for the procedure. This requires more chair time in the office. Surgeons must know more things about the patient's lifestyle, visual needs, and personality. I tell each patient that it is better not to do the procedure if they can not assume some photic phenomena, or if they are expecting a perfect vision, or if they are looking for perfection in near or distance vision with poor light conditions.

All my patients who have been operated on are driving during day and night without difficulties. The majority do not notice halos or glare at three months and can read without any prescription. I always inform them about the possibility of needing glasses for some tasks that they considered as very tricky or in unusual light conditions.

Recommendations

Surgeons who are going to begin using both a refractive and diffractive lens in the same patient must keep in mind that the selection of the patient is critical, and it is important to discharge those who will be uncomfortable.

Also, it is crucial to get emmetropia and I recommend the use of IOL Master biometry with The Haigis Formula. I also do arcuate keratotomy at the end of the lens extraction. A LASIK or PRK touch-up is necessary if there is any residual refraction remaining two months after lens surgery as any residual error will lead to an unsatisfied patient.

“A LASIK or PRK touch-up is necessary if there is any residual refraction remaining two months after lens surgery as any residual error will lead to an unsatisfied patient”

If you reckon the patient is happy, but is still complaining, you can suggest removal of the IOL and exchange for a monofocal warning them that they will lose the ability to read without glasses. I believe all of the patients would not accept that option and would choose their present situation.

To date, I have not had any need for a lens exchange; and therefore in my opinion it is an option worth considering for our presbyopic and cataract patients.

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Presbyopia Treatment

Aspheric Presbyopic Ablations International Update

International study results for correction of presbyopia show good, stable results over 12 months

By W. Bruce Jackson, MD

Long-term International/Canadian study results for the correction of hyperopic presbyopia are excellent with 100% of subjects achieving simultaneous 20/25 distance vision and J3 near vision at 12 months. In the majority of cases, spectacle independence is achieved and maintained. In addition, patients report a high level of satisfaction.

Treatment Design

The treatment design uses a patented wavefront-guided aspheric presbyopic ablation profile and VSS ablation technology is used to create subtle ablation shape changes to the subject’s wavefront map. The central zone is steepened to provide near vision and the peripheral zone is targeted for distance vision.

The combination of the pupil-size dependent central zone, the peripheral zone, and the LASIK flap produces an aspheric curve that is customized to the patients’ eye and expands the depth of focus.

Results

In the multicenter trial, 82 eyes of 49 hyperopic presbyopic subjects received treatment. Preoperative refractions include mean manifest sphere of +1.66 D ± 0.60 (range +0.5 to +3.50 D), and cylinder: +0.43 D ± 0.35 (range +0.00 to +1.50 D). The mean patient age was 56 ± 5 (range 47 to 68) and 68% were female. Follow up is available for 12 months.

Most patients received bilateral LASIK treatments with the AMO Advanced CustomVue aspheric ablation treatment. This was a pupil-size dependent presbyopic correction with no nomogram adjustment and no retreatments. The Amadeus microkeratome was used in all cases.

At 12 months, 91% of the eyes were 20/20 or better for binocular uncorrected visual acuity for distance vision. For binocular uncorrected near vision, 100% were J3 or better and 88% were J1 or better.

In terms of efficacy, 80% of eyes are within ±0.5 D of emmetropia. Simultaneous uncorrected distance and near vision was achieved in the majority of eyes. For monocular simultaneous uncorrected distance and near vision, 80% of eyes achieve both 20/25 distance and J3 near or better. For binocular simultaneous uncorrected distance and near vision, 100% of subjects achieved both 20/25 distance and J3 near or better; and 88% achieve 20/25 and J1.

Patient Satisfaction

We surveyed patients on numerous specific areas of visual quality and overall, they have reported a high level of satisfaction.

At 12 months postop without correction, 80% of patients indicated high satisfaction with their overall visual sharpness and clarity. Similarly, at 12 months without correction, 92% indicated that they were satisfied/very satisfied with their distance vision (bright). Seventy-one percent of patients reported satisfaction with near vision (bright) at this time as well. Seventy-eight percent reported high satisfaction for their vision at night.

Most patients achieved spectacle independence at 12 months. Patients reported that they no longer used their spectacles for recreational activities and day or night driving. When patients decided to use their spectacles it was for reading (57%) or computer use (41%).

Presbyopic Outlook

Monocular uncorrected distance vision compared to binocular vision shows that there is a definite improvement when both eyes are treated with the aspheric ablation. While monocular results are good, the binocular treatment does represent quite an improvement. Thus, treating both eyes with the multifocal affect seems to have an added advantage.

Furthermore, patients are very happy with distance and night vision with this treatment. Although near vision is also very good, patients indicate that they would like to have a bit more improved near vision.

We also observed that the results improved over time to 12 months, especially for distance vision. More importantly, they remained stable out to 12 months.

W. Bruce Jackson, MD, FRCSC, is Professor and Chairman of the Department of Ophthalmology at the University of Ottawa Eye Institute and Director General of the University of Ottawa Eye Institute at The Ottawa Hospital, General Campus in Canada. Dr. Jackson may be reached at (613) 737-8759 or (613) 737-8374; bjackson@ottawahospital.on.ca.
Photoprotection of Blue-Blocking IOLs Comes at a High Price

Blue light is important for mesopic and scotopic vision and critical for entraining biological clocks to environmental day-night rhythms.

Ophthalmologist-physicist Martin A. Mainster, PhD, MD, FRCOphth, became involved in this subject almost 30 years ago. As the debate rages on, he wanted clinicians to recognize how IOL chromophores balance retinal photoprotection with photoreception.

AMD and Retinal Phototoxicity
There are at least two forms of retinal phototoxicity: Blue-green and UV-blue. Blue-green phototoxicity is mediated by rhodopsin, the same photopigment involved in scotopic vision. The second type of retinal phototoxicity, UV-blue, increases with decreasing wavelength. In other words, UV radiation (100-400 nm) is more hazardous than violet light (400-440 nm), which in turn is more hazardous than blue light (440-500 nm). UV radiation is responsible for 67% of acute UV-blue phototoxicity in the part of the spectrum that can reach the retina through an IOL, while violet light accounts for 18% and blue light for 14%.

Articles Mainster wrote in 1978 about the potentially harmful effects of UV radiation1-2 eventually led to the inclusion of UV-blocking chromophores in nearly all IOLs on the market today. Recently, it has been suggested that violet- and blue-blocking lenses (AcrySof Natural, Alcon Laboratories; AF-1, Hoya Corporation) may help prevent AMD.

Visual Benefits of Blue Light
Blue light is much more important for mesopic and scotopic vision than it is for photopic vision. According to Mainster, blue light provides 35% of aphaic scotopic and 7% of photopic sensitivity.

“Rod photoreceptors are responsible for scotopic and lower mesopic vision,” he said. “They contain the photopigment rhodopsin, which has peak sensitivity near 500 nm, the border between blue and green light. That explains why blue light is so important for scotopic vision.”

In older adults, declining photoreceptor populations cause scotopic threshold and contrast sensitivity to decrease and dark adaptation to slow. In addition, age-related pupillary miosis reduces retinal illumination. “Impaired dark adaptation increases the risk of falling in older adults, and falling increases the risk of debilitating injuries, costly long-term hospitalization and death,” Mainster said.

Cataract surgery can’t replace lost rod photoreceptors, but it does increase retinal illumination, particularly the blue light needed for vision in dim environments.

Health Benefits of Blue Light
Melatonin is a potent free-radical scavenger with numerous neuroprotective, anti-cancer and anti-aging functions. Retinal ganglion photoreceptors control suppression and secretion of melatonin using signals sent to the suprachiasmatic nucleus, the human body’s master biological clock. These retinal ganglion cells express the blue-light sensitive photopigment melanopsin. According to Mainster, “Blue light is responsible for over 50% of melanopsin sensitivity. In comparison to standard UV-only blocking IOLs, blue-blockers reduce melatonin suppression efficiency by 27–38%, depending on their dioptic power.”

Age-related pupillary miosis and crystalline lens yellowing conspire to reduce older adults’ effective blue light exposure to one-tenth that of younger people. “Numerous clinical studies have shown the risks of disturbed circadian photoentrainment and the benefits of optimal rhythmicity,” Mainster said.

Weighing the Tradeoffs
In the end, one has to consider the tradeoffs inherent in increasing retinal photoprotection. “UV radiation is potentially hazardous for the retina. It’s not useful for vision, so it makes good sense to block it with IOL chromophores,” said Mainster. But he isn’t satisfied with tradeoffs between photoprotection and photoreception made by blue-blocking IOLs.

In 1986, Dr. Mainster suggested blocking violet light in addition to UV to increase retinal photoprotection3. He recently showed that violet-blocking IOLs can provide the same level of UV-blue photoprotection as blue-blockers but reduce scotopic and melanopsin sensitivity loss by 50%.

“I believe that it is important for older adults to have all the blue light possible for retinal rod and ganglion cell photoreception, particularly since there is no clinical or experimental proof that chronic exposure to environmental light harms the human retina,” Mainster said. “Cataract surgery that improves a patient’s environmental blue light exposure helps assure their proper circadian photoentrainment and increase their chances of good physical and mental health.”

Dr. Mainster is the Luther L. Fry Professor and Vice Chairman of the Department of Ophthalmology at the University of Kansas Medical School in Kansas City, Kansas. Contact him at mmainste@kumc.edu.

References
Comparing Aspheric IOLs

New data indicates that the Tecnis Outperforms Other Aspheric IOLs

By Ralph Chu, MD

The preliminary results from the prospective, randomized double-masked trial comparing the three FDA-approved aspheric monofocal IOLs demonstrated that the Tecnis was the most effective in reducing spherical aberration to zero, regardless of the patient’s preoperative spherical aberration. For this study, our goal was to compare the performance of these three aspheric optic designs that correct different values of spherical aberration.

The Study

We evaluated the Tecnis, from Advanced Medical Optics, Inc., the Acrysof IQ lens from Alcon, and LI61AO from B&L.

Analysis of the average amount of corneal spherical aberration in a population of normal virgin eyes has shown that most eyes have approximately 0.27 microns of corneal spherical aberration. The Tecnis was developed based on this analysis, as a result it is the only lens designed to reduce spherical aberration to zero, thus improving quality of vision in patients, night driving and safety.

The Acrysof IQ lens is designed to correct for a lesser amount of spherical aberration than the Tecnis, leaving the average eye with at least 0.1 micron of residual SA.

Finally, the B&L LI61AO lens is designed to leave the eye with all corneal spherical aberration and is predicted to leave the largest amount of residual SA, approximately 0.27 microns or more.

This prospective, randomized double-masked trial is ongoing and patients are still being enrolled. Patients have been randomized to the three lenses in general population to see which patients if any would have benefits or detriments from these lenses. Patients have not been screened out and the lens was not customized based on preop spherical aberration, refraction, or vision.

Results

The two main measures of the study (in addition to visual acuity) were contrast sensitivity and postop wavefront measurements for spherical aberration.

The data are still being collated, but the trends in the data are the same as those from the pilot study in which we looked at wavefront aberrations – not at contrast sensitivity. In the pilot study, we found that the Tecnis lens was superior in terms of reducing spherical aberration to zero regardless of the preop spherical aberration.

The Acrysof IQ lens ranked second. It corrected less spherical aberration in the eye, but it performed better than the AO B&L lens, which performed similarly to a spherical lens in terms of correcting corneal spherical aberration. We look forward to obtaining and reporting on more thorough data once these other patients are fully enrolled and followed up.

Lens Selection

Considering the three different aspheric monofocal IOL choices, the Tecnis appears to be the best choice for the cataract population.

For patients who have had hyperopic refractive surgery, I would opt for a spherical lens over an aspheric lens. In these cases, hyperopic treatment induces negative spherical aberration and because aspheric lenses also give negative spherical aberration, I would implant a spherical lens.

As clinicians, we have an array of IOL choices, including multifocal, monofocal, and accommodating IOLs. In talking to patients, I present all the choices to them in terms of the presbyopic IOLS, like the multifocal IOLs and the accommodating IOLS. We discuss their visual needs and we try to determine how important it is for them to be out of reading glasses. If they desire spectacle independence, we spend time talking multifocal lens and accommodating lens.

If they say spectacle independence is not a priority, I focus our discussion on monofocal lenses and we discuss the benefits of an aspheric IOL and how it can improve quality of vision.

Refractive Surgery

An aspheric lens can be an excellent stepping stone for surgeons with cataract practices who are looking to expand into refractive IOLs, like the presbyopic correcting IOLs.

By using an aspheric IOL, cataract surgeons can advise their patients and staff that they are using the latest wavefront technology IOL for all of their cataract patients. In my opinion, the Tecnis is the best aspheric IOL for the patient population.

Y. Ralph Chu, MD, is the founder of the Chu Vision Institute in Edina, MN.

Comparing Aspheric IOLs

New data indicates that the Tecnis Outperforms Other Aspheric IOLs
Relationship Between Spherical Aberration and Acuity is Complex

In young patients with excellent vision, spherical aberration is not statistically different from zero and is not correlated with visual performance.

By Pablo Artal, PhD

My colleagues and I at the University of Murcia, in Spain, have been looking at the interactions between the optics of the eye and quality of vision for many years. From a number of experiments performed under tightly controlled conditions, we know two things for certain. The first is that there is a clear correlation between poor optics and poor performance. A highly abberated eye simply cannot provide high quality vision.

The second lesson we've learned more recently in a series of studies by Eloy Villegas, Encarna Alcon, and myself, however, runs counter to the conventional wisdom. In individuals with "normal" optics, we find no correlation between aberrations and visual performance. Even those individuals with excellent vision—better than 20/15—do not have perfect optics.

With this research at our foundation, we have recently begun looking specifically at spherical aberration (SA) to see if we could determine an optimal value for this particular higher-order aberration (HOA).

Spherical aberration is of particular importance, for several reasons. First of all, we know that it changes continuously with age. Young subjects have a low value of SA but it always increases with age. SA is also one of the predominant HOAs in the eye. It is rotationally symmetrical and, therefore, the easiest aberration to correct, from a technical standpoint.

When a conventional intraocular lens is implanted following cataract surgery, it randomly adds to or subtracts from SA, which is already elevated naturally in the older eye. In the last few years, several manufacturers have introduced aspheric intraocular lenses that propose to deliberately cancel or partially compensate for the SA of the aging cornea in order to improve visual performance.

SA in Young Subjects with Excellent Vision

In our most recent study, we evaluated SA in a group of young subjects with exceptional natural visual acuity (VA) of 20/15 to 20/10. Subjects were nearly emmetropic (-1.0 to +1.0 D) with very low astigmatism (< 0.5 D). The average age was 25.3 years. High-contrast VA was measured using a forced choice procedure that is more robust than a standard Snellen eye chart. We measured wavefront aberrations for different pupil diameters using our own research prototype wavefront sensor. Accommodation was strictly controlled so that spherical aberration data could be obtained from the eye in its unaccommodated state.

All of the subjects had good—but not perfect—optics, reinforcing our previous findings that better-than-normal acuity does not require a perfectly flat wavefront.

The average magnitude of SA was small and was not correlated with visual acuity. In other words, the 20/10 eyes did not have less SA than the 20/15 eyes in average. SA was correlated with age. Even in this young group, patients younger than 25 had lower SA than those who were older than 25.

Across the entire group of 46 subjects, the average SA for a 5-mm pupil was slightly positive (0.032 ± 0.047 microns). For a 4-mm pupil the average SA was 0.017 ± 0.024 microns. The average SA for a 5-mm pupil in the subgroup younger than 25 was 0.02 ± 0.052 microns, which is not statistically different from zero.

"The higher the SA target, the greater the chance of inducing or leaving too much SA"

Trying to replicate the slight positive SA we found in our study after implantation of an IOL or laser surgery could be counterproductive. First of all, the SA present in these young eyes was essentially zero. Secondly, lens implants almost never hit a target exactly. A target of zero means that a small margin of error may, in fact, result in a slight positive amount of SA. The higher the SA target, the greater the chance of inducing or leaving too much SA. Several years ago, we proposed that the optimal target for SA in an older eye should be zero, and I believe this study supports that recommendation.

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Wavefront-Guided LVC Produces Superior Visual Quality

Patients presenting with either low or high amounts of pre-op higher order aberrations benefit from a wavefront-guided treatment.

By Captain Steve Schallhorn, MD

The visual quality of wavefront-guided LASIK is predicted to be better than optimized LASIK, according to results from a model we developed to simulate visual performance.

From the model, we determined that wavefront-guided laser vision correction (LVC) would induce fewer aberrations than wavefront-optimized LVC regardless of the preoperative higher order aberrations (HOAs). This includes patients with a low amount of preoperative HOA.

Differences in the Ablation Profiles

The treatment basis of WFG LASIK is the optical path deviation derived from a wavefront aberrometer measurement. The optical path deviation, which can also be visualized as a wavefront pattern, contains both the lower order (sphere and cylinder) and higher order (coma, trefoil, spherical aberration, etc.) aberrations of the entire ocular system. This is then used to create an appropriate ablation profile for the excimer laser. The ablation profile can be extraordinarily complex dependent on the amount of higher order aberrations.

“Optimized” LASIK was designed to reduce the induction of spherical aberration, the most commonly induced higher order aberration after conventional LASIK. It does this with a special aspheric ablation profile tailored to the amount of intended sphere correction. It cannot treat pre-existing higher order aberrations. The treatment basis is the same as conventional LASIK, namely, sphere and cylinder.

The Study

Many investigators have shown that LASIK typically induces higher HOA, most prominently spherical aberration, while wavefront-guided (WFG) LASIK induces less higher order aberrations. Analyzing WFG LASIK in greater detail shows that patients who have small amounts of preoperative higher order aberrations tend to have an increase, whereas patients who have a larger amount (above 0.3 microns) tend to have a reduction.

Our model simulates visual performance of optimized and wavefront-guided LASIK, and assumed a perfect correction of sphere and cylinder. Patterned after the dataset of conventional and WFG LASIK, the induction or reduction of higher order aberrations was modeled to the preoperative level of higher order aberrations and the type of surgery.

We assumed the best case scenario that optimized surgery induced no spherical aberration, but that the induction or reduction of other higher order aberrations would be the same as conventional.

For the simulation, we used a wavefront dataset (all 6-mm entrance pupil analysis) from patients before and one month after conventional and wavefront-guided LASIK in a large sample size at our center. We generated 10,000 random preoperative wavefront maps, model ‘eyes’, to simulate a normal population.

There is considerable population variability in the preop to postop change of higher order Zernike terms after any type of surgery. To model this variation, the simulated postoperative higher order aberrations were randomly assigned to be within one standard deviation of the mean change, dependent on the type of surgery (optimize and WFG) and the level of preoperative higher order aberrations.

The basic outcome of the model showed that in every case optimized LVC induced more higher order aberrations than wavefront-guided LVC. (Figure 1)

Visual Outcomes

Based on these simulations, wavefront optimized LVC would have a greater chance of inducing higher order aberrations compared to a wavefront-guided procedure.

Most important, this applies even to patients with low preoperative higher order aberrations. In fact, the clinical benefit of WFG LASIK may be most apparent in this group of patients. These patients did not have many higher order aberrations before surgery. They may not adapt as well to an increase in HOA after surgery as patients who had a higher amount before surgery.

Patients with a high amount of preoperative higher order aberrations also benefit from WFG LASIK. The aberrometer is able to measure and the laser is able to treat the aberrations.

Captain Steve Schallhorn, MD, is the director of refractive surgery at the Naval Medical Center, San Diego.
Wavefront-Guided Surgery Yields Better Contrast Sensitivity, Aberration Profile

Both wavefront-guided and wavefront-optimized LASIK produce good results, but there is a difference in the quality of vision, especially at higher acuities.

By Mounir A. Khalifa, MD

I recently conducted a prospective study comparing wavefront-guided customized ablation to wavefront-optimized ablations.

The study participants were 24 consecutive refractive surgery patients with myopia or myopic astigmatism. They were randomized to either Group A (wavefront-guided) or Group B (wavefront-optimized), with 12 patients (24 eyes) in each group.

All of the patients had LASIK. All patients were evaluated pre- and post-operatively using the Visx WaveScan wavefront aberrometer and CSV-1000 contrast sensitivity testing. Patients whose post-operative WaveScan pupil diameter differed from the pre-operative pupil diameter were excluded to avoid any variations in higher-order aberrations (HOAs) due to pupil size.

Group A was treated with custom wavefront-guided ablations using the Visx Advanced CustomVue platform (Advanced Medical Optics) with Fourier analysis and iris registration. Group B was treated with wavefront-optimized standard ablation using the WaveLight Allegretto laser. This laser performs a conventional ablation but it incorporates software that is supposed to compensate for and neutralize induced spherical aberration.

Visual acuity, HOAs, and contrast sensitivity were evaluated at three months. Paired t-tests with equal variance were used in the data analysis.

Study Results

Wavefront-guided surgery was significantly more predictable, with 87.5% of patients achieving results that were within 0.5 D of intended, compared to 63.0% of the wavefront-optimized group. The percentage of both groups achieving results within 1.0 D of intended was about the same.

Significantly more of the wavefront-guided eyes achieved 20/16 or better vision. In my opinion, this is due to three factors. The first is the precise axial and torsional registration of iris registration. Second, there is some reduction in human error in the wavefront-guided results, because lower-order aberrations are corrected as measured by the WaveScan rather than manifest refraction as measured and entered by the physician or staff. Third, there is a significant difference in the postoperative HOAs.

When we compared pre- and post-op HOA, the wavefront-guided group had no significant change in mean total HOA or in any individual aberration other than spherical aberration. In the wavefront-optimized group, there was significant induction of coma, trefoil, spherical aberration, secondary astigmatism and total HOA. In addition, post-operative HOAs were significantly higher in wavefront-optimized eyes than in wavefront-guided eyes, in total and for every aberration except quadrafoil.

Spherical Aberration

The spherical aberration (SA) results are most interesting. At least in this small study, wavefront-optimized corrections did not neutralize SA, as this laser is purported to do. In fact, the induction of SA in Group B, the optimized group, was significantly higher than in the wavefront-guided group, even though the two were statistically equivalent pre-operatively.

Contrast Sensitivity

We also measured pre- and post-operative scotopic contrast sensitivity using the CSV-1000 test. Again, the two groups were similar pre-operatively. Post-operatively, the wavefront-guided group had significantly better contrast sensitivity at all cycles per degree than the wavefront-optimized group.

In addition, when we compare eyes from both groups with “super acuity” (20/16 or better) on a Snellen chart under photopic conditions, we see a distinct difference in the quality of vision these eyes achieve under scotopic conditions. This is most likely because the influence of HOAs is greater as the pupil dilates. Therefore, in the wavefront-optimized eyes, which had higher levels of post-operative HOAs, there was lower contrast sensitivity.

It makes sense that we see the greatest differences between these two groups at higher levels of visual acuity and in visual quality measures. After all, most excimer lasers perform quite gross corrections quite well. The advantages of wavefront-guided technology are really in the fine correction of the eye’s optics.

In conclusion, wavefront-guided LASIK was more predictable and more effective in achieving the highest levels of visual acuity with the lowest levels of wavefront error. Wavefront-optimized treatments were not able to correct or neutralize spherical aberration as purported and in fact induced significantly more SA than wavefront-guided treatment, resulting in better quality of vision in the wavefront-guided group.

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Registration Plays a Vital Role in Treating Complex Cases
In post-surgical and highly aberrated eyes, even small shifts in the pupil centroid can have profound visual consequences.

Refractive surgeons have increasingly realized the importance of accurate registration of wavefront treatments to the cornea. Iris registration, used by the Visx CustomVue system (AMO), relies on matching iris features in images taken at the time of measurement and treatment. The system then compensates for any cyclotorsion or pupil centroid shift that may have occurred between the initial wavefront capture and the time of ablation.

Previously, Douglas D. Koch, MD, and Li Wang, MD, of Baylor College of Medicine, used theoretical modeling to calculate the typical amount of wavefront aberration induced in normal eyes without iris registration. They looked at what happened to total, lower-order, and higher-order RMS error with average mis-registrations—that is, a 2.1-degree counter-clockwise rotation or a horizontal pupil centroid shift of 0.27 mm. They found that decentration of the treatment has a much greater influence on residual higher-order aberration than rotational shifts. The most commonly induced aberration from X-Y mis-registration was coma.

Julian Stevens, FRCS, was curious to see what the effects of mis-registration would be in the more highly aberrated therapeutic cases that he often treats. "By definition, the effects of such mis-registration, both rotational and X-Y, potentially can be much greater than in normal eyes," he said.

At this year’s ASCRS meeting in San Francisco, Stevens presented the challenging case of an airline pilot whose vision had deteriorated to such an extent that he could no longer fly. The patient had bilateral corneal grafts due to Fuchs’ corneal degeneration. His refraction was -5.17 -3.27 x 148 OD and -3.57 -4.38 x 168 OS. In addition to the very high cylinder, he had huge (> 8.0 mm) pupils that exceeded the diameter of the corneal grafts. There were also some lenticular changes.

Stevens planned a two-stage therapeutic treatment, beginning with phacoemulsification and lens surgery. He made a small, 5.0-mm capsulorrhesis to act as a pupil stop, which avoided the poor optics of the peripheral graft, and targeted a hyperopic result. The second step in the treatment would be wavefront-guided LASIK with Fourier reconstruction and iris registration. "The reason I target hyperopia in these eyes is so that the subsequent laser ablation will be performed around the periphery," he said. "With all of the pulses in that peripheral region you will get a more effective ablation."

The treatment was carefully registered and the end result, following bilateral IOL implantation and wavefront-guided LASIK, was uncorrected visual acuity of 20/15 OD and 20/20 OS. The pilot, who was able to fly again, was delighted.

Stevens used this patient’s preoperative point spread function (PSF) to demonstrate the effects of shifting the treatment slightly along the X-Y axis, as could happen in a treatment that did not compensate for pupil centroid shift.

In his simulation, minor changes in the X or Y coordinate of 0.25 to 0.50 mm resulted in dramatic shifts in the PSF as well as the wavefront map. There was also an effect on lower-order sphere and cylinder.

"If you have an offset error of 0.25 mm in the X meridian, the resultant sphere will have +0.25 to -0.25 D of cylinder. A 0.5-mm offset in an oblique meridian results in induced cylinder of a full diopter at 67 degrees," Stevens explained. "In complex eyes, even a small amount of X-Y mis-registration is a potent source of postop aberrations, with very profound optical effects," he said.

Using the same X and Y axis shifts, Stevens also demonstrated what happens to the convolved theoretical E when there is a vertical, horizontal, or oblique shift (Fig. 1-2). As the amount of pupil centroid shift increases, although still within the normal range, the letter E deteriorates significantly, especially when the decentration is oblique. "Oblique movements are the most visually significant because our optics are very much biased towards vertical and horizontal lines," he explained.

His demonstration showed clearly that decentration of wavefront-guided LASIK treatments in highly aberrated eyes not only affects coma, but also changes the sphere, cylinder, and spherical aberration correction.

"A mis-registered ablation causes a very rapid decrease in the quality of vision, and very significant coma functions, occurring close to the optic axis. We can now map the cornea very accurately using Fourier high resolution reconstruction, so we are beholden to try and use iris registration as often as possible before applying that map to the cornea," he said.

Stevens noted that there are still complex biomechanical effects and issues of measurement, healing, and epithelial remodeling in therapeutic treatments. "But we have had vastly improved outcomes and quality of vision using iris registration in therapeutic cases," he said.

As the amount of pupil centroid shift increases horizontally, the letter E deteriorates significantly.
A study that evaluated the residual wavefront aberrations induced by the cyclotorsional rotation and pupil centroid shift demonstrated that, for normal eyes with astigmatism less than 2D, the pupil centroid shift feature provides greater visual benefit than cyclotorsional rotation. However, for eyes with astigmatism greater than 2D, cyclotorsional rotation registration provides comparable or greater visual benefit, according to Douglas D. Koch, MD, a professor and the Allen, Mosbacher, and Law Chair in Ophthalmology, Cullen Eye Institute, Baylor College of Medicine, in Houston, TX.

Registration
Iris registration permits verification of patient identification and intraoperative registration. Most excimer lasers track horizontal and vertical movements of the pupil. The unique advantages of the new VISX IR system are cyclotorsional registration and pupil centroid shift adjustment. Cyclotorsional registration is essential to optimize outcomes, he said, noting that the literature supports that cyclotorsional movement is 2°-5° on average, but can be significantly higher in some cases.

Cyclotorsional registration allows for the alignment of the treatment to the original wavefront that has been measured on the patient. “The patient’s pupil size at the time the WaveScan is acquired is often different from its size under the laser in the operating room. Pupil centroid shift results when these changes in pupil size move the center of the pupil between wavefront acquisition and treatment. This new laser feature negates this problem by orienting the treatment to the outer iris boundary, adjacent to the limbus. Therefore, even if a pupil centroid shift occurs, the laser places the treatment in the same spot as was measured preoperatively. The obvious benefit is the potential to avoid ostensibly small but visually critical decentrations,” he explained.

The Study
“We wanted to investigate the effect on residual wavefront aberrations if you had that amount of cyclotorsional registration error or that amount of error in the pupil centroid shift, or as if the VISX IR system was not used,” he explained.

Corneas from 50 eyes of 50 subjects were used to evaluate the effect of rotation and decentration. They then evaluated the impact of the average cyclotorsional rotation of 2.1° and the horizontal decentration of 0.27 mm of the pupil. The investigators used the VOL-CT program (Sarver and Associates) that enabled them to take a corneal map, import it, create the wavefront from it and then manipulate it.

To evaluate the residual aberrations, they used the root-mean-square (RMS) of total and higher order aberrations and the Strehl ratio. The Strehl ratio is the ratio of the peak focal intensities in the aberrated point spread function, relative to ideal or diffraction-limited point spread function.

For a perfect treatment, the RMS value will equal zero and the Strehl ratio will equal 1. “For an imperfect treatment (rotated or decentered), the RMS value is greater than zero, while the Strehl ration is less than one,” Dr. Koch said.

Results
“Our results indicated that the biggest benefit was in the centroid shift,” he noted.

With the average values for cyclotorsional rotation and pupil centroid shift of the study eyes, by both metrics poorer visual performance was seen for centroid shift than for cyclotorsional error: the total and higher-order RMS values were higher and the Strehl ratios were lower.

Visual performance as measured by both metrics decreased with increasing amounts of topographic astigmatism. “Although the RMS values increased with increasing amounts of astigmatism, pupil centroid shift errors consistently resulted in higher RMS values than did cyclorotational errors, regardless of the magnitude of pre-existing astigmatism,” he said.

However, in eyes with astigmatism of >2 D, the Strehl ratio was comparable to that seen with decentration. “Therefore, using the Strehl ratio metric, cyclotorsional error becomes as important as pupil centroid shift when astigmatism is around 2 diopters or more,” he said.

“These different results with RMS values and Strehl ratios is not surprising. That’s why you have more than one metric for visual quality. We are still learning which of these is more important is assessing visual function,” he said.
Wavefront LASIK Helps Multifocal Pseudophakes Achieve Spectacle Independence

In most patients, wavefront-guided LASIK can be used effectively to fine tune refractive results.

At our clinic, we now offer a bioptics package that includes lens replacement surgery and wavefront-guided LASIK, if needed, to fine tune the results.

For cataract or lens replacement patients there are two options. The first is a standard monofocal lens, although in our practice this has been almost entirely replaced by the aspheric Tecnis monofocal IOL.

The second option is to replace the crystalline lens with a multifocal IOL to correct presbyopia and provide good near and distance vision without any glasses. Currently, I implant the Tecnis Multifocal, ReZoom and ReStor multifocal lenses.

Implanting a multifocal IOL is essentially a promise of spectacle independence to my patients. Emmetropia must be achieved. However, we all know that there is no way to guarantee an emmetropic outcome, even with very careful lens calculations. This is why we elect to perform LASIK in those patients in whom emmetropia is not achieved, about 15% of the cases. Patients with even a little bit of residual refractive error postop will not be happy with their vision.

Wavefront Correction in Pseudophakes

In our practice, we perform customized laser surgery on our laser refractive surgery patients, using the Visx Star S4 laser with iris registration.

A wavefront-driven ablation is desirable in pseudophakes for the same reasons we do it in non-lensectomy patients. It allows us to correct not only the sphere and cylinder, but also any higher-order aberrations (HOAs). It is even more important in pseudophakes because minor decentration of the IOL with respect to the visual axis may induce HOAs, specifically coma.

Initially I expected to encounter problems performing custom LASIK following a multifocal implant, especially with capturing a wavefront image. In our experience, about 70% of eyes with multifocal implants can be easily captured by the WaveScan aberrometer, compared to nearly 100% of “normal” eyes or even eyes with monofocal implants.

Even with a successful capture, I recommend performing a wavefront-guided ablation only when the manifest refraction and WaveScan refraction match closely. Assuming that one encounters neither of these problems, there does not seem to be any problem with the interaction of the multifocal implant and the treatment pattern designed by the laser. I now have many patients with multifocal IOL implants and subsequent wavefront-guided LASIK for fine-tuning. We have seen tremendous improvement in vision and full spectacle independence with this approach.

Case Study

One recent case is illustrative of our bioptics patients. Preoperatively, this 56-year-old male’s refraction in the left eye was +5.50 sphere. After cataract extraction, I implanted a Tecnis Multifocal IOL. Postoperatively, there was 1.50 D of residual hyperopia and, as expected, his uncorrected visual acuity was only 20/40.

We then performed wavefront-guided LASIK with the Visx CustomVue system. Following LASIK, his refraction was +0.50 -0.25 x 10, with uncorrected acuity exactly as we wanted at 20/20 and N1 (even better than J1).

When we look at this patient’s wavefront data, it is clear that not only did we correct the residual sphere, but also significantly reduced coma, one of the higher-order aberrations. One can also see significant improvement in the point-spread function (PSF) from preop to postop (Fig 1). The PSF for both all aberrations and for only higher-order aberrations improved.

I recommend wavefront-guided LASIK with iris registration whenever possible, provided there is a good match between the wavefront and manifest refractions. If there is even the slightest capsular opacification present, a Nd:YAG capsulotomy should be performed prior to LASIK.

If one follows these general guidelines, multifocal and aspheric IOLs can be successfully combined with wavefront-driven ablations to achieve excellent visual results that satisfy the very high expectations of modern cataract patients.

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By David R. Hardten, MD

Multifocal IOLs have transformed cataract surgery into a consumer-driven market. Patient expectations of surgery with these premium lenses are very high. If the postoperative outcome isn’t exactly on target or if the patient finds that near vision is not what he or she had hoped, some form of enhancement may be necessary.

Of course, prevention is the best tactic. Good biometry, precise calibration of the keratometer, and using the latest-generation IOL power calculation formulas are all important factors in achieving refractive accuracy and success with premium lens implants. That said, there will always be some unexpected outcomes or cases where the target refraction needs to be adjusted postoperatively based on patient feedback.

For residual myopia or hyperopia, I prefer laser vision correction as the most accurate way of enhancing the outcome for most patients. Piggyback IOLs should probably make up less than 5% of total enhancements. I rely on them primarily in cases of high spherical error without much residual cylinder. IOL exchange should be done even more rarely.

Correcting Cylinder
At this point, we can’t correct astigmatism with multifocal IOLs. I will generally recommend trying to correct the cylinder at the time of surgery with limbal relaxing incisions (LRIs) or astigmatic keratotomy (AK), with the caveat that we may need to do a laser vision procedure afterwards. Although incisional techniques do not offer the same degree of predictability and accuracy as laser vision correction, doing them in the OR at the time of surgery is convenient and saves the patient from having a second surgical procedure.

If there is some cylinder remaining after lens implantation and a postoperative enhancement is necessary, I always prefer to use the laser. Ideally, I will do an Advanced CustomVue procedure with iris registration to most accurately treat the cylinder, but if the capsulorhexis is too small to get a 5.0-mm capture, or if the wavefront doesn’t match the refraction or is not compatible with the uncorrected vision, then I plan for a standard treatment. I prefer LASIK in most patients because of the quicker recovery, but if there are any corneal health issues, or if I made any LRI or AK incisions during the initial surgery, I opt for PRK.

Timing the Second Intervention
In a bilateral case I typically wait to enhance until I have implanted IOLs in both eyes, so that we know the balance of the optics. If one eye is myopic and the other close to emmetropia, for example, the patient may be happy without any further correction.

After that, I generally follow the same principles I do for laser vision correction. If there is a large residual error that I know is not going to resolve itself I will do an early enhancement. So in the case of an unusual 2.0-D surprise, I may wait just a month or so for the vision to stabilize, and then perform a second intervention so the patient doesn’t have to suffer for a long period of time. In some of these cases, I may opt for a lens exchange or piggyback IOL.

In most cases, however, the refractive result is within 1.0 D of the intended correction, and I generally wait 6 months before enhancing. The refraction may change again or the patient may be able to adapt to the mild residual error. If there is any capsular fibrosis or haze I perform a Nd:YAG capsulotomy at around 4-5 months postop, prior to laser vision correction.

Custom or Conventional?
Whenever possible, I prefer to perform a wavefront-guided enhancement after multifocal IOL implantation. Customized corrections offer better astigmatic targeting, especially with iris registration, and the ability to address corneal higher order aberrations.

However, it is important to make sure that the manifest and the wavefront refractions match. If there is any doubt, I perform a conventional ablation, making sure to push the plus and do a careful refraction.

In summary, surgeons who implant multifocal and other premium IOLs are going to need to enhance the refractive outcome, at least occasionally. In my opinion, laser vision correction provides the most accurate method for addressing residual sphere and cylinder, but one should also be familiar with IOL exchange or piggyback IOL implantation for cases in which the refractive error is large or corneal surgery is contraindicated.

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### Average Pre-op Astigmatism

Approximately 1/3 of patients have more than 1.0 D of pre-op astigmatism that could negatively impact quality of vision post-lens implantation.