

# Ultrasound and Optical Biometry

Both technologies are needed in the modern cataract and refractive surgery practice.

BY JACK T. HOLLADAY, MD, MSEE

Ultrasound technology has been used in ophthalmology since D. Jackson Coleman, MD, and others described its use for the evaluation of ocular pathology in the late 1960s and early 1970s.<sup>1-3</sup> When IOLs began to gain popularity later in the 1970s, cataract surgeons adopted ultrasound A-scans to measure the axial length of the eye for IOL power calculation.

A-scan biometry became more accurate over time, with the addition of gates to take into account changes in the velocity of sound as it travels through the different media in the eye. Refinements of the technology soon allowed measurement of lens thickness, anterior chamber depth, and other parameters in addition to axial length. By the 1990s, ultrasound measurement of axial length was accurate to approximately 0.1 mm, reliable, and the de facto gold standard for the calculation of IOL power in cataract surgery.

In the late 1990s, an alternative to ultrasound biometry was introduced: optical biometry, based on the principle of partial coherence interferometry.<sup>4</sup> With greater operator independence than ultrasound and increased accuracy (approximately 0.05 mm), optical biometry has arguably become the gold standard for axial length measurement in ophthalmology over the past 10 years. There are now two optical biometry devices on the market, the IOLMaster (Carl Zeiss Meditec, Jena, Germany) and the more recently introduced Lenstar LS 900 (Haag-Streit AG, Koeniz, Switzerland). However, it is not yet time to throw out your A-scan unit.

The modern ophthalmic practice must employ both ultrasound and optical biometry technologies. This article explores the differences in the two technologies and the reasons why they are both still essential tools for the cataract surgeon.

## MEASURING AXIAL LENGTH ACCURATELY

Ultrasound measurement has always had two major limitations as a starting point for IOL power calculation. First, ultrasound measures the anatomic axial length of the eye, from the anterior pole to the posterior pole, not the optical axial length along the visual axis. The visual axis of the human eye is not identical to the anatomic (or geometric)

axis. The macula is located on the temporal side of the retina, and the optical axis extends from the fovea out through the nasal side of the cornea. As a result, the optical axis in the typical human eye is tilted approximately 5° horizontally and 1° vertically relative to the anatomic axis.

Because ultrasound does not depend on patient fixation, it measures the anatomic length of the eye, from the corneal vertex to the posterior pole, rather than the optical length. For IOL power calculation, the ophthalmologist must know the distance from the corneal vertex to the fovea, but the anatomic length that ultrasound biometry measures is almost always longer than this distance.

Roberto Zaldivar, MD, and I showed that, in eyes with axial length greater than 26 mm, the anatomic axial length is a mean 0.8 mm longer than the optical axial length.<sup>5</sup> With a posterior staphyloma, the difference between the measured length and the optical length becomes even greater; in the same study, we found a range of up to 3 mm difference between the two distances. An error of 1 mm in axial length measurement yields a refractive surprise of approximately 2.80 D, so an error of 3 mm could mean a surprise of almost 9.00 D.

The second problem with ultrasound biometry is that it measures to the front of the retina, the internal limiting membrane, but the photoreceptors used for sight are at the back of the retina, near Bruch's membrane. The average thickness of the retina is 200  $\mu\text{m}$ . Because of this, IOL power calculation formulas dating back to the 1970s have added 200  $\mu\text{m}$  to the measured axial length to make up the difference. However, 200  $\mu\text{m}$  is an average figure; retinal thickness can range from 160 to 400  $\mu\text{m}$ , and therefore the 200  $\mu\text{m}$  addition is not accurate for all patients.

With the introduction of optical biometry, these two problems with ultrasound were addressed. For optical biometry, whether with the IOLMaster or the Lenstar, the patient fixates on a target light. As a result, the device actually measures the distance we want, from the corneal vertex to the fovea, rather than the anatomic length.

Second, the optical signal measures to Bruch's membrane, the back of the retina, rather than the anterior limiting membrane. Therefore, we do not have to assume the 200

µm retinal thickness; the device measures the true distance.

Optical biometry gives us the true optical axial length of the eye, from the anterior corneal vertex to the photoreceptors on the back of the retina, eliminating the two intrinsic problems of ultrasound biometry.

Additionally, there is a third advantage of optical biometry over ultrasound. Because optical biometry uses light instead of sound for measurement, it produces a more accurate result. The wavelengths used in ultrasound are many times longer than the wavelength of light; the shorter the wavelength the more precise the measurement. Biometry using light is inherently more accurate than ultrasound simply because of the shorter wavelength.

These three attributes have made optical biometry the standard of care today. However, there is one limitation of the technology; to obtain a measurement, a fairly good optical pathway is required. In an eye with a 4+ nuclear sclerotic cataract or a white cataract, optical biometry cannot get a reading. The patient has to be able to see out through the cataract to achieve fixation, and the light from the instrument has to be able to reach the fovea and return to the detector. With cataracts that reduce the patient's visual acuity to 20/400 to count fingers—about 5% to 10% of patients in a typical practice—the technology will not work. In those patients, the biometrist must use the available back-up technology, which is ultrasound.

The percentage of patients that can be measured with optical biometry has increased since the introduction of the technology 10 years ago. With early versions of the IOLMaster, up to software version 4.0, as many as 20% of patients could not be measured. Starting with version 5.0, the device has used averaging to increase the signal-to-noise ratio; now approximately 90% to 95% of patients can be measured.

This figure varies depending on the nature of the surgeon's patient population. In a rural area where patients might wait longer for surgery, the surgeon might see a greater percentage of 4+ cataracts and thus a greater percentage of eyes that cannot be measured with optical technology. In a big city practice with a lot of 20/30 or 20/40 patients seeking cataract surgery, there may not be any eyes that cannot be measured. The incidence of 4+ and white cataracts in the patient population will determine the percentage that cannot be measured with optical biometry.

So far, the only downside seen with optical biometry is this inability to obtain a reading in certain eyes. The use of light instead of sound guarantees a more accurate measurement, and the patient's fixation guarantees that the device is actually measuring to the fovea.

Over time, studies will compare the accuracy of the IOLMaster and Lenstar, but at this time no published, objective studies demonstrate any differences in performance. The Lenstar software has added a few features

### TAKE-HOME MESSAGE

- The modern ophthalmic practice must employ both ultrasound and optical biometry.
- The ophthalmologist must keep ultrasound biometry on hand for patients who cannot be measured with optical biometry.

such as measuring crystalline lens thickness. Both units measure anterior chamber depth. But the biometry results are apparently equally accurate.

The optics of the two devices are not identical, but both use the principle of partial coherence interferometry, which is similar to optical coherence tomography — it could really be called *optical coherence biometry*. The device sends a monochromatic wavefront of infrared light into the eye and captures it when the light reflects back from the retina. Based on the interference patterns between the signal sent and the signal detected upon return, the device calculates the length of the eye.

It is hard to conceive of how the precision of axial length measurement can be increased much further beyond what is possible with optical biometry. The result of this increased precision has been an improvement in the accuracy of IOL calculation in recent years. (In fact, with biometry so much improved, it is no longer the limiting factor in IOL power calculation; increasingly, keratometry will become the limiting factor in our aim for IOL accuracy. But that is a topic for another article.)

We must remember, however, that because of the optical nature of these devices, they will not function in eyes with very dense cataracts. For the time being at least, the ophthalmologist must keep ultrasound biometry on hand for patients who cannot be measured with optical biometry. The two technologies will be complementary for the foreseeable future. ■

*Jack T. Holladay, MD, MSEE, is a Clinical Professor of Ophthalmology at Baylor College of Medicine, Houston, and Founder and Medical Director of the Holladay LASIK Institute, Bellaire, Texas. He is author of the Holladay Formulas and provides consultations for A-scan companies that use his formulas. Dr. Holladay may be reached at e-mail: [holladay@docholladay.com](mailto:holladay@docholladay.com); Web: [www.docholladay.com](http://www.docholladay.com).*



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