

## CATARACT SURGERY

# Multifocal IOLs for Post-LASIK Patients: Establishing Clinical Guidelines for Patient Selection

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**In which post-LASIK patients can we implant multifocal IOLs? New clinical criteria may help select the appropriate candidates.**

Aging baby boomers are beginning to have a major impact on the presbyopia-correcting intraocular lens (PC-IOL) market, just as they did on the LASIK market 10 to 15 years ago. Back then, dissatisfaction with glasses and contact lenses caused them to pursue laser vision correction. Having now reached their 60s, their dissatisfaction with glasses is undiminished.

Monofocal IOLs that leave baby boomers completely dependent on reading glasses or accommodating IOLs that leave them partially dependent are unsatisfactory. Instead, these patients are seeking out multifocal IOLs that can give them nearly complete spectacle independence. Since a significant portion of the 8 million Americans who have had LASIK are baby boomers, who are now entering the cataract surgery market at an ever increasing rate (roughly 10,000 boomers turn 65 every day), the number of multifocal IOLs implanted should increase dramatically from its present low level in the upcoming years. But this will happen only if we learn how to deselect those post-LASIK patients who will not do well with multifocal IOLs.

### Traditional Trepidation

Implanting multifocal IOLs in post-LASIK eyes has traditionally been regarded as problematic. Irregular corneas and ocular surface disease are more prevalent in post-LASIK eyes, and these conditions can interfere with the optical performance of multifocal IOLs.

However, the vast majority of LASIK patients are, in fact, pleased with their post-LASIK vision, and this absence of visual complaint signals that their corneas must be reasonably regular. Denying a large group of patients the opportunity to enjoy good, uncorrected reading vision through the use of multifocal IOLs just because a small minority of them

may have problems is neither fair nor rational. Nevertheless, the prevailing view that multifocal IOLs are problematic in post-LASIK eyes, combined with an absence of clinical guidelines for patient selection, have made clinicians cautious—perhaps overly so—about implanting multifocal IOLs in post-LASIK eyes.

### A New Analytical Model

We describe here a semiquantitative analytical model to help establish clinical guidelines for identifying the appropriate post-LASIK patients for multifocal IOLs. The model is based on two related concepts: *spatial precision* (SP) of the cornea and *spatial tolerance* (ST) of the selected IOL.

SP measures corneal irregularity in terms of the physical dimensions of the specific surface irregularity. A normal cornea is highly regular—with only micron-level irregularities—and thus has a small SP value. In contrast, keratoconic corneas typically have large irregularities and, thus, large SP values.

The complementary parameter, ST, is a measure of the size of corneal irregularity that an IOL can “tolerate” (ie, the degree of corneal irregularity the IOL can be matched with before the IOLs optical performance is degraded). Since all IOLs of a given design are identical with respect to the size of their surface irregularities, the ST value is fixed for each IOL and is a function of the IOL design.

For example, a monofocal IOL has a uniform surface, and can thus provide acceptable vision even in the presence of an irregular cornea. Therefore, monofocal IOLs can be said to be “tolerant” of large amounts of corneal

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irregularity and thus have high ST values. In contrast, multifocal IOLs have small optical steps on their surfaces. They function poorly when paired with corneas that are even mildly irregular. Hence, multifocal IOLs are said to have low ST values.

### Corneal SP

Corneal SP values can vary significantly from one patient to another, depending on the actual size of corneal irregularity in each case. Theoretically, in order for a cornea to refract visible light (which has a wavelength,  $\lambda$ , of 0.4 to 0.7 microns), the higher order aberration (HOA) of the cornea—defined as wavefront-arrival delay—should be less than half of  $\lambda$ , namely, 0.2 to 0.4 microns. In real life, the SP value of a cornea is typically larger, and is determined in each case based on the size of corneal irregularity seen on corneal topography.

### IOL ST

A monofocal IOL is uniform—the refractive power changes very little across the 3-mm radius of the lens. Hence, a monofocal IOL has a large ST value (half of the radius, or 1.5 mm).

In contrast, the surface of a multifocal IOL is non-uniform and is broken into multiple small zones. For example, an AcrySof® IQ ReSTOR® multifocal IOL (Alcon) has a 6-mm optic, which comprises a central refractive button that is 0.82 mm in diameter and a diffractive zone with multiple steps from 0.82 to 3.6 mm. The diffractive zone is surrounded by an outer refractive zone that goes from 3.6 mm to the edge of the optic at 6.0 mm. Within the diffractive zone, there are 9 rings, or 18 zones. The zone size, or “step,” of the diffractive zone of a ReSTOR lens, can be calculated as:  $(3.6 - 0.82) / (2 \times 18) = 75$  microns. This can be considered as the ST value of ReSTOR lenses (ie, the size of corneal irregularity that the lens can tolerate without suffering significant degradation of its optical function).

We can apply the same method of calculation to the Tecnis® Multifocal IOL (Abbott Medical Optics). The optic of a Tecnis is also 6.0 mm and the central button is 1.0 mm in diameter; the diffractive zones go from 1.0 mm to 6.0 mm. There are 29 rings, or 58 zones. Hence the ST value of a Tecnis lens is  $(6.0 - 1.0) / (2 \times 58) = 45$  microns.

### Accommodating IOL

Crystalens® (Bausch + Lomb) is an accommodating IOL with a small (5-mm) optic that achieves accommodation via a presumed Z-axis movement of the lens. If we assume an effective refractive change of 1 D (which corresponds to 330 microns of movement on the Z-axis), we can then transform this Z-axis movement to the X-Y plane by noting that the anterior chamber depth is 3 mm and the corneal radius is 6 mm. Hence, the corresponding change in the X-Y plane is  $(6/3) \times 330 = 660$  microns, which gives us a nominal value for the ST of a Crystalens.

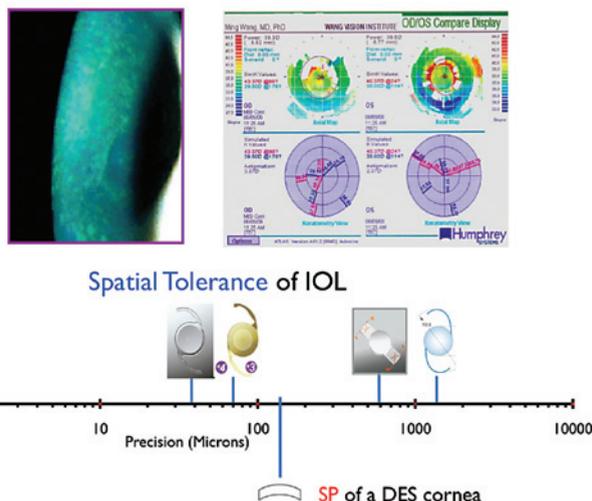
### SP/ST Analysis

In the SP/ST model, one compares a patient’s corneal SP value with that of ST of the desired IOL and determines whether such a cornea-IOL match is appropriate. If the corneal SP is smaller than the ST of the IOL (ie, the cornea is more optically regular than the IOL), then the IOL in question can be implanted and expected to function properly. On the other hand, if the corneal SP value is greater than the IOL’s ST, then the cornea is optically more irregular than the IOL and a cornea-IOL match is inappropriate.

In the following sections, we will use the SP/ST analysis to examine a series of clinical cases that demonstrate the utility of this model in helping to: a) identify key causes for visual problems in eyes implanted with presbyopia-correcting IOLs, and b) formulate clinical guidelines for selecting appropriate post-LASIK patients for multifocal IOLs.

### Clinical Cases

**Case 1:** A post-LASIK patient with dry eyes complained of blurry vision with a multifocal IOL. In this case, the size of the corneal irregularity (the SP value of the cornea), is equal to the size of the topographic defect caused by dry eye (Figure 1). As can be seen on topography, the defect is on the order of 150 microns, which is greater than the ST value of either the ReSTOR or the Tecnis multifocal IOL (75 and 45 microns, respectively). Hence, the model predicts that multifocal IOLs will work poorly in this eye. The model further suggests that a multifocal IOL *could* work if the patient’s dry eye were treated to such an extent that the corneal SP is reduced to below the ST of the multifocal IOL.

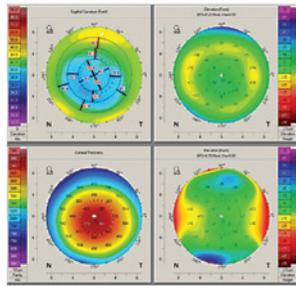


**FIGURE 1** Case 1: Dry eyes and multifocal IOL.

**Case 2:** This patient had undergone an 8.00-D myopic LASIK correction and complained of blurry vision following cataract surgery with Crystalens implantation. Figure 2 reveals that the LASIK treatment was in fact *decentered* from the visual axis by about 1 mm. We can take that offset as the SP value of the cornea. Since the corneal SP is thus

greater than the ST value of the Crystalens (0.66 mm), the model predicts Crystalens failure in this eye. According to the model, a monofocal IOL (ST = 1.5 mm) should perform satisfactorily.

between the apex of the hyperopic treatment and the visual axis (Figure 4). We can take this as the SP value of the cornea, and since it is larger than the ST of either multifocal IOL, the model would predict poor vision with a multifocal IOL. However, since at 0.5 mm the corneal SP value is still smaller than the STs of either a Crystalens (0.66 mm) or a monofocal IOL (1.5 mm), either of those two IOLs should work.



Spatial Tolerance of IOL

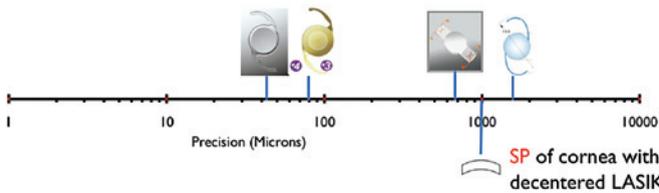
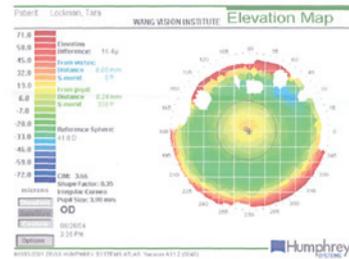


FIGURE 2 Case 2: Decentered LASIK and Crystalens.



Spatial Tolerance of IOL

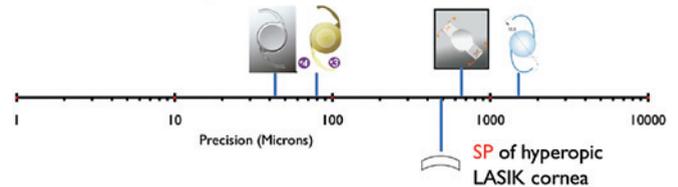
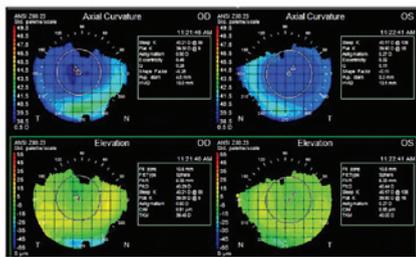


FIGURE 4 Case 4: Hyperopic LASIK and multifocal IOL.



Spatial Tolerance of IOL

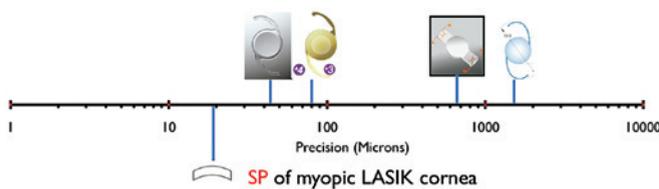
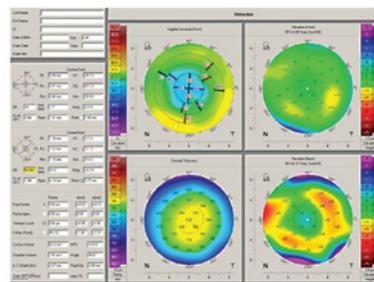


FIGURE 3 Case 3: Moderate myopic LASIK and multifocal IOL.

**Case 3:** A patient who had a previous successful 5.50-D myopic LASIK was happy with the vision with a multifocal IOL. The SP value of such a normal post-LASIK cornea can be related to the accuracy of the laser procedure. By Munnerlyn's formula, a refractive target accuracy of 1 D corresponds to 10-micron steps in the Z axis or a 20-micron step in the X-Y plane, which can be considered the SP value of the cornea. As such, corneal SP is smaller than the ST of either multifocal IOL, confirming our clinical finding here that the multifocal IOL does actually work well in this post-moderate myopic LASIK eye (Figure 3).

**Case 4:** A patient who had previous hyperopic LASIK was dissatisfied with vision with a multifocal IOL. Looking at the topography we see that there is about 0.5 mm distance



Spatial Tolerance of IOL

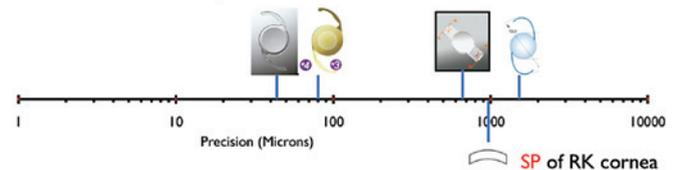


FIGURE 5 Case 5: RK and multifocal IOL.

**Case 5:** This patient had prior radial keratotomy (RK) and was not happy with his vision after a multifocal IOL implantation. The SP value of the cornea can be taken from the size of the "RK bumps" typically seen on the posterior corneal surface of such post-RK eyes, which in this case is about 1 mm (Figure 5). Since the corneal SP is greater than the STs of either a multifocal IOL (45 or 75 microns) or a Crystalens (0.66 mm), the model suggests that neither of these two IOL modalities would work, and only a monofocal IOL (1.5 mm) can be paired with this cornea.

## Selection Criteria

These retrospective analyses show that SP/ST values may be useful in identifying the appropriate cornea-IOL pair, as well as for selecting the appropriate post-LASIK patients for multifocal IOL implantation. Post-LASIK patients who are good candidates for multifocal IOLs are those who have undergone low-to-moderate myopic LASIK corrections with good post-LASIK vision (Case 3). In contrast, post-LASIK patients who are poor candidates for multifocal IOLs have corneas that are grossly irregular, due to ocular surface problems such as dry eye (Case 1); problems with the LASIK surgery itself such as decentration (Case 2); or a history of hyperopic LASIK (Case 4), or RK (Case 5).

Based on these cases and prior discussions, we have formulated the following clinical guidelines for identifying the appropriate post-LASIK patients for implanting multifocal IOLs:

- LASIK for up  $-6.00$  D with good postoperative vision.
- Minimal corneal irregularity (HOA  $< 0.4$  microns).
- Absence of ocular surface disease.

## Conclusion

The SP/ST analysis is a semiquantitative model based on the idea that the spatial accuracy of both corneas and IOLs can be defined, compared, and used to identify appropriate cornea-IOL matches. The model was used to formulate clinical guidelines for identifying appropriate post-LASIK patients for multifocal IOLs. The small series of clinical cases

described here illustrates the potential utility of this model.

Although the SP/ST model is a highly simplified approach to a very complex problem, the concept itself, as a first approximation, captures the essence of the physics involved in corneal and IOL optics. Larger clinical studies are needed to validate this approach.

## THE BOTTOM LINE

**SP/ST analysis is a semiquantitative means to predict success or failure in certain cornea-IOL matches. The model was used to formulate the clinical guidelines for selecting appropriate post-LASIK patients for multifocal IOLs. Acceptable multifocal IOL candidates include myopic LASIK corrections of up to  $-6.00$  D with good post-LASIK vision, absence of ocular surface disease, and corneal higher order aberrations of less than 0.4 microns.**

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