IOL Power Calculations

Achieving optimal refractive outcomes.

BY WARREN E. HILL, MD

IOL calculations begin with an understanding of what the patient wants. In other words, calculating IOL power starts with clearly identifying the patient's postoperative refractive objective. As surgeons, our objective should be to do all that we can to meet these goals. We should also strive to be the most knowledgeable person in the clinic regarding all aspects of IOL power calculations. Be involved; do not become complacent and fall into the trap of delegating everything. Consistently good outcomes and consistently happy patients flow from an organized team approach.

> "How do you get consistently good outcomes for normal eyes? Optimize every component of the IOL power calculation process."

VALIDATION CRITERIA

When viewed as a refractive procedure, the practical goal of cataract surgery is a postoperative spherical equivalent that falls within ±0.50 D of the target refraction. However, this level of accuracy can only be approached if we adopt well-defined validation criteria for each aspect of the IOL power calculation process. Validation criteria can be considered our first line of defense in identifying potential problems long before they become a postoperative refractive surprise.

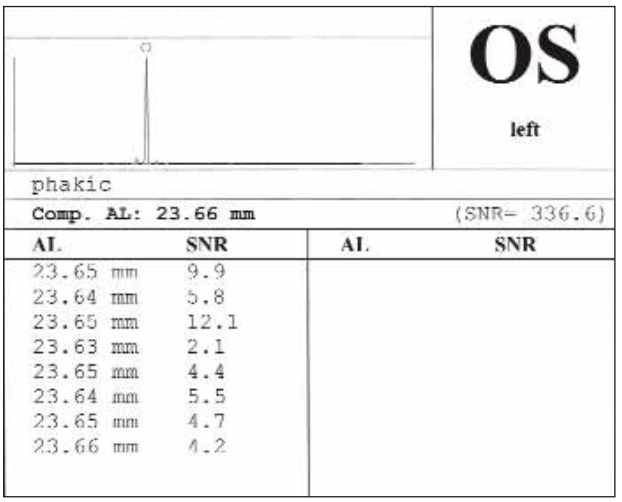

Figure 1. A composite axial length display for the IOLMaster software version 5.4. Note the very high composite signal-to-noise ratio of 336.6.

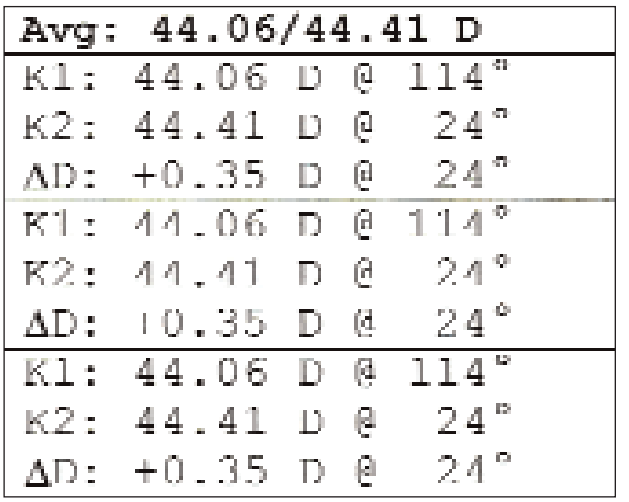

Figure 2. Ks obtained by the autokeratometry feature of the IOLMaster. The validation criterion is three sets of Ks within 0.25 D in each of the principal meridians.

The steady migration of cataract surgeons to the IOLMaster (Carl Zeiss Meditec, Inc., Jena, Germany) has transformed the overall process of preoperative measurements (Figure 1), and most of what is described herein will pertain to this useful instrument. The latest version of the IOLMaster has a number of important validation criteria built into its software. I have also posted a comprehensive set of IOLMaster validation criteria on my Web site (www.doctorhill.com/iol-master/iol-master_main.htm) that may be downloaded for free.

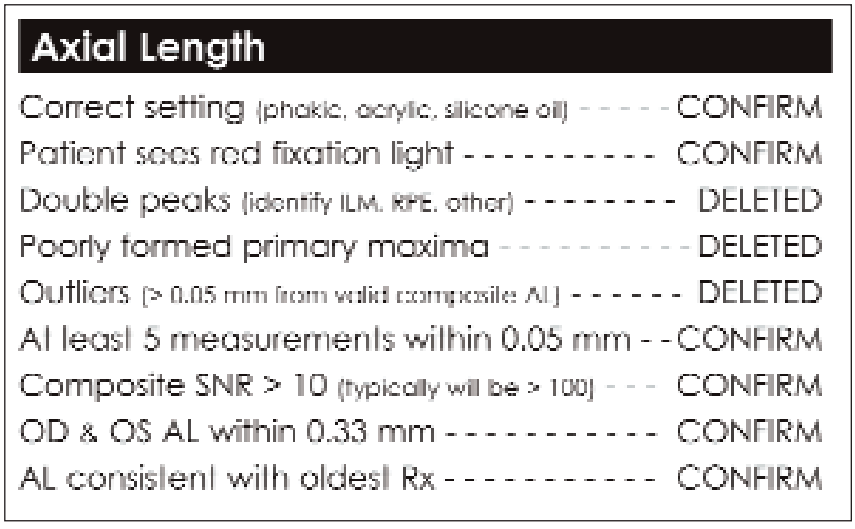

Figure 3. An axial length validation criteria checklist for the IOLMaster.

KERATOMETRY

It is helpful to remember that an error in keratometry has a 1:1 correlation with a postoperative deviation from the refractive target. In other words, keratometry that is off by 1.00 D will result in a 1.00 D refractive surprise.

So, how can we ensure that our keratometry is as accurate and consistent as possible? To begin, make the decision today to use a single device for all preoperative measurements in an effort to limit variability. The rationale for this streamlining is that topographic simKs, manual keratometry, and autokeratometry all measure different areas of the cornea, use different methods for extrapolating the central corneal power, and will invariably return different values for the same eye. Failing to limit measurements to a single device introduces significant variability and will impact the refractive outcome.

In our office, we are now using IOLMaster autokeratometry with the software version 5.4. This updated device is emerging as one of the more accurate and reproducible methods for measuring central corneal power. The most basic validation criterion for IOLMaster keratometry is three measurements within 0.25 D in each of the principal meridians (Figure 2).

AXIAL LENGTH VALIDATION CRITERIA

The process for validating axial length starts with checking the accuracy of the IOLMaster each morning against the calibration block that comes with the instrument (Figure 3). We will typically have a second person confirm our axial length measurements and sign the patient's chart if the difference between eyes is more than 0.3 mm or if it correlates poorly with the refraction (eg, a refractive hyperope showing a long axial length). A second set of measurements is also warranted for eyes that are very long (> 28 mm) and very short (< 21 mm).

If we notice obvious double peaks in the primary maxima, it is sometimes helpful to delete these measurements so that the digital signal processing software does not include them in the production of a final composite axial length.

CORNEAL POWER VALIDATION CRITERIA

The best policy for your staff to follow for validating corneal power is to check against the calibration block at the beginning of each day, print out the results, and place them in a folder in case there are any questions at a later date. Delete outlier measurements, and repeat measurements until the validation criterion is met. Also, delete any measurements in which an "X" appears in any of the LED locations; it means that one of the LEDs did not generate a valid measurement.

Situations in which a second observer should confirm the accuracy of keratometry and sign the chart include the presence of:

- significant inconsistencies between measurements
- a very flat (< 40 D) or very steep (> 48 D) K reading
- an average difference in power of more than 1.50 D between eyes
- K1 and K2 readings that differ by more than 3.00 D

If an eye has significant corneal astigmatism, it is useful to obtain a topographic axial map to screen for an anterior corneal dystrophy.

If you have any difficulty obtaining measurements, resolve the problem before you move on, even if you have to bring

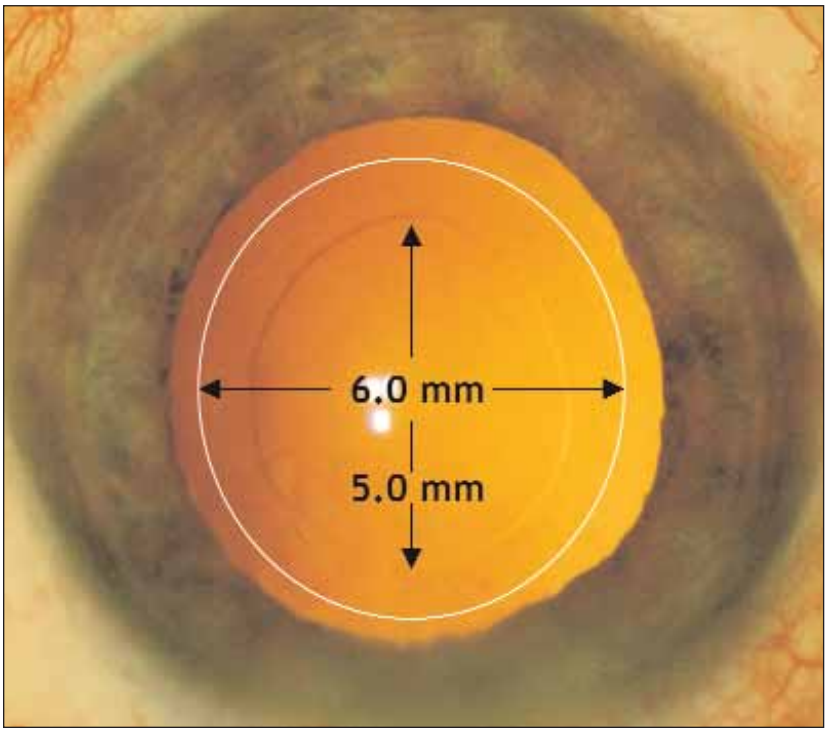

Figure 4. In terms of refractive outcomes, the capsulorhexis should be thought of as the defining portion of phacoemulsification. It should be round, centered, and approximately 1.0 mm smaller than the diameter of the optic of the IOL.

the patient back on another day. As carpenters say, it is always better to measure twice and cut once.

THE CAPSULORHEXIS

Due to its influence on the position of the IOL's optic relative to the cornea, the capsulorhexis is now considered an important component of the IOL calculation process (Figure 4). Along these lines, the capsulorhexis should be viewed as the defining portion of the surgical procedure in terms of refractive outcomes, because (1) the capsulorhexis should be smaller than the optic to contain the lens within the capsular bag so as to prevent anterior displacement when the forces of capsular bag contractions are brought to bear; and (2) it should be round and centered to limit the possibility of decentration and tilt.

ANTERIOR CHAMBER DEPTH

The latest version of the IOLMaster software has a traffic light indicator to help the user understand when he or she is measuring the anterior chamber depth correctly. Before the software version 5.4, the IOLMaster's measurement of anterior chamber depth was highly operator dependent. Now, the measurements are almost as accurate as those by immersion ultrasound for anterior chamber depths greater than 3.2 mm. The only eyes for which my staff and I still obtain an immersion A-scan are those with an ACD of less than 3.0 mm or an axial length of less than 22.0 mm. For shorter eyes, the ACD and lens thickness take on an increasingly important role for the Holladay 2 formula.

IMPROVED ACCURACY

Optical coherence biometry has turned the measurement of axial length in difficult eyes, such as those with a posterior staphyloma or indwelling silicone oil, into a very straightforward and completely routine task. Also, through the use of digital signal processing, the IOLMaster's software versions 5.0 and higher generate a hyperaccurate composite axial length based on information from multiple measurements. Thus, the system can now measure eyes with very dense cataracts and posterior subcapsular plaques.

GETTING OPTIMAL RESULTS WITH OLDER SOFTWARE

With older IOLMaster software versions 1 through 4, the axial length displayed is the arithmetic mean of the best measurements for each eye. For this method to work best, the operator must first eliminate any measurements that may be erroneous. The ideal configuration of the primary maxima is a morphology that resembles the appearance of the Chrysler building, with long, straight sides and what looks like a small, thin radio antenna on top. Primary maxima that appear differently (such as those with double peaks) must be individually deleted. A summary of proper primary maxima morphology for different signal-to-noise ratios can be found at www.doctorhill.com/iol-master-/iolmaster_com.htm.

Because the human cataract is typically quite heterogeneous rather than homogenous, a best practice is to avoid taking all measurements in the same place. Instead, get into the habit of sampling within the boundaries of the measurement reticule, but take measurements above the center, below, to the right, to the left, and in the oblique meridians. The objective is to discover the location within the measurement reticule that produces the best axial length display morphology. A summary of this process is available at the aforementioned Web site.

For example, measuring around a dense, central posterior subcapsular plaque will produce a useable image as

REAL WORLD TIPS TO BOOST PATIENT SATISFACTION

Following are practical pearls from successful refractive cataract surgeons.

SAME-DAY APPOINTMENTS

Dr. Hill

"We conduct patient satisfaction surveys as well as exit surveys after every procedure for the patient to tell us what that experience was like. We have also introduced a program we call *Advanced Access*, which allows callers to get an appointment that day. Our retinal colleagues down the street taught us this magic phrase: 'Have the patient come right over.' Advanced Access does not cost patients more; we simply changed our scheduling to open free time slots each day for each of our three physicians. Our Web site reads, 'With Advanced Access, your appointment is today.' We have been amazed at what this has done for our practice. We used to be scheduled out 3 to 4 months, and all that does is displace the people who want to see you. The only thing that matters is the number of patients you see each day. If your receptionist tells Mrs. Jones, 'Why don't you come right over,' Mrs. Jones will tell everyone she knows, because such treatment is so rare."

CELL PHONE NUMBER

Douglas Katzev, MD, Santa Barbara, California

"I give my postoperative patients my cell phone number and tell them to call me if they have any problems. They rarely use it, but they tell all their friends that I gave it to them."

E-MAIL

Timothy Cavanaugh, MD, Overland Park, Kansas

"E-mail really helps. Patients really appreciate having a conduit for communication."

POSTOPERATIVE PHONE CALL

Jennifer Murray, MD, Pensacola, Florida

"I call my patients the night of their surgery to see if they're feeling OK. They also tell their friends that 'My doctor called me.'"

EYEMAGINATIONS VIDEOS

Timothy Cavanaugh, MD, Overland Park, Kansas, and Sonia Yoo, MD, Miami

"I use videos from Eyemaginations, Inc. (Towson, MD), to educate patients about multifocal IOLs. I can send them a link to a specific video through e-mail."

"The tutorials on presbyopia and the IOL options are fantastic. I use them in my examination rooms. I specifically use the videos on cataracts and the IOL options."

TAKE STAFF TO OPHTHALMIC MEETINGS

Douglas Katsev, MD

"I take each of my core staff members to an ophthalmic meeting every other year. I can't tell you what this does for their morale."

A FRIEND IN THE EXAMINATION ROOM

Kerry D. Solomon, MD, Mount Pleasant, South Carolina

"We have patients bring a friend or family member in the examination room with them. This tactic puts patients at ease and helps tremendously with conversion to presbyopia-correcting IOLs, because this advocate will encourage patients to spend the extra money on themselves."

REAL WORLD TIPS TO BOOST PATIENT SATISFACTION

FIX REFRACTIVE ERROR

Robert J. Cionni, MD, Cincinnati

"The best insurance for happy patients is to get rid of residual refractive error."

PUT YOURSELF AT THEIR LEVEL

Dr. Solomon

"Lower your chair to be at or below the level of the patient's. You do not want them to feel that you are looking down on them."

long as the axial length display maintains a configuration resembling the Chrysler building (even if the signal-to-noise ratio is low).

IOL POWER CALCULATION FORMULAS

All IOL power formulas have advantages and shortcomings. However, contrary to conventional wisdom, the accuracy of 3rd-generation, two-variable formulas (Hoffer Q, SRK/T, and Holladay 1) is not related to axial length but to the anatomy of the anterior segment. For example, long eyes tend to have deeper anterior segments, but short eyes in the pseudophakic state tend to have completely normal anterior segment parameters. Short eyes in the phakic state have large lenses that often displace the iris anteriorly. Once the native lens has been removed, however, the anterior segment's anatomy is often quite normal.[1]

Aside from the method used to estimate the effective lens position of the IOL, the vergence portion of these formulas is mathematically about the same. They mostly differ in how they calculate where the lens sits in the eye, also known as the *effective lens position*. Recall that the power of the lens inside the eye (a two-lens system) is relative and not absolute.

The fundamental weakness of all theoretic IOL power calculation formulas is their limited ability to estimate the position of the thin lens equivalent of the optic of the IOL in the pseudophakic state. Some two-variable formulas incorrectly assume that the anterior and posterior segments of the eye are proportional and that the effective lens position is always related to the central corneal power and the axial length. This is not necessarily so. It has been shown that up to 30% of refractive surprises are the result of an error in a two-variable, 3rd-generation formula's ability to properly predict the effective lens position in the pseudophakic state and not from the preoperative measurements.[2-4] This may be a very good time for all ophthalmologists to adopt newer-generation IOL power calculations formulas, such as the Haigis or Holladay 2.

DETERMINING YOUR ACCURACY

How do you know how well you are performing IOL calculations? For normal eyes, this question was addressed in the United Kingdom by the National Health Service in the 2006 study entitled: "Benchmark standards for refractive outcomes after NHS cataract surgery."[5] The authors concluded that the benchmark for acceptable refractive outcomes for normal eyes following cataract surgery (using ultrasound and the IOLMaster, with optimized lens constants) should be within ±0.50 D for 55% of cases and within ±1.00 D for 85% of cases. This is the absolute minimum level of postoperative refractive accuracy that every ophthalmologic practice in North America should accept.

OPTIMIZE EVERY COMPONENT

So, how do you get consistently good outcomes for normal eyes? Optimize every component of the IOL power calculation process. Because IOL power calculations are the result of a multipart process, one perfect component (such as axial length) will not ensure a perfect outcome, but one bad component will invariably result in a refractive surprise.[6] ■

Warren E. Hill, MD, is in private practice at East Valley Ophthalmology in Mesa, Arizona. He is a consultant to Alcon Laboratories, Inc., in the area of intraocular lens mathematics and to Carl Zeiss Meditec, Inc., in the area of optical coherence biometry. He acknowledged no financial interest in the products mentioned herein. Dr. Hill may be reached at (480) 981-6111; hill@doctor-hill.com.

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