Peer-Reviewed Literature:

The Measurement of Ocular Accommodation in Pseudophakia

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There is a growing interest in restoring accommodation in presbyopes by means of accommodative IOLs, scleral expansion surgical procedures, or laser/chemical lens modifications. Ophthalmologists planning on using these restorative procedures should consider pairing them with objective measurements of accommodation. Although a general, subjective assessment of a patient's distance-corrected, functional, near visual ability is important, of equal significance is to verify if and by how much accommodation can be restored. Such a mechanistic understanding of accommodation may be especially important in optimizing surgical improvement in near vision and in planning new lens designs and surgical techniques. The following articles were reviewed:

1. *Wold JE, Hu A, Chen S, Glasser A. Subjective and objective measurement of human accommodative amplitude.* J Cataract Refract Surg. *2003;29:1878-1888.*
2. *Ostrin LA, Glasser A. Accommodation measurements in a pre-presbyopic and presbyopic population.* J Cataract Refract Surg. *2004;30:1435-1444.*
3. *Qazi MA, Pepose JS, Shuster JJ. Implantation of scleral expansion band segments for the treatment of presbyopia.* Am J Ophthalmol. *2002;134:808-815.*
4. *Ostrin LA, Kasthurirangan S, Glasser A. Evaluation of a satisfied bilateral scleral expansion band patient.* J Cataract Refract Surg. *2004;30:1445-1453.*
5. *Findl O, Kriechbaum K, Menapace R, et al. Laserinterferometric assessment of pilocarpine-induced movement of an accommodating intraocular lens: a randomized trial.* Ophthalmology. *2004;111:1515-1521.*
6. *Wolffsohn JS, O'Donnell C, Charman WN, Gilmartin B. Simultaneous continuous recording of accommodation and pupil size using the modified Shin-Nippon SRW-5000 autorefractor.* Ophthalmic Physiol Opt. *2004;24:142–147.*
7. *Wolffsohn JS, Hunt OA, Gilmartin B. Continuous measurement of accommodation in human factor applications.* Ophthalmic Physiol Opt. *2002;22:380-384.*
8. *Kasthurirangan S, Vilupuru AS, Glasser A. Amplitude dependent accommodative dynamics in humans.* Vision Res. *2003;43:2945–2956.*
9. *Langenbucher A, Huber S, Nguyen NX, et al. Measurement of accommodation after implantation of an accommodating posterior chamber intraocular lens.* J Cataract Refract Surg. *2003;29:677-685.*
10. *Langenbucher A, Seitz B, Huber S, et al. Theoretical and measured pseudophakic accommodation after implantation of a new accommodative posterior chamber intraocular lens.* Arch Ophthalmol. *2003;121:1722-1727.*
11. *Kuchle M, Seitz B, Langenbucher A, et al. Stability of refraction, accommodation, and lens position after implantation of the 1CU accommodating posterior chamber intraocular lens.* J Cataract Refract Surg. *2003;29:2324-2329.*
12. *Nawa Y, Ueda T, Nakatsuka M, et al. Accommodation obtained per 1.0mm from movement of a posterior chamber intraocular lens.* J Cataract Refract Surg. *2003;29:2069-2072.*

OBJECTIVELY MEASURING ACCOMMODATION

Accommodation is a dioptric, optical change in the power of the eye,[1] traditionally defined as the result of alterations in the shape of the lens following contraction of the ciliary muscle. This narrow definition may need to be broadened, because a change in the power of the eye can also be accomplished by the forward movement of an optic and by the increased separation between dual-optic IOLs.

A patient's ability to decipher a high-contrast near reading chart through a distance correction relies on a combination of static and dynamic components. Static components (which include pseudoaccommodation) are independent of the ciliary muscle's contraction. These mechanisms include the instantaneous depth of focus (affected by pupil size, ptotic eyelids, and squinting), residual myopic astigmatism, the polychromatic and monochromatic higher-order aberrations of the eye (particularly spherical aberration and coma), object contrast and illumination, redundancies in spatial frequency of the test object, and blur interpretation and different adaptive states of neural processing of the near image.

Dynamic, subjective tests that rely on the response of the patient cannot easily distinguish or weigh the accommodative and pseudoaccommodative components that conjoin to enable near reading vision. Accommodation has traditionally been measured clinically using the push-up test, wherein the subject looks at a given line of text through his distance correction and is instructed to indicate when the object is moved close enough to blur the line. The push-up test is not objective, overestimates accommodative amplitude, and does not unequivocally measure accommodation.[1,2] The test is sensitive to optotype size, illumination, and distance from the subject (eg, if the object is always out of focus or of little interest to the viewer, there may be little accommodative effort made). A push-up test performed on a patient with multifocal IOLs may lead to the erroneous conclusion that the multifocality provides functional accommodation.

A truly objective technique for testing accommodation requires no evaluation from the patient or from the clinician. Ideally, an objective instrument completes the measurement of accommodation and provides the result. The push-up test requires a nonobjective report from the subject. Streak retinoscopy, although objective with respect to the subject requires the clinician to subjectively evaluate the movement of the retinoscopic reflex. The presence of ocular aberrations can cause retinoscopic movements that are difficult to interpret. An autorefractor, which measures and provides the refraction of the eye, is objective with respect to the subject and the clinician. It is important to understand the near reading ability of a patient. However, in order to understand if accommodation can be restored in presbyopes, there is no alternative to the use of an objective measurement of accommodation.

RESTORING PHAKIC ACCOMMODATION

Phakic-accommodation-restoration procedures provide no significant challenges to objective accommodation measurements. Subjective testing measures functional near vision, an important calculation. The push-up test is easy to administer, and there is ample justification for its use.[3] However, in conjunction with subjective testing, an autorefractor should also be used to provide an objective measurement.[4] A variety of methods may be employed both to stimulate and to measure accommodation and may provide different, yet complementary information.[5] Most modern autorefractors can measure the refractive state of the eye as accommodation is induced with near objects, and as defocus of distant letter charts is induced with trial lenses or with the topical application of pilocarpine.[1,2,4]

> "Different methods of stimulating and measuring accommodation or IOL movements will produce different responses."

STIMULATING ACCOMMODATION

To measure an accommodative response, it must be stimulated effectively. The amplitude of the accommodative response varies with different stimuli.[1,2] A high-contrast letter chart moved toward the patient and viewed binocularly provides blur, proximity, and convergence cues, which all enhance the accommodative effect. In presbyopic or near-presbyopic patients, an auxiliary plus lens will allow clear viewing of a near target as it is moved closer to the patient.[3] Topical pilocarpine produces an accommodative response through the involuntary drug-induced contraction of the ciliary muscle.[4,5] Although topical pilocarpine is a useful method to stimulate accommodation, its effects vary with iris color and ocular pigmentation.[1,2] The topical application of pilocarpine causes a strong and rapid pupillary constriction. Therefore, any method used subsequently to measure the accommodative response objectively should be capable of measuring through pupils 1 to 2mm in diameter. It is important to recognize that a pilocarpine-induced accommodative response may differ from that induced by a visual stimulus, so, when possible, visual-stimulus–driven accommodation should be utilized.

MEASURING DYNAMIC ACCOMMODATION

Because accommodation is a dynamic process, there is much to be learned from continuous, dynamic measurement.[6-8] A standard autorefractor will normally measure the refractive status of the eye at only one point in time.[6] If a near stimulus is presented, accommodation fluctuates, and the eyes do not sustain a constant accommodative tonus. At the very least, three to five static measurements should be made when assessing accommodation, but a system that measures the refractive state of the eye continuously (at 30Hz) is preferable. Many different methods have been used to measure accommodation dynamically, and much success is achieved with instruments that allow relatively unconstrained viewing with an open viewing field.[6,7] This broad-field, binocular-distance view facilitates a relaxation of accommodation, thereby minimizing problems with "instrument myopia." These devices and methods allow for the quantification of much more than the accommodative amplitude, including the velocity of the response, how it differs between accommodation and the relaxation of accommodation (disaccommodation), and how well a response may be maintained.[8] These instruments also allow the dynamic measurement of the pupillary response.[4,6]

MEASURING THE PUPIL'S DIAMETER

The accommodative response consists of the neurally coupled accommodative triad—namely, accommodation, pupil constriction, and convergence. The extent of the accommodative effort exerted is reflected by the extent of the accommodative pupillary constriction. A presbyope with little or no accommodation will show an increasingly pronounced pupillary constriction in attempting to accommodate as an accommodative stimulus is increased.[4] This reaction demonstrates that an increasingly strong accommodative effort is taking place even if no accommodation occurs. Knowledge of the pupil's diameter can also provide an indication of the extent to which improved functional near vision is due to the increased depth of field of the eye as a result of pupillary constriction.

MEASURING PSEUDOPHAKIC ACCOMMODATION

Objective pseudophakic accommodative measurement poses unique challenges, such as measuring small amplitudes that may be expected or measuring accurately in the presence of bright Purkinje images that are reflected off relatively flat, spherical IOLs with a high refractive index. In single-optic pseudophakic accommodation, an accommodative optical change in ocular refraction would directly relate to the extent of the forward movement of an IOL. Therefore, measuring the benefits to the patient with subjective push-up tests, measuring the optical accommodative response objectively with autorefractors, and measuring the movements of an IOL (such as with A-scan ultrasound, laser interferometry, or Scheimpflug slit-lamp photography), all provide useful information and serve to distinguish pseudo- from true accommodation.[9-12] Knowledge of the movement and power of an optic, together with ocular biometry, can be used to calculate the expected accommodative amplitude.[10,12]

BOTTOM LINE

Although no standardized methods currently exist for measuring phakic or pseudophakic accommodation, a variety of techniques are available and can be routinely used in clinical practice. Different methods of stimulating and measuring accommodation or IOL movements will produce different responses. Using a variety of techniques including both subjective and objective methods is important for understanding and differentiating between pseudo- and true accommodation. ■

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