Cataract surgery has advanced in a rocket pace in the recent past making it a kind of refractive surgery, aimed at an unaided restoration of the perfect range of vision of 6/6 N6 with perfect intermediate vision too. The surgical techniques have also advanced with femtosecond laser cataract surgery gaining popularity, and premium IOLs- multifocal, multifocal toric, trifocal and accommodative IOLs being the in thing.

It is in this pretext that a precise biometry and a perfect IOL power calculation becomes a very essential prerequisite for a perfect cataract surgery. There is no space for a residual error in the premium cataract surgery scenario.

What is Biometry?
Biometry is a precise technique, fine tuned over time, to calculate the exact power of the Intraocular Lens to be implanted in the capsular bag after cataract removal, so as to give the patient an emmetropic correction for far vision and if possible near and intermediate too.

Major factors affecting IOL power calculation
The major factors which determine the IOL power calculation are mainly the following
1. Axial length measurement of the eye
2. Corneal curvature measurement ie : keratometry
3. Estimation of the anterior chamber depth (ACD)
4. Personalisation of A Constants/Surgeons factor(SF)
5. Prediction of Effective Lens Position (ELP)

Although ELP is not taken into consideration in the older formulae, in the fourth generation formulae like the Holladay 2 it is an important determinant of the IOL power.

Keratometry
Accurate assessment of the corneal curvature is of utmost importance in many ways
1. To plan the incision site for the cataract procedure. An incision placed on the steep meridian can negate or reduce preexistent corneal astigmatism.

2. To aid in the IOL power calculation as inputs into the various formulae used
3. In calculations for Toric IOLs using online calculators as inputs, in eyes with significant preexistent corneal astigmatism

Each dioptre of error in keratometry can give rise to a 0.9 D error in the IOL power prediction.

Keratometry can be done in 4 ways
1. Manual Keratometry : This technique uses a manual B&L model keratometer. Mires projected onto the corneal surface are mechanically aligned to get the horizontal(K1) and vertical(K2) K readings. The central 3 mm of the cornea is measured. An experienced technician can obtain fairly accurate readings with this equipment. The equipment is quite economical. Regular calibration aids is increasing accuracy.
2. Automated keratometry : This mode uses the Autorefractokeratometers(ARK) for measuring K values. Most of the commercially available models yield reasonably accurate values. It is upto the technician to take repeated measurements and delete bizarre readings so as to obtain accuracy. Regular calibration is a must with this tool too.
3. Automated keratometry of the IOL Master/ Lenstar: As opposed to the manual keratometer these measure the central 2.5 mm of the cornea. About 60 data points are measured with each attempt and an averaging is done which makes it quite accurate.
4. Topographic Keratometry : In centres where a topographic facility is available, topobased K values will aid accuracy

Axial length measurement
The two major modalities of axial length assessment are
1. Ultrasound Biometry- A Scan : This is a time tested and still relevant modality. One could do a contact method or an Immersion method which is much more accurate.
2. Optical Biometry : This is a relatively new modality. It
uses Partial Coherence Interferometry or Polarimetry\textsuperscript{1,2} for measuring axial length. It is much more precise than the ultrasound. Although more precise, this method has the disadvantage of not being able to assess the axial length in white mature cataracts and thick posterior subcapsular cataracts.

**Ultrasonic biometry**

A transducer probe emitting ultrasonic waves of 10 MHz is used. The waves travel from the anterior corneal surface to the vitreo-retinal interface and back, which is picked up by the probe and the axial length is interpolated from the time taken for the travel. The axial length is measured in mm from the anterior cornea to the Internal Limiting Membrane (ILM).

The procedure claims an accuracy of +/- 0.1 mm, in experienced hands and a relatively emmetropic eye.

**A Scan Ultrasound machine with immersion technique compatibility**

**Contact Method**

Here the transducer probe, after anaesthetizing the cornea, is placed in direct contact to the anterior corneal surface centrally at the pupillary area in a perpendicular fashion. A number of readings are taken in a manual or auto mode. The readings with improper spikes are deleted and an averaging is done.

Due to the possibility of inadvertent pressure on the cornea, an indentation of upto 0.3 mm is possible in this method which can cause an error of 1.0 to 1.5 Dioptre in the IOL calculation. Hence this technique is getting obsolete in most of the Ophthalmic Centres world wide.

**Immersion Technique**

This is a much more accurate technique. Here a waterbath is placed on the cornea using a sclera shell (eg. Praeger Shell). The hard tip transducer is applied to the shell. The rest of the procedure is similar to the contact method.

If done properly, immersion technique gives very accurate and reproducible results in all types of cataracts. The technique does not require any expensive add ons except the Praeger shell, which now is supplied by most manufacturers of A Scan equipment. The procedure has a very short learning curve.

To those of us who still use the contact method, it is highly recommended to shift to immersion as soon as possible for very obvious reasons.

**Prager sclera shell used for immersion ultrasound**

**A scan**

**Optical biometry**

This method utilizes Partial Coherence Interferometry for axial length measurement. The IOL Master from Carl Zeiss is an example. The IOL Master utilizes a modified Michaels Interferometer and uses coaxial infrared rays of 780 nm wavelength and a coherence length of 130 nm.

It is a non contact, no anaesthesia procedure and is very fast. It measures the axial length from the anterior cornea to the Retinal Pigment Epithelium (RPE).

The equipment claims an accuracy of 0.01 to 0.02 mm, which is almost 5 times that of the ultrasound.

Unlike ultrasound, it is not much affected by the extremes of axial length i.e. too long or too short, which makes it more useful in ammetropic patients.

The technique is also not much affected by the state of accommodation and pupil size.

The settings are also easily adjustable for aphakia, pseudophakia and silicon oil filled eyes.

One major advantage is that it is an all in all procedures for
biometry ie, keratometry, axial length and AC Depth are all measured in one go. There is no need for entering values from outside to the equipment. This eliminates errors in IOL power calculations due to clerical data entry errors.

The IOL Master- Optical Biometry

ACD Measurement

This is a standard modality now in most advanced A Scan machines as well as the Optical Biometry devices. The ACD can be calculated from the corneal epithelium or the endothelium.

The IOL master typically measures ACD from the corneal epithelium. It is possible in phakic eyes only. It is a slit based, measurement from the anterior corneal vertex to the anterior lens vertex. It has an accuracy of +/- 0.1 mm. The ACD is needed in the 4th generation formulae to predict the effective lens position (ELP).

How to perform a good biometry?

Always pre- assess the eye to be scanned prior to the procedure. It is always better to treat or stabilize any ocular surface disease or dry eye prior to the procedure. Liberal use of lubricants is beneficial to get proper keratometric readings.

Keratometry

Always do the keratometry prior to any procedure which involves corneal contact ie, applanation tonometry, contact biometry etc. It is also advisable to avoid use of anaesthetic drops, stains like fluorescein etc since these can alter the corneal surface characteristics.

Manual keratometry

Make sure that the equipment has been calibrated. Position the patient and the eye comfortably and properly on the keratometer. Ask the patient to blink so as to wet the ocular surface. Project the mires onto the cornea and focus the mires so as to make it crisp and clear. Align the mires in the horizontal and vertical meridia using the turning knobs on either sides. Ensure perfect superimposition of the plus and minus symbols.

In case the mires are not parallel, turn the tube in a circular fashion till they becomes parallel and then align and superimpose. Take multiple readings from each eye. After excluding bizarre reading take an average.

Automated keratometry - ARK/ IOL Master/Lenstar

Calibrate the machine

Ensure proper wetting of the cornea by blinking or use lubricants

Instruct the patient to look at the fixation light or target depending on the machine.

Take multiple readings and delete bizarre ones.

Take an average of all the acceptable readings.

Topographic K readings

Wherever possible try and get Topographic K Readings

It is always advisable to use more than one method of keratometry, to reduce chances of errors. Whenever there is a suspicion of error please repeat the procedure and take multiple readings. If there is a difference of more than 1 D in the average K between the eyes, it is better to repeat, if possible by a second technician or surgeon.

Anterior chamber depth

This can be done using the newer generation ultrasound based machines and the optical equipment like the IOL Master. In the IOL Master go to the ACD measurement mode, which gives you a slit beam. Use the joystick to focus the light spot crisp on the anterior lens surface. Click the button once focused. Delete bizarre readings and take the average.

Axial length measurement

If you are planning a Non Contact Biometry, like the IOL Master, always do that first, before an Ultrasonic Biometry since it involves contact to the corneal surface by the waterbath/sclera shell/fluid. This may affect the keratometric/axial length reading acquisitions.

Immersion biometry – ultrasonic

Calibrate your equipment at least once at the beginning of the day. Carefully enter the keratometric values to the equipment, to avoid clerical errors. Make the patient lie down comfortably. Anaesthetise the cornea with proparacaine/ lignocaine eye drops. Place the Praeger shell on the eyeball and fill it up with saline. Take multiple readings and delete the ones with improper spikes. In a good measurement there should be 5 spikes of equal and full heights, the cornea, the anterior lens spike, the posterior lens spike, the retina, the sclera. Posterior to the sclera, the orbital spikes should be gradually attenuating.

Any measurement with irregular or incomplete spikes should be discarded or deleted. Always try to measure the contralateral eye also, wherever possible. Repeat measurements by a second person if there is a difference of more than 0.5 mm in axial length between the eyes unless there is a preexistent evidence for anisometropia.
Ascan picture showing an acceptable recording.
Note that the corneal, lens, retinal and sclera spikes are full and of equal heights.

Optical Biometry
Always make sure that the eye is moist, by blinking or use of artificial tears. Position the patient on the machine and align the device to get a proper focus. Ask the patient to look straight into focusing target.

Use the joystick to get a good focus and press the click button to acquire the readings. Follow the instructions given by the machine eg. Ask the patient to blink etc.

Delete all bizarre readings. Take the average as the axial length. Like in ultrasound always measure both eyes and repeat if there is more than 0.5 mm difference in AL.

Choosing the right formula for IOL calculation
Perhaps this is one area where a lot of prudence is required in obtaining target emmetropia. The common formulae in use presently are:

- Empirical: SRK II
- Geometric Optical: SRK-T, Hoffer Q, Haigis and Holladay SRK II

This formula can still be used and gives relatively good results in normal axial lengths. However in longer and shorter eyes the results are erratic. The following nomogram can be used in these circumstances.

- Axial length > 24.5 mm: Minus 0.5 D
- SRK-T
  This formula is the most widely used presently. It gives relatively accurate IOL calculations in normal to moderately long eyes ie 22.5 mm to 28.0 mm. In longer eyes over 28 mm the results become less accurate with an underestimation of the IOL power.
- Holladay 1
  This formula can be used in normal to long eyes of axial lengths of 22.5 to 32 mm. The calculations are relatively more accurate in axial lengths of more than 28 mm when compared to the SRK-T
- Hoffer Q
  This is useful in short eyes, normal and slightly long eyes of axial lengths 20.0 D to 26.0 D
- Haigis
  This formula can be used over a wide range of axial lengths with the use of optimized A constants
  A0.a1.a2 optimised a constants
  Extreme short to short eyes: 17mm to 19 mm and long eyes: 28mm to 34 mm
  Ao optimised A constant
  AL: 19mm to 28 mm
- Holladay 2 IOL Consultant
  Relatively most accurate in all ranges of axial lengths of 17 mm to 34 mm
- Personalising A constants
  Select 15 or more patients with each IOL being used
  Take the preop( wherever possible) and post op refraction readings.
  Calculate the ideal IOL power based on the residua refractive error. Calculate the error in IOL power if any. Take an average of the errors in IOL powers and make suitable adjustments to the A constant provided by the manufacturers to arrive at your personalized A constant.

Example:
If you are getting an average error in IOL power of -0.25 with an IOL of A constant 118.0, then your personalized A constant would be 118.25

If you are using an Optical equipment like the IOL Master, then your pre and post op data for 15 patients each of all the IOLs can be fed directly to the machine and the software will...
Mean absolute prediction errors with various formulae

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automatically personalize your A constant.

ULIB
This site [http://www.augenklinik.uni-wuerzburg.de/eulib.com](http://www.augenklinik.uni-wuerzburg.de/eulib.com) allows you to download personalised A constants for most of the IOLs. This is provided and updated by a user group of IOL Master. This data can be fed to your IOL Master.

Biometry in post refractive surgical cases

This topic itself is exhaustive and beyond the scope of this article. However, we shall briefly discuss this issue. The main problem here is the error possible in the keratometric value determination since the corneal curvature and thickness have been modified by the refractive surgical procedure.

If you have the preop and post op refraction readings, keratometric and topographic data then the History method can be used to calculate the K reading to be fed into the Biometry.

\[
K_{act} = K_{pre} + Rx_{pre} - Rx_{act} \\
1-0.012 Rx_{pre} 1-0.012 Rx_{act}
\]

Kact : needed actual corneal power
Kpre : corneal power before refractive surgery
Ract : actual refraction
Rxpre: refraction before refractive surgery

Contact lens method
Here an over refraction is done after placing a hard contact lens

\[
K_{act} = P_{cl} + P_{zcl} + Rx_{with} - Rx_{without} \\
1-0.012 Rx_{with} 1-0.012 Rx_{without}
\]

Rx with: Refraction with Contact Lens
Rx without: Refraction without Contact Lens
Pcl: Power of hard Contact lens
Pzcl: Power of the back surface (base curve) of the hard contact lens

The newer formulae like the Shammas can be used which has provisions for entering the pre refractive and post refractive surgical data directly into the formula.

One can also use the Arranberrys double K method for the calculations. Normograms are provided whereby depending on the axial length and the refractive correction done values are available to be added or reduced from the IOL power obtained. The normograms are available individually for various formulae.

The ascrs website ([ASCRS POST KERATOREFRACTIVE ONLINE CALCULATOR](http://www.doctor-hill.com)) or the site [www.doctor-hill.com](http://www.doctor-hill.com) can be helpful. The Holladay 2 IOL consultant will also be of help in these situations.

Common contributing factors for poor refractive outcomes after Lens surgery

1. Use of outdated formulae/non optimized IOL constants
2. Incorrect measurement of axial length
3. Incorrect Keratometry values
4. Mistakes in entry of data into the IOL calculation programme
5. Incorrect labeling or packaging by the manufacturer
6. Mistakes in providing the correct IOL at the time of surgery eg: mix up IOL with another patient

Golden rules for a perfect IOL power calculation

1. Have well trained and experienced technicians attentive to the minutest details in performing keratometry and biometry
2. Calibrate all equipment for keratometry and biometry periodically
3. Measure both eyes always wherever possible.
4. Repeat or double check the measurements whenever in doubt and whenever possible especially when there is a difference of more than 0.2 mm in the same eye or more than 0.3 mm between the eyes unless explained by reasons like preexistent anisometropia.
5. Always use 3rd generation formulae or 4th generation formulae
6. Double check all manual entries like keratometry and axial length.
7. Use special formulae or special methods for calculating
the corneal power to be fed in post refractive surgical cases.
8. Have a proper IOL calculation report in the OR and make a final verification prior to IOL implant.

References