The Fundamentals of Customized Ablation

Customized treatments are especially useful when aberrations are high and symptomatic.

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When refractive surgeons began to understand ocular aberrations, and laser platforms that could perform complex treatments became available, the ability to perform customized treatments that would target ocular aberrations became an exciting possibility. First, with the treatment of postoperative aberrations, we hoped that the visual symptoms that were a nightmare for patients and surgeons alike would soon become a thing of the past. Second—and potentially more exciting—we wondered if these protocols could even improve the quality of vision of an eye that was receiving treatment for the first time.

Over the past few years, results have shown that customized treatments are not the panacea we had hoped they would be, but they have been useful in specific conditions, especially when aberrations are high and symptomatic. Additionally, the ability to take into account induced aberrations in refractive surgery has led to a general improvement of laser profiles, even for noncustomized treatments.

WAVEFRONT ANALYSIS

The purpose of wavefront analysis is to measure the deviation of the wavefront of a real eye from the plane of reference of an ideal, nonaberrated eye, with the aim of obtaining information regarding the optical qualities of that eye. This deviation can be described mathematically in different ways. The most commonly used (and most user-friendly) method is the use of the Zernike polynomials, represented in a pyramid.

In the radial order 0, we find the piston term (constant phase shift), which does not induce image distortion. The aberrations with radial order 1 correspond to tilt (prismatic error), which does not alter the shape of the wavefront either, but deviates it from its original position. Piston and tilt do not need to be treated by wavefront-guided ablations.

In the second radial order, we find defocus and astigmatism (ie, spherocylindrical ametropia); these are considered lower-order aberrations.

The Zernike terms in the third radial order and higher are considered higher-order aberrations (HOAs). In the third
radial order are coma and trefoil, and these are usually increased after corneal refractive surgery. A high degree of coma aberration can be seen after a decentered treatment or as a result of corneal scarring, and this causes symptoms of ghosting and monocular diplopia (Figures 1 and 2).

The fourth radial order includes, among others, spherical aberration. A normal cornea has positive spherical aberration. Myopic laser refractive surgery induces positive spherical aberration, whereas hyperopic correction induces a negative change in spherical aberration. A high degree of spherical aberration causes significant night vision symptoms. Spherical aberration is usually high and symptomatic after treatments with small optical zones and after corneal grafts (Figure 3).

Aberrations of the fifth radial order are usually low in normal eyes, but they may become symptomatic in corneas with irregularity caused by corneal scarring or corneal surgery.

Each Zernike term for a given eye has a value of its root mean square coefficient, but the magnitude of the root mean square does not directly reflect the effect of that particular term on the quality of vision of the eye. Ocular aberrations work in a slightly more complicated way. Some aberrations combined with others can lead to better image quality; some corneal aberrations are compensated by internal aberrations (eg, the positive spherical aberration of the cornea is compensated by the measuring the global aberrations of the eye. The most common are Hartmann-Shack devices, which base their analyses on the wavefront of a foveally reflected light coming out of the eye. This method analyzes the aberrations of the eye as a whole, including not only the aberrations of the cornea but also internal ones.

Another possibility for studying ocular aberrations is to focus only on those created by the cornea. In a normal eye, 90% of the total aberrations are caused by the corneal optics, and this percentage increases when the cornea shows some degree of irregularity. To measure only corneal aberrations, a high-resolution topography image is obtained, and the aberrations are derived by a mathematical transformation from that topographic image.

The disadvantages of whole-eye aberrometry include its dependence on accommodation and pupil diameter and, primarily, its limited ability to reliably measure highly distorted wavefronts. Corneal aberrometry is not affected by pupil dilation or accommodation and can obtain measurements from irregular corneas.

The information obtained from wavefront devices is used to plan an ablation profile that is transferred to the excimer laser platform. Flying-spot technology with a small laser spot allows a smoother and more precise ablation profile with better correction of HOAs than earlier laser delivery methods. However, the smaller the laser spot, the more sensitive it is to eye movements.
To obtain good results, the centration of the laser ablation must be extremely precise. The laser platform needs a perfect tracker to maintain the centration of the ablation and to avoid the influence of cyclotorsion that may occur in the supine position.

**LASER PROFILES**

There are two types of aberration-based profiles in laser refractive surgery: (1) optimized ablations based on corneal asphericity and (2) customized ablations based on wavefront analysis.

**Optimized ablations.**

These are designed to obtain better postoperative asphericity of the cornea to prevent the induction of aberrations in a nonindividualized manner. They do not aim to treat preoperative aberrations. Optimized profiles still induce HOAs, but they tend to induce less spherical aberration than conventional treatments and achieve better contrast sensitivity.

**Customized ablations.**

By contrast, wavefront-guided treatments aim to correct not only existing lower-order aberrations (ie, defocus and astigmatism) but also HOAs, based either on global (ie, whole-eye) aberrometry or on corneal aberrometry alone, with the aim of improving quality of vision postoperatively.

Does global wavefront-guided LASIK really achieve better results than conventional LASIK? It has been shown that global wavefront-guided refractive surgery does not eliminate preoperative HOAs, but it seems to reduce the induction of HOAs when compared with conventional treatments. This may, however, be dependent on the individual laser platform. In different studies performed in normal, healthy eyes, global wavefront-guided treatments achieved either similar or better refractive accuracy and UCVA compared with conventional treatments, and they resulted...
What about global wavefront-guided compared with optimized treatments with lasers that have both capabilities? Again, it seems that global wavefront-guided treatment offers only some advantage, in the sense of a better postoperative aberration profile than optimized treatments in eyes with high HOAs preoperatively, and achieves similar visual and refractive results.\textsuperscript{6,11-12}

Global wavefront-guided treatments do not offer any advantage, however, not even in the aberration profile, if preoperative HOAs are low, which is the most common situation (around 80% of normal patients requiring refractive surgery). Most of the studies cited here have been done with the WaveLight Allegretto system (Alcon).

Why is it that a treatment that should theoretically improve visual quality by decreasing the irregularities of the eye does not seem to achieve this? On one hand, this is a result of the biomechanical changes and corneal wound healing that follow flap creation and laser ablation, which modify the planned surgical outcome. On the other, it is due to limitations in measuring aberrations, especially with global aberrometers.

There are two interesting studies on this subject, one of which\textsuperscript{13} shows the limitations of a Hartmann-Shack aberrometer (Zywave; Bausch + Lomb). The measurements of third- and fourth-order terms obtained in improved contrast sensitivity and fewer visual symptoms, such as glare or halos at night.\textsuperscript{8-10} In virgin corneas with normal preoperative HOAs, these treatments do not seem to offer any benefit (except over some laser platforms with older conventional profiles); however, they are recommended over conventional treatments if a particular patient’s preoperative HOAs are high (more than 0.35 μm).

**TAKE-HOME MESSAGE**

- Customized treatments are not the panacea surgeons had hoped they would be, but they have been shown to be useful in specific conditions, especially when aberrations are high and symptomatic.
- Consideration of induced aberrations in refractive surgery has led to a general improvement of laser profiles, even for noncustomized treatments.
- There are several guidelines regarding when to use each type of customized treatment, and these are applicable to each surgeon’s practice depending on the options offered by his or her laser platform.
this study were repeatable between sessions, but they were not so reproducible between visits. Fourth-order terms, except for spherical aberration, and fifth-order terms were not measured with sufficient reliability for clinical decision-making or treatment, the study authors found. It is important for surgeons to know the repeatability of their wavefront aberrometers and to treat only those cases in which the measurements are higher than the repeatability of the device; otherwise, the surgeon could just be treating noise. A second study focused on which refraction to use to plan the laser treatment: the manifest refraction or the aberrometric refraction as measured by the global aberrometer. This study showed that the predicted refractive results were better when manifest refraction was used.

Other customized profiles are based only on corneal data. These treatments aim to correct corneal HOAs, not the aberrations of the whole eye. Topography-guided or wavefront-guided treatments have repeatedly shown good results in multiple studies, unlike the less-reliable results obtained with global wavefront-guided profiles. Treatments based on corneal aberrations have been shown to decrease HOAs and symptoms, and to improve visual and refractive results in several settings, including the correction of decentrations, small optical zones, and symptomatic HOAs due to corneal surgery (Figure 4) or corneal disease. Even in uneventful previous laser surgery that induced postoperative HOAs, these treatments have been shown to improve the aberration profile after retreatment. However, in eyes that are highly aberrated, even when these laser treatments can improve the aberration profile and associated symptoms, they cannot eliminate them completely, and patients must therefore have realistic expectations for surgery. Corneal-guided treatment can also be used simultaneously with corneal collagen crosslinking in selected cases of corneal ectasia, and in this setting it has been shown to improve vision and refraction.

**SUMMARY**

There are several guidelines regarding when to use each type of customized treatment, and these are applicable to each surgeon’s practice depending on the options offered by his or her laser platform. In primary cases and in enhancements after uneventful primary laser, with preoperative HOAs lower than 0.3 μm, optimized profiles should be used. Only in patients whose preoperative HOAs are high (greater than 0.3 μm) does a wavefront-guided treatment seem to offer a slight advantage. In these cases, if a retreatment is planned in a patient whose HOAs are due to previous corneal ablation, a corneal wavefront-guided treatment would likely be a more logical approach. However, the clearest indication for corneal wavefront-guided ablations is in highly aberrated corneas, in which these types of profiles can offer some improvement.

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