Over the last two decades, the accuracy of intraocular lens (IOL) power calculations has improved dramatically. The days of approximate results are behind us. Today’s technology makes it possible to be within ±0.50 D in 95% or better of surgeries. This article will examine the steps involved in biometry and the ways in which mistakes can be minimized, based on feedback from ophthalmic staff in busy units.

In order to determine the power of intraocular lens several values need to be known:

- Eye’s axial length (AL)
- Corneal power (K)
- Postoperative IOL position within the eye known as estimated lens position (ELP)
- The anterior chamber constant: A-constant or another lens related constant

Of these parameters the first two are measured before the implantation, the third parameter, the ELP, need to be estimated mathematically before the implantation and the last parameter is provided by the manufacturer of the intraocular lens. If these calculations are not performed accurately then patients may be left with a significant refractive error. The aim of an accurate IOL power calculation is to provide an IOL that fits the specific needs and desires of the individual patient. The development of better instrumentation for measuring the eye’s AL and the use of more precise mathematical formulas to perform the appropriate calculations have significantly improved the accuracy with which the surgeon determines the IOL power.

Need for accurate biometry

The axial length is the distance between the anterior surface of the cornea and the fovea and usually measured by A-scan ultrasonography or optical coherence biometry. The AL is the most important factor in IOL calculation: A 1-mm error in AL measurement results in a refractive error of approximately 2.35 D in an average eye. The central corneal power is the second important factor in the calculation formula. To simplify the calculation, the cornea is assumed to be a thin spherical lens with a fixed anterior to posterior corneal curvature ratio and an index of refraction of 1.3375. Central corneal power can be measured by keratometry or corneal topography. Corneal radius of curvature relates to corneal power with the equation: \( r = \frac{337.5}{K} \). The average keratometry (K) reading is 43.0 - 44.0 D, with one eye typically within a diopter of each other. Just as precise axial length and keratometry are critical for good surgical outcomes, correct IOL placement by the surgeon is also essential. A 0.19 D postoperative refractive error occurs for every 0.1 mm PCIOL displacement.

Steps in selecting the correct IOL

Identifying the refractive needs of the patient

Emmetropia will be the goal for most patients, but some may benefit from being left intentionally myopic post-operatively (or, rarely, hypermetropic), depending upon their preference and the refraction of the other eye. Care should be taken to keep anisometropia below 3 dioptres. The need for reading glasses should be explained and the patient made aware of the options.

Measuring the axial length of the eye
The axial length measurement has the greatest potential for error in calculating IOL power. A parallel sound beam is emitted from the probe tip at approximately 10 MHz, which echoes back into the probe tip as the sound beam strikes each interface. The echoes received back into the probe from each of these interfaces are converted by the biometer to spikes arising from baseline. Two types of A-scan ultrasound biometry are currently in use. The first is contact applanation biometry. This technique requires placing an ultrasound probe on the central cornea. While this is a convenient way to determine the AL for most normal eyes, errors in measurement almost invariably result from the probe indenting the cornea and shallowing the anterior chamber. Since the compression error is variable, it cannot be compensated for by a constant. IOL power calculations using these measurements will lead to an overestimation of the IOL power. In shorter eyes, this effect is amplified. The second type is immersion A-scan biometry, which requires placing a saline filled scleral shell (Prager) between the probe and the eye. Since the probe does not exert direct pressure on the cornea, compression of the anterior chamber is avoided. A mean shortening of 0.25–0.33mm has been reported between applanation and immersion AL measurements, which can translate into an error of IOL power by approximately 1 D. In general, immersion biometry has been shown to be more accurate than contact applanation biometry in several studies. The main limitation with the A-scan ultrasound is the poor image resolution due to the use of a relatively long, low-resolution wavelength (10 MHz) to measure a relatively short distance. In addition, variations in retinal thickness surrounding the fovea contribute to inconsistency in the final measurement.

The Zeiss IOLMaster was the first device to use partial coherence interferometry (PCI) in clinical ophthalmology. The technique of partial coherence interferometry measures the time required for infrared light to travel to the retina. Because light travels at too high a speed to be measured directly, light interference methodology is used to determine the transit time and thus the AL. This technique does not require contact with the globe, so corneal compression artifacts are eliminated. Compared with ultrasonography, the PCI provides more accurate, reproducible AL measurement. However, it is difficult to obtain a measurement in the presence of a dense cataract or other media opacities, which limits the use of this technique.

Another advantage of PCI over ultrasound biometry is that the AL measurement is performed through the visual axis since the patient is asked to fixate into the laser spot. In highly myopic or staphylomatous eyes, this can be particularly advantageous since it can sometimes be difficult to measure the true AL through the visual axis with an ultrasound probe. PCI is also superior to ultrasound in the measurement of pseudophakic and silicone oil-filled eyes. Lenstar LS 900 (Haag-Streit) is relatively a newer optical biometer approved by the FDA in October 2009 that is designed to provide more accurate measurements for IOL power calculations than was previously possible. Unlike IOL master, the Lenstar LS 900 captures all biometric measurements on the patient's visual axis. It is more precise, combines axial length and keratometry, and enables different formulae to be used. This is extremely helpful in extremely short eyes, very long eyes with posterior staphylomata, eyes containing silicone oil, and pseudophakic eyes. It should be noted that the axial length obtained from PCI may be slightly longer than that obtained from ultrasound. This is due to PCI measuring the distance from the corneal surface to the RPE while ultrasound measures to the anterior retinal surface. Therefore, many IOL measurement machines require refined IOL constants unique to their mechanism.

Tips for accurate measurement of axial length (using applanation):

- Ensure the machine is calibrated and set for the correct velocity setting (e.g. cataract, aphakia, pseudophakia)
- The echoes from cornea, anterior lens, posterior lens, and retina should be present and of good amplitude
- Misalignment along the optic nerve is recognised by an absent scleral spike
- The gain should be set at the lowest level at which a good reading is obtained
- Take care with axial alignment, especially with a hand-held probe and a moving patient (as described above)
- Do not push too hard – corneal compression commonly causes errors
- Average the 5–10 most consistent results giving the lowest standard deviation (ideally < 0.06 mm)
Errors may arise from an insufficient or greasy corneal meniscus due to ointment or methylcellulose used previously.

Take note of eyes that are very short (less than 22 mm) or very long (more than 25 mm). Axial length errors are more significant in short eyes and a posterior staphyloma may be present in a long eye. Look out for the unexpected result, for example an axial length of 27 mm in a patient with a +4.00 D refractive error. Always measure both eyes and repeat if the difference between eyes is greater than 0.3 mm, or if consecutive measurements differ by more than 0.2 mm.

Measuring the power of the cornea

Corneal power measurement is required by all the formulas used to calculate the power of the IOL to be implanted in cataract surgery. Traditionally, corneal power has been determined using instruments able to measure the anterior corneal curvature. These include manual keratometers, auto-keratometers, and Placido ring–based corneal topographers. Once the anterior corneal curvature has been converted to the overall corneal power by means of the keratometric index, these methods allow accurate IOL power calculations for most patients.

Manual keratometry is the most commonly used method to measure corneal curvature. Keratometry should be done before AL measurement, and for both eyes. The patient is seated with the chin positioned in the chin rest and the head resting on the head band. The keratometer is focused on the central portion of the cornea to be examined using the focusing knobs. The instrument is now rotated to align the (-) signs in the same vertical meridian and the (+) signs in the same horizontal meridian. This will determine the axis of the pre-existing astigmatism. The left drum is rotated to superimpose the (+) signs and the horizontal measurement is read out. The right drum is now rotated to superimpose the (-) signs and the vertical measurement reading is recorded.

Tips for accurate manual keratometry:

- Calibrate and check the accuracy of the keratometer
- Use a dedicated single instrument that is known to be accurate
- Do not touch the cornea beforehand and ensure a good tear film
- Adjust the eyepiece to bring the central cross-hairs into focus
- Make sure that the patient’s other eye is occluded and that the cornea is centred
- Take an average of three readings, including the axes
- If high or low results are encountered (< 40.00 D or > 48.00 D), it is advisable to have a second person check the measurements
- Repeat if the difference in total keratometric power between the eyes exceeds 1.50 D
- In a scarred cornea, use the fellow eye or average the results.

The IOL Master (Carl Zeiss Meditec) is an automated keratometer that calculates K readings by analyzing 6 light reflections projected onto the anterior cornea within a 2.3 mm radius. IOL master cannot image the very center of the cornea, which is also problematic in eyes that have had previous refractive surgery; in these cases, assumptions regarding the steepness of the central cornea might be invalid.

Newer technologies, including Scheimpflug cameras, have been shown to give similar results when combined with Placido ring–based corneal topography, and, albeit to a slightly less extent, when not combined with Placido ring–based corneal topography. Scheimpflug cameras have the added ability of measuring the posterior corneal curvature, which may theoretically lead to improved accuracy in IOL power calculation because they bypass the keratometric index of refraction problem. The Pentacam (Oculus, Inc.) uses a rotating Scheimpflug camera to image the anterior segment of the eye. Its capabilities include corneal topography, pachymetry anterior chamber photography, and keratometry (K).

Using the appropriate formula
The Hoffer Q, Holladay I, and SRK/T formulae are all commonly used, but the SRK I and II regression formulae are now regarded as obsolete. More recent formulae, are the Holladay II or Haigis. Where audit software is in use, the personalisation of calculation constants can increase accuracy.

Difficult eyes

- Intumescent cataracts will yield a 0.15 mm longer axial length resulting in a +0.4 to +0.5 hyperopia postoperatively.
- For aphakic eyes being planned for ACIOL or scleral fixated IOL, the appropriate A constant must be used and the mode of the machine changed to compensate for the change in speed of the sound waves.
- In eyes with silicone filled vitreous, the sensitivity of the system should be increased to visualize the retinal echospike and the components of the eye must be measured separately to reach an accurate result.
- After corneal refractive surgery, the K reading may not truly reflect the corneal power. Hence the refractive history method or the contact lens method must be used to obtain corrected K value.
- In eyes with high myopia, a B-scan examination is recommended to rule out a posterior staphyloma or other retinal pathologies. Identification of the posterior pole may be difficult. The problem is compounded in unilateral cases.

Some common mistakes:

- Wrong A-constant selected
- Wrong formula used
- Wrong K-readings entered by hand (90 degrees out)
- Biometry print-out stuck in wrong patient’s notes
- Incorrectly labelled IOL
- Wrong patient in theatre
- Reversed IOL optic
- Wrong IOL implanted (25.5 D implanted instead of 22.5 D or +30 D instead of +3.0 D).

Another factor to consider is the postoperative position of the IOL. Inadvertent placement in the sulcus will cause a 0.75 D myopic shift. If an anterior chamber IOL has to be used, the A-constant will be different.

Pediatric Cases

In children, it is wise practice to remove the cataract and use contact lens correction if the surgery is being performed within the first year of life, because growth of the eye will result in a large myopic shift if IOL has been implanted with intraoperative K and axial length measurements. When surgery is being performed after the age of two years, a myopic shift of 4-6 D is expected depending upon the age. Under correcting the IOL power compensates for this.

Biometry in children is difficult and may require general anesthesia. The lack of fixation in children who have keratometry under general anesthesia may lead to inaccurate keratometry readings. Partial coherence interferometry (PCI) has been used in cooperative children with reliability and accuracy. PCI requires patient cooperation and thus may not be a viable option in infants and young children.

Intraocular Lens Power Calculation in Pediatric Patients

Previous studies showed that the SRK II, SRK T, and Holladay I formulas had no significant difference in lens power predictability in children. However, there was increased variability in postoperative refractive outcome in patients younger than 2 years of age with all formulas. The Hoffer Q formula had a tendency to overestimate the IOL power and showed the greatest degree of variability. Newer formulas such as the Holladay II formula were designed to
increase the accuracy of the IOL power calculation. The Holladay II formula incorporates measured anterior chamber depth, lens thickness, and corneal diameter. However as per a recent study at L.V. Prasad Eye Institute, SRK II is the best formula for calculation of IOL power in children.

**Conclusion**

Departments should aim for consistency in their biometry and audit their results. Mistakes are easy to make, but difficult (and sometimes expensive) to rectify. It is better to have a few well-trained and experienced members of staff who can get consistent results, than to have many people with limited training and experience. In biometry, 90 per cent of eyes should be within 1 dioptre of their intended refraction. Try to identify any issues that are leading to consistent errors. Because we must remember that in current scenario, cataract surgery is not only a rehabilitative procedure but a refractive as well.

**References**