Pseudophakic Accommodation

An update on accommodative physiology, technology, and measurement.

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Accommodative ability gradually decreases with increasing age and is lost completely by about age 55.1 The effects of presbyopia become evident around the age of 45, as the accommodative amplitude recedes beyond a comfortable reading distance. It is widely accepted that presbyopia results from stiffening of the lens to a point where the shape of the lens can no longer be changed by the accommodative mechanism.2,3 Although spectacles can effectively compensate for this loss, they are a poor substitute for the active and dynamic accommodation of a young eye.4

There is considerable interest in whether the presbyopic eye’s accommodative ability can be restored. The idea is not simply to bring back functional near vision, which can be accomplished with near reading adds, progressive addition lenses, or optical multifocality through contact lenses, corneal refractive procedures, or multifocal IOLs. Rather, the goal is to restore true active and dynamic accommodation. Current efforts in this area include laser or pharmacological modification or softening of the natural phakic presbyopic lens and the development of so-called accommodating IOLs.

ACCOMMODATIVE MECHANISM

Accommodation is a dioptric change in the power of the eye consequent to contraction of the ciliary muscle. When the ciliary muscle contracts in the natural, young phakic eye, the apex of this muscle moves toward the lens equator.5 This action releases zonular tension around the lens equator and allows the elastic lens capsule to mold the young, soft lens into a more spherical and accommodated form. The accommodative increase in the optical power of the lens comes about by virtue of an increase in the anterior and posterior surface curvatures of the lens. As a result, the optical power of the lens increases, and the eye changes focus from distance to near. A distant object subtends parallel rays at the cornea, with zero vergence at the eye. A near object has divergent rays at the cornea; the accommodative increase in the optical power of the eye is necessary to overcome this divergence and create a focused image on the retina.

CALCULATIONS OF ACCOMMODATION

The success of accommodating IOLs will be determined by how well they can produce an accommodative increase in the optical power of the eye. Simple schematic eye-model calculations demonstrate the accommodative amplitudes that can be achieved based on movements or changes in an IOL.6,7 An accommodative increase in the optical power of a pseudophakic eye can

Figure 1. The accommodative response of two schematic eyes as a function of the decrease in anterior chamber depth. In the pseudophakic eye, the 20.00 D IOL was moved forward in the eye. In the phakic eye, the natural accommodative response was simulated as an increase in lens thickness, a decrease in anterior chamber depth, and an increase in the curvature of the anterior and posterior lens surfaces based on what actually occurs in the young phakic eye. The markedly greater accommodative response in the phakic eye occurs predominantly due to changes in the curvature of the lens surfaces but with considerably smaller dimensional changes than in the pseudophakic eye.
be accomplished in several ways. For example, a 1-mm forward movement of a 20.00 D single-optic IOL will produce 1.20 D of accommodation (Figure 1). Accommodative movements of the natural phakic lens, however, are small; for example, lens thickness increases by only about 300 µm for 5.00 D of accommodation (Figure 2). A 1-mm forward movement of a single-optic IOL is therefore unlikely to occur; a 300-µm forward movement of a 20.00 D single-optic IOL would produce only about 0.40 D of accommodation.

Calculations with an anatomically based schematic eye that has a natural phakic lens can produce 10.00 D of accommodation. During accommodation of the natural phakic lens, the anterior surface of the lens moves forward by about 400 µm.\(^8\) The much more efficient accommodative response in the natural phakic lens is, of course, not due to forward movement but an increase in the curvature of the anterior and posterior surfaces. As the natural phakic lens accommodates, diameter decreases, thickness increases, the anterior surface moves anteriorly, and the posterior surface moves posteriorly. More important to the accommodative optical change in the power of the eye, the curvature of the lens anterior and posterior surfaces becomes steeper. An accommodating IOL that mimics natural accommodation by changing the curvature of its surfaces will maximize accommodative capacity.

THE OBJECTIVE MEASUREMENT OF ACCOMMODATION

In subjective tests of accommodation, the patient is asked to report on his or her ability to read at near. Although assessing and understanding patients’ visual performance is important, it is no substitute for objective accommodation. Patients’ subjective performance can be misleading. For example, in a completely presbyopic eye, pupillary constriction alone can increase depth of field, and the patient will report that text can be moved closer to his or her eye and still remain in focus. Similarly, a distance-corrected patient with a multifocal IOL will have some degree of functional near vision, but this will be due to the multifocal optics and cannot be considered accommodation. The subjective measurement of accommodation is affected by factors such as depth of field and ocular aberrations that have nothing to do with the active and dynamic increase in the eye’s optical power consequent to the ciliary muscle’s contraction.

Establishing if an accommodating IOL can undergo an accommodative increase in the optical power of the eye with an effort to focus at near requires an objective measurement.\(^9\) Such testing necessitates the use of an objective instrument such as the iTrace wavefront aberrometer (Tracey Technologies, Inc., Houston, TX) or Grand-Seiko autorefractor (Grand-Seiko Co, Ltd., Hiroshima, Japan).\(^9\) Biometry instruments such as optical coherence tomographers (Figure 3) and ultrasound biomicroscopes (Figure 4) can measure physical accommodative changes in the eye such as the forward movement of an IOL or a change in the surface curvature of the lens.

Regardless of which objective method is used, the testing procedure should be first to measure the distance-corrected eye while it is viewing a distant target at 6 m to determine baseline refraction or biometry. A target at 6 m subtends close to zero vergence at the cornea, so accommodation...
would be relaxed. A compelling accommodative stimulus should then be presented at several progressively increasing accommodative demands in predetermined dioptric steps (Figure 5). Next, the refraction or biometry of the eye should be measured while the patient is asked to focus on each progressively closer near stimulus. A compelling stimulus should be used that includes high-contrast letters with sufficient illumination to make the target clearly visible. The goal is to provide the most compelling stimulus so as to elicit the strongest accommodative response to each stimulus. Multiple measures should be taken for each near stimulus presented so the variance of the measurements can also be determined. The accommodative response is calculated by subtracting the distance measurement from the response obtained for each near stimulus presented. The result is an accommodative stimulus-response curve, with error bars from which the accommodative amplitude can readily be determined.

CONCLUSION

If accommodating IOLs are to succeed in restoring accommodation to the presbyopic eye, their design should be based on a sound understanding of the mechanism of accommodation and the causes of presbyopia. Accommodating IOLs with surfaces that change curvature have considerably greater potential for generating significant accommodation than IOLs that move forward in the eye without a change in surface curvature. Accommodating IOLs will benefit from technological improvements in their design and fabrication as well as rigorous and appropriate clinical assessments of accommodation. That requires objective—not subjective—measurements.

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