CERTIFICATE

This is to certify that **Dr. S.GANAPATHI RAJESH, M.S.**, Post Graduate student in ophthalmology, Regional Institute of Ophthalmology, Government Ophthalmic Hospital, attached to Madras Medical College, Chennai, carried out this Dissertation titled, **RELIABILITY OF BIOMETRY** by himself under my guidance and direct supervision, during the period July 2003 – September 2006. This dissertation is submitted to the Tamil Nadu Dr. MGR Medical University, Chennai in partial fulfillment of the award of M.S Degree in Ophthalmology.

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ACKNOWLEDGEMENT

I am grateful to **Prof. Kalavathy Ponniraivan, B.Sc., M.D.,** Dean, Madras Medical College, Chennai for permitting me to utilize the clinical materials and allowing me to do this study.

I express my profound gratitude to **Prof. V. Velayutham, M.S., D.O.,** Director and superintendent, Regional institute of ophthalmology, Government Ophthalmic Hospital, Madras Medical College, Chennai for his valuable guidance and through his vast experience has guided me throughout this study and made the completion of study a reality.

I am extremely grateful to **Prof. K.Vasantha, M.S., FRCS** who with her vast experience had rendered valuable guidance at various stages.

I wish to thank **Dr.M.Anandbabu,M.S.,D.O, Dr.R.Malarvizhi, M.S.,D.O** and **Dr C.L.Chitra,D.O** for their help and support.

I am thankful to all my colleagues for heir valuable help.

I am grateful to all my patients without their co-operation this study would not have been possible.

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PART I

INTRODUCTION

INTRODUCTION

The refractive power of Pseudophakos is final and the patient must live with any mistake committed (or) be subjected to a very dangerous operation, namely, to the removal and replacement of the intraocular lens (IOL).

To ensure that our patient will have the optimal correction, the power of the lens to be implanted must be determined precisely and perfectly in every case.

DETERMINATION OF INTRAOCULAR LENS POWER

DETERMINATION OF INTRAOCULAR LENS POWER

There are two ways to 0predetermine the power of the intraocular lens to be implanted in order to achieve the desired postoperative result.

1. Estimation of the Lens power on the basis of primary refraction
2. Calculation of the lens power on the basis of measurements.

Manufacturer produces lenses of different dioptric power by varying radii of curvatures using formula

$$D_{Lens} = \frac{N_{lens} - N_{AV}}{R_{lens}}$$

D_{lens} = Desired power of pseudophako

N_{lens} = Refractive index of pseudophako

N_{AV} = Refractive index of aqueous and vitreous

R_{lens} = Radius of pseudophako in meters

ESTIMATION OF IOL POWER TO BE IMPLANTED BASED ON PRIMARY REFRACTION

To achieve emmetropia (or) the preoperative basic refractive error, the power of the pseudophakos should be less than that of crystallize lens because the

pseudophakos is in a more forward position than the crystalline lens.

The basic refraction was used at a time when iris – fixated IOL, were in vogue. An 18-D iris fixated lens tends to restore the basic refraction. Adjustment were made up or down from 18D depending on how far from Emmetropia the basic refraction was. Because of the change of vertex distance from spectacles to an implant, 1.25 D was added to 18D for each diopter of Hypermetropia to be corrected and 1.25D was subtracted from 18D for each Diopter of myopia.

When using this method for posterior chamber lenses a factor of 1.6 is more reasonable than 1.25 because of their more posterior position.

CALCULATIONS OF THE POWER OF IOL TO BE IMPLANTED BASED ON MASUREMENTS

Human eye is an optical instrument that combines two light – bending elements

1. The anterior surface of cornea
2. The crystalline Lens

The power of the lens implant can be calculated if the following values are known.

1. The refraction of anterior surface of cornea
2. The distance of Retina from the anterior corneal surface
3. The anticipated distance of the IOL from the anterior corneal surface.

1. The Refractive power of the cornea

The refractive power of the cornea can be precisely calculated from the radius of curvature of the anterior corneal surface and from the refractive index of the anterior chamber fluid & vitreous.

The true refractive index of the cornea is 1.376. In order to consider the divergent effect of the posterior corneal surface in the calculation, it is customary to choose a fictitious refractive index of 1.337 for the calculation of the air – cornea – chamber fluid vitreous system

$$P_{Cornea} = \frac{N_{Cornea} - N_{air}}{R_{Cornea}\ (meters)}$$

P_{Cornea} = Refractive power of anterior corneal surface in diopters

N_{Cornea} = Refractive index of cornea

N_{air} = Refractive index of air

R_{Cornea} = Radius of anterior corneal surface in meters

In the presence of corneal astigmatism we have to take the median value reading as the working figure.

K readings can be taken either with a standard manual keratometer or with an automated keratometer. Automated keratometry is commonly used in many offices and these measurements are accurate for most patients with normal, average corneas. For the difficult, uncooperative patient, or those with unusual, highly toric or distorted corneas an Auto – K may be unreliable and should be confirmed with manual readings

The accuracy of Auto-K measurements can be determined by referring the confidence factor of the reading that is noted on the printout. Any reading with a confidence factor less than 75% should be discarded.

The keratometer measures the central anterior radius of curvature, information that is valuable in calculating the power of IOL implant. Only 2 points approximately 3 mm apart, are reliably measured. The mires of the keratometer are reflected by the cornea, which acts as a convex mirror, forming an erect, virtual image about 4 mm behind the cornea. The dioptric power of the cornea then is calculated by simple formula

$$D = \frac{1}{\text{Focal length}} = \frac{1}{r/2}.$$

Where D is corneal power in diopters and r is the radius of curvature in meters.

Two of the more commonly used instruments are the Bausch & Lomb keratometer and the Haag- Streit keratometer.

BAUSCH AND LOMB KERATOMETER

The Bausch & Lomb keratometer uses a method that holds the object size constant while changing the separation of two reflected images with a doubling prism. An image, consisting of a white illuminated circle along with plus and minus signs, is reflected by the cornea, traverses the telescope, and is focused at the focal plane of the objective lens.

The examiner focuses the instrument, rendering the doubled image single. The plus signs are aligned to measure one principal meridian, and the minus signs are aligned to measure the other principal meridian. Regularity of the elliptical image indicates regularity of corneal astigmatism. If high regular astigmatism is present, the image appears regular and elliptical. If irregular corneal astigmatism is present, the outline of the image is irregular.

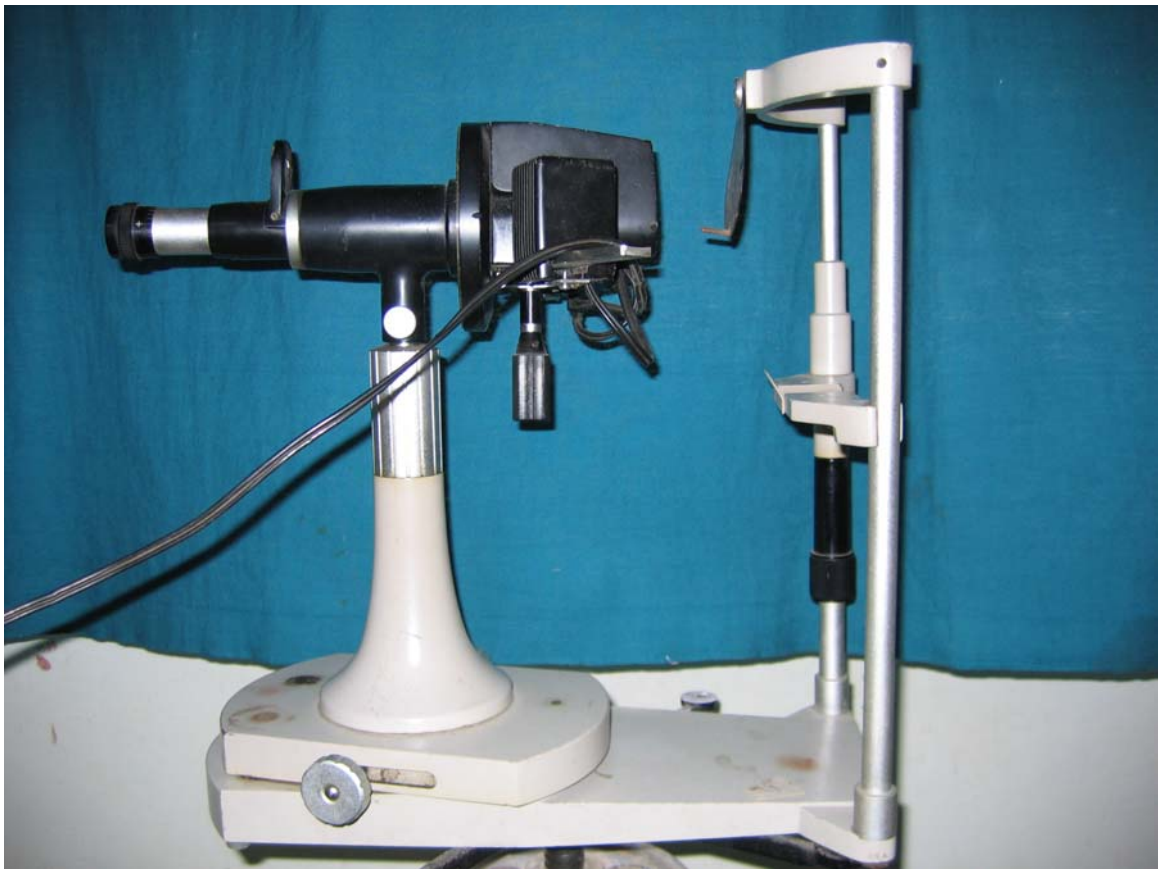
BAUSCH AND LOMB KERATOMETER

HAAG-STREIT KERATOMETER

The Haag- Streit ophthalmometer is the modern version of the Javal-Schiotz or universal ophthalmometer. To determine the size of the image reflected by the cornea, this instrument employs a method that changes the size of the object by a known amount while object distance and other factors are held constant. Two mires, one a red box and the other a green step formation, are reflected by the cornea. A telescope that traverses a circular track focuses these images. The examiner turns a thumbscrew to bring the mires together or apart, and rotates the circular track to align the thin black line bisecting each mire. Corneal curvature is read as radius in millimeters on one scale and as diopters of power on another.

The keratometer readings are recorded as power in the meridians measured. Corneal cylinder in minus power is the difference between the two meridians measured with the axis in the flatter meridian. Regular astigmatism exists when the mires are not distorted and are approximately 90 degrees apart. Irregular astigmatism exists when the mires are distorted or the principal meridians are not located 90 degrees apart. Corneal astigmatism is described as “with the rule” when the

JAVAL - SCHIOTZ KERATOMETER



vertical meridian is steeper of the two principal meridians. “Against the rule” astigmatism is present when the horizantal meridian is steeper.

Accurate K Reading Steps

Obtain patient cooperation and proper positioning

Focus the eyepiece

Obtain the K measurements for the horizontal (K1) and Vertical (K2) meridians

Validate the K readings

Procedure for Keratometry Measurement and Validation

Step 1: Turn dials on keratometer until the mires are properly superimposed. Remember the readings. Write them down if necessary.

Step 2. Turn the dials to unfocus the mires and then repeat step I until two readings are obtained in each meridian that are within 0.12D

Step 3. For significantly toric corneas (>3.00 D of astigmatism or difference between K1 and k2), the keratometer should be rotated 90 degree. Measure the vertical meridian with the plus “+” mire because it is easier to visualize and superimpose.

Step 4. Record the reading. Note the clarity of the mires.

Step 5. Determine if the readings obtained are unusual as described in Table given below. If unusual, repeat Steps 1-3 to validate the accuracy of the readings. It may be appropriate in extremely unusual eyes to have another examiner also take K to validate the accuracy.

The following K readings should be considered to present **unusual eyes:**

1. K. readings is < 40.00 D
2. K readings is > 47.00 D
3. The difference between the average Ks(difference between K1 & K2) between the two eyes is more than 1.00 D
4. The corneal cylinder (difference between K1 and K2) correlates poorly with the refraction cylinder

5.The keratometry mires are very distorted

Tips for Accurate K readings

1) K readings should be taken the same day as the A scan or as near to as possible

2) Focus the eyepiece by viewing the black "+" crosshair. Mark the position of the eyepiece. Each person who uses the same keratometer should focus the eyepiece to their

eye. This procedure is very important and often overlooked. Failure to focus the eyepiece properly can contribute to up to 0.50 D error in K

3) The keratometer should be calibrated using calibration spheres of three different radii of curvature.

A scan biometry

Ultrasound was first used in ocular diagnosis in 1956 by Mundt and Hughes. Oksala of Finland further refined this technique in the early 1960s. Ossoing further refined and developed meticulous examination techniques for both A- and B- scan, and the combined use of the two has today evolved into standardized echography.

Physics of ultrasound

Ultrasonography is based on the propagation, reflection and attenuation of sound waves. Ultrasound consists of high frequency sound waves of greater than 20 kilohertz. Those used for diagnostic ophthalmic ultrasound have a frequency of 7.5 to 12 megahertz (1 MHz = 10 6 Hz). These high frequency waves have a small penetration (approximately 6 cm at 7.5 MHz) but provide good resolution of minute structures in the

eye and orbit. The speed at which ultrasound travels depend on the medium through which it passes. As the ultrasound passes through tissues, part of the wave may be reflected back towards the probe; this reflected wave is referred to as an echo. Echoes are produced by acoustic interfaces that are created at the junction of media with different sound velocities. The greater the difference in sound velocities of the media at the interface, the stronger is the echo. The returning echoes are affected by many factors, including the size and shape of acoustic interfaces, the angle of incidence of sound beam, absorption, scattering and refraction. The detected echo is highest when the beam is incident perpendicular to the interface.

Sound velocity in various media

Anterior chamber	- 1533m/s
Normal lens	- 1641m/s
Vitreous	- 1532m/s
Cataract	- 1629m/s
Aphakic	- 1532m/s
PMMA IOL	- 2718m/s

A-MODE (AMPLITUDE MODULATION)

A-scan (A for amplitude) is a one-dimensional display in which echoes are represented as vertical spikes from a baseline. These spikes represent reflectivity, location and size of the anatomic structure.

The A-mode display is a time-amplitude display. The X-axis represents time elapsed, which is a function of tissue depth. Knowing the speed of ultrasound in soft tissues the distance between the spikes can be derived. The reflectivity is measured in decibels on the Y-axis and is directly related to the height of the spike above baseline. When on highest gain, the sound beam is widest, the penetration highest and the spike amplitude maximum, enabling visualization of the weak signals. When gain is lowered, the sound beam is narrower, with less penetration, and the spike amplitude is decreased. This eliminates the weaker signals but improves resolution (ability to display two interfaces as separate spikes).

The A-Scan represents the amplitude or height as it relates to the echo. An accurate reading can be obtained by observing the height of the echoes as they encounter ocular structure.

The objective of the A-Scan measurement is to maximize the reflection of the signal to confirm the perpendicular alignment of the fovea. In an accurate reading, the alignment of the sound beam is along the optical axis of the eye. Axial length is determined by measuring the time interval between the reflections or echoes of the sound wave resulting in recognizable pattern.

It will be beneficial for the beginner to understand the sound beam incidence on the ocular structures. An echo of high reflectivity is displayed from a large, smooth, interface (such as retina) when sound beam incidence is perpendicular. When the sound beam is directed towards that same interface at an oblique angle, the echo of lower reflectivity is displayed. It takes time, practice and patience to become proficient.

A-Scan measurement is the basis of IOL Power Calculation and has a significant impact on the calculated IOL power.

The A-scan probe of a frequency of 7.5 to 8 MHz is used for the orbit and 10 MHz for the globe. A non-focused beam is used, which has parallel borders allowing pattern recognition at different distances from the ultrasound probe.

INTERPRETATION OF NORMAL A-SCAN

Examination of a normal globe displays the following echo spikes from left to right.

1. The initial spike (I) represents reverberations at the probe tip and has no clinical significance.
2. The baseline (B) represents the vitreous cavity, which is characterized by absence of echospikes in normal conditions. The presence of any blip on the horizontal line needs evaluation to rule out a pathological condition.
3. The retinal spike (R) is a straight, high rising echospike perpendicular to the baseline. A jagged echospike means that the probe is not perpendicularly placed.
4. The choroidal spikes are multiple high reflective echospikes which are seen between the retinal spike (R) and the scleral spikes(S).
5. The scleral spike (S) is difficult to differentiate from choroidal spikes.
6. The orbital spikes(O) are multiple echospikes behind the scleral spike. The initial spikes are high reflective and the

reflectivity decreases rapidly because of sound attenuation in the orbit.

7. An electronic scale(E) is displayed on the lower part of the screen. Examination at low system sensitivity (low gain) clearly identifies the retinal and scleral echospikes.

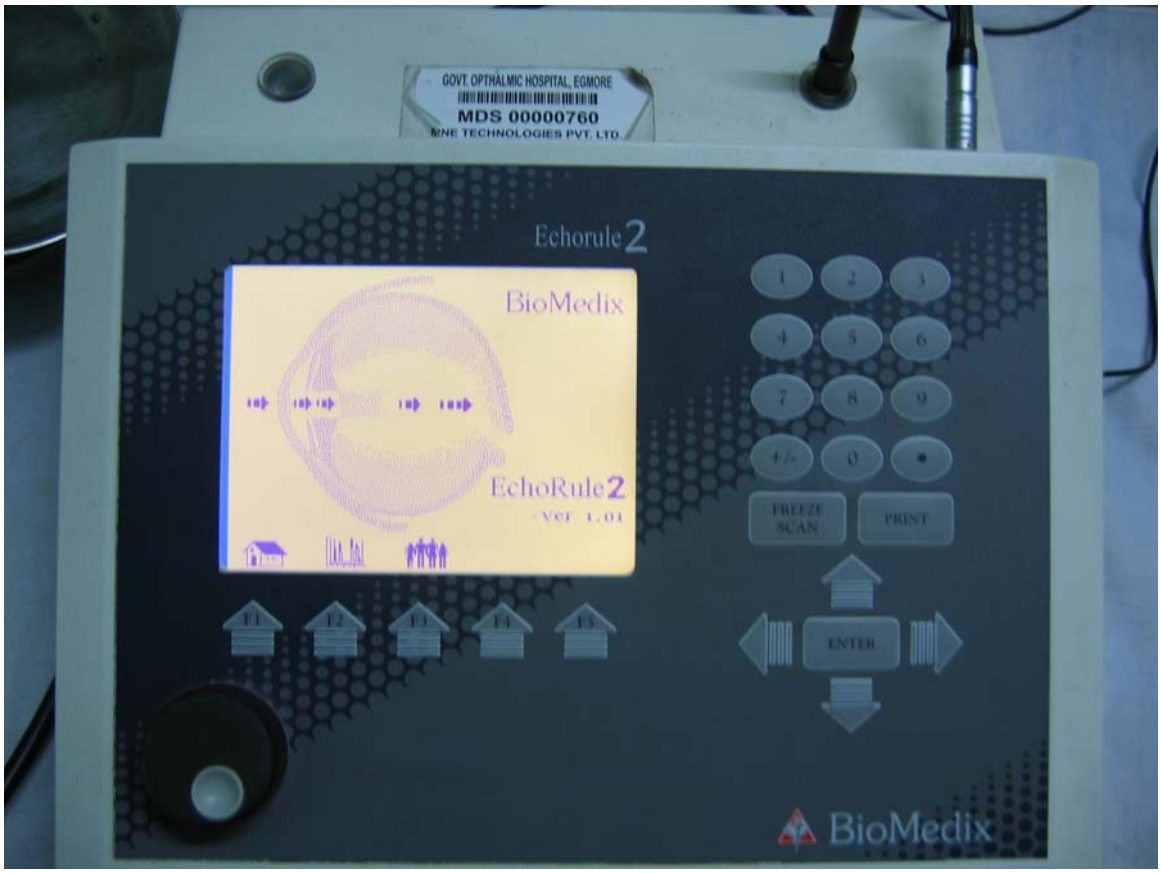
BIOMETRY

The most commonly used function of the A-scan is for measurements in the eye, i.e. Biometry. This includes measurement of axial length for IOL calculations, for monitoring eyes with congenital glaucoma, myopia and nanophthalmos and measuring intraocular parameters like anterior chamber depth and lens thickness.

Method

The A-scan biometer is a 10MHz solid probe with an inbuilt fixation light. The probe has to be aligned with the optical axis of the eye for accurate axial length measurement. This can be done by the immersion or the contact technique.

BIOMEDIX- A SCAN BIOMETER



Immersion Technique

The patient is placed in a supine position and local anesthetic instilled in both eyes. A scleral cup is placed between the lids, filled with 2 percent methylcellulose which is free of air bubbles. The probe is immersed in the fluid keeping it 5-10mm away the cornea. It does not touch the cornea and thus avoids any corneal compression.

The immersion technique is becoming more popular as the demand for perfection in post-operative visual acuity increase. The traditional immersion technique is performed with the patient in a semi-reclined position and using a scleral shell beneath the eye lids.

The transducer does not come into contact with the cornea, thus preventing the chances of corneal compression.

Procedure for Immersion Technique

Step1. Position the patent in a semi-reclined position in the examination chair, with their head securely in the headrest. Position the Biometry so that the screen can be easily seen whilst concentrating on the patient eye.

Step2. After checking all instrument settings, anesthetic drops are instilled in the patient eye and necessary instructions are given.

Step 3. A small plastic cylinder called the Prager's Shell is used in immersion technique. The transducer is introduced into the shell through the top end, till its tip is in line with the circular marker. Use the Set Screw to fasten the transducer at that position – now the transducer tip is approximately 9.5 mm from the corneal surface. Place the shell beneath the eye lids of the patient eye.

Step4. Once the Prager's Shell is well positioned beneath the patient's eye lids. Balanced Salt Solution is injected from a 15ml plastic bottle or a syringe through the thin plastic tubing that is attached to a port on the side of the shell.

Step5. As the patient gazes at the fixation light with the transducer probe, the sound beam is easily aligned to the visual axis. Continuous automatic readings are taken with indicative beeps from the machine.

Step6. Ensure that the transducer tip is fully immersed in the fluid before taking the measurement and also no air bubbles should be present inside the shell.

Step7. Review the AL & ACD Measurements by observing the corresponding spike patterns and also evaluate the Standard Deviation and Average Length displayed.

ADVANTAGES AND DISADVANTAGES OF IMMERSION BIOMETRY

This technique has some distinct advantages. Firstly, the cornea cannot be compressed because of the fluid bridge between the transducer tip and the cornea. Secondly, correct beam alignment is assured once all 5 spikes (cornea, anterior and posterior lens capsule, retina and sclera) are steeply rising and all of maximum height. If one or more of the spikes are indistinct or has a lower amplitude, then the sound beam is not aligned with the visual axis.

The immersion technique can provide consistently accurate readings. The technique can be performed more rapidly and with greater ease with some amount of practice.

The main disadvantage of the immersion technique is that it can take more time and has perhaps a learning curve. Air bubbles must be removed as they can give erroneous readings.

Contact technique

The patient is examined in the seated position after instilling local anesthetic drops. The patient is asked to fixate a target straight ahead with the non-testing eye or to look directly at the probe's fixation light with the tested eye. The probe is brought forward to touch the cornea without indenting it. It is properly aligned along the visual axis to optimize the five high amplitude spikes on the screen.

Procedure for Hand-Held Transducer Applanation Technique

Step1. Position the patient in a semi-reclined position in the examination chair with their head securely in the headrest, Position the Biometry so the screen can be easily seen with a minimum amount of movement by the physician.

Step2. Hold the transducer securely in the preferred hand. Rest the heal of the palm on the patient's face for stability.

Step3. Instruct the patient to gaze steadily into the LED fixation target. Hold the eye lids open. It may be necessary for an assistant to help with the lids.

Step4. Slowly bring the transducer in contact with the cornea. Ensure that the transducer is aligned exactly along the optical axis.

Step5. Do not leave the transducer on the cornea for more than 10 seconds. Do not slide the transducer on the cornea. If repositioning is necessary, pull the probe back away from the cornea, realign and then re-establish contact.

Step6. Ask the patient to blink in between the applantaion procedure, in order to keep the cornea moist.

Step7. Listen for the beeps which indicate the completion of a measurement. The Biometry will continuously record the measurement till 10 readings are registered in it.

Step8. Repeat steps 4 & 5 until satisfactory scans are obtained.

Step9. Repeat procedure with the opposite eye. Be sure to use the current Phakic Status (sound velocity) for the fellow eye.

Step10. Review the scan recorded one by one and evaluate with the help of Standard Deviation and Average calculations. Corresponding ACD (Anterior Chamber Depth) values are also displayed.

Procedure for Stand-Mounted Transducer Applanation Technique

In the Stand-Mounted method, a chinrest apparatus either independent or a part of the slit lamp is used. The transducer can be

mounted in a Goldmann or any other Tonometer Apparatus usually accompanied by a slit lamp.

Instructions for Balancing the Tonometer

When a Tonometer apparatus is used to hold the transducer, it must be balanced with the Transducer in place prior to taking a reading.

Step1. Remove the prism and place the tranducer in the tonometer head, entering from the back. Remove the small screw in the tonometer head if necessary. The transducer head should project approximately 2 cm though the front of the tonometer head.

Step2. Turn the tonometer dial to zero

Step3. Begin to slowly turn the dial while observing the transducer. Continue turning until the transducer falls forward and stops.

Steps4. Press gently on the transducer face with your index finger. With gentle pressure, the transducer should shift back slightly and fall forward again when released. If not, turn the dial until this result is achieved.

Step5. Loop the transducer cord around the slit lamp eye piece to help maintain proper balance of the transducer in the Tonometer head.

Steps for taking Measurements:

Step1. Properly position patient and physician.

Step2. Instruct the patient to gaze steadily at the fixation target.

Step3. Slowly approach the eye with the transducer centered on the optical center of the eye or papillary reflex. Gently make contact with the cornea and observe the Biometry for a display of the scan.

Step4. Pull the transducer back very slightly until contact is broken

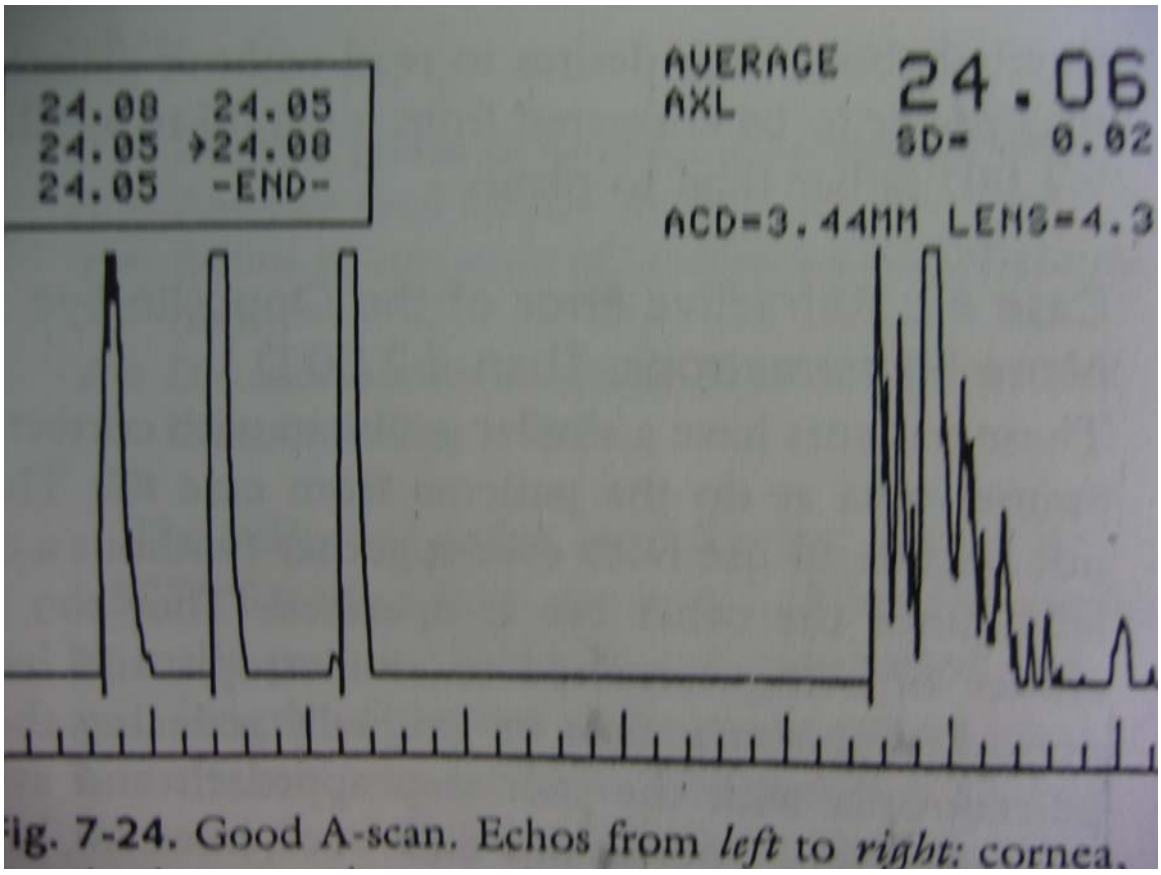
Step5. Re-establish corneal contact with a minimum amount of pressure, until the display shows a valid scan.

The five spikes in a phakic patient represent from left to right:

1. the anterior surface of the cornea,
2. anterior lens surface,
3. posterior lens surface,
4. anterior surface of retina, and
5. sclera.

An aphakic eye will not show the lens spikes though sometimes a spike of intact posterior capsule, if present, may be seen.

A - SCAN WITH CLEAR SPIKES



ig. 7-24. Good A-scan. Echos from *left* to *right:* cornea.

The leading edge of each echo spike should be perpendicular to the horizontal baseline. The gain is kept at the minimum level that allows proper resolution of these spikes. The density of the cataract determines the need for changing the gain setting, due to absorption of sound. The more dense the cataract, the higher the gain necessary to achieve good resolution. The anterior chamber depth which appears on the screen should also be monitored to detect corneal compression during contact biometry.

The biometer has an automatic as well as manual mode. Using the automatic mode increases the risk of error as the biometer may capture poor quality scans. Biometers are programmed to capture any scans with spikes that are of high amplitude within their given appropriate area. However, they cannot determine if the spike arose steeply from the baseline or if a step or hump was present in the spike origin. Manual mode is preferable, in which the examiner presses a foot switch to capture the scan when it is seen to be of high quality.

The axial length of the eyeball is measured from corneal surface to retinal surface and an electronic readout is obtained.

Characteristics of a Good A-Scan

1. A tall echo from the cornea, one peak with a contact probe, and a double peaked echo with an immersion probe.
2. Tall echoes from the anterior and posterior lens capsules
3. Tall sharply rising echo from the retina.
4. Medium tall to tall echo from the sclera
5. Medium to low echoes from the orbital fat.

In some patients it will be difficult to obtain all five criteria. In these cases atleast one should see a tall retinal echo that rises at 90 degree from the baseline and has no stair steps on the leading edge.

If this does not occur, then either

1. The probe is not perpendicular to the retina
2. There is some pathology interfering with A-scan

Height of echo pattern:

1. Anterior lens = 90 % of maximum
2. Posterior lens = 50 – 75 % of maximum
3. Retina = 75 % of maximum

Angle of echo rise of the retinal echo

1. Retinal echo must be a sharp 90 degree angle

Appearance of echo peaks

1. Echo peaks should be sharp peaks (not flat topped) and clear

If echoes from sclera & orbital fat are missing, this mean the sound is reflecting off the optic nerve head rather than the sclera.

Care to be taken doing A-scan

1. Makes sure the machine is set appropriately
2. Should not compress the cornea with the probe.
3. Make sure the measurement can be reproduced with reasonable precision

UNUSUAL EYES – DATA VALIDATION

Some patients have unusual eye parameter, including axial length and/or keratometry readings. It is important to recognize these patients because the change for error in both measurement and IOL power calculation is significantly increased. Data validation helps to identify unusual eyes. All unusual eyes should be remeasured and verified thoroughly so that the readings obtained are correct

In General, the axial length correlates some what to the patient's refractive error. Myopic patients tend to have longer axial lengths. Hyperopic patients tend to have shorter axial lengths. The exception to this may be induced myopia related to cataract or diabetes. In some cases, it may be helpful to look at the patient's earliest refraction for any indication regarding their original pre-cataract refractive error.

Most patients have similar refractive errors between the two eyes. A difference in axial length should trigger suspicion about the accuracy of the measurements. If after the eyes are remeasured, a difference of >0.3mm is still present, check the patient history for some evidence of a

significant difference in refractive error. It is extremely important to always measure both of the patients eye each time an axial length and IOL power calculation is performed.

The following cases should considered to represent **unusual eyes**:

1. Axial length <22.00 mm
2. Axial length > 25.00 mm
3. Difference in axial length between the two eyes of >0.3 mm
4. Axial length does not correlate well with the patient refraction
5. Patient has poor cooperation
6. Patient has poor fixation due to a very dense cataract
7. Patient has poor fixation due to other significant ocular pathology such as diabetic retinopathy or corneal disease

HOLLADAY'S Criteria for suspecting inaccurate preoperative measurement

1. Arial length < 22.0 (or) > 25.00 mm
2. Average corneal power < 40D (or) > 47D
3. Calculated emmetropic implant power & more than 3D from the average for the specific style used.
4. Between eyes the difference is
    a. Average corneal power > 1 D
    b. Arial length > 0.3mm
    c. Emmetropic implant power > 1 D

FORMULAS

FORMULAS

Using the described parameters, namely, the refractive power of the cornea from the radius of the corneal curvature, the axial length of the eye, as well as the assumed values of the cornea, lens distance and the shape (biconvex-Plano convex) and thickness of the IOL, we can calculate the power of the lens to be implanted. The pertinent rules were published by Gernet et al. as early as 1970, as well as by C.D. Binkhorst (1972, 1973a, b), R.D. Hinkhorst (1974), Colenbrander (1973), Fyodorov et al. (1975), Gills (1980), Retzlaff et al. (1982), Thijssen (1979), and van der Heijde (1975).

The accuracy of the IOL power calculation formulas is influenced by lens style, surgical technique, and the equipment used to measure axial length and corneal curvature.

Colenbrander's Formula

Fritz has shown that the formulas of Colenbrander, Binkhorst et al., and Fyodorov are essentially equal.

Colenbrander's formula for his determination of the power of the planoconvex emmetropic lens is as follows

$$P_{lens} = \frac{N_{AV}}{L_{eye} - (L_{CL} + d)} - \frac{N_{AV}}{\frac{N_{AV}}{K} - (L_{CL} + d)}$$

Where P_{lens} = power of the IOL (in diopters in water);

N_{AV} = refractive index of aqueous vitreous = 1.336;

L_{eye} = axial length of eye (in meters);

L_{CL} = distance of apex of the anterior corneal surface to the apex of the anterior surface of the IOL (in meters);

K = refractive power of cornea in diopters;

d = distance of the second principal points of the IOL from the apex of its anterior surface, equals 0.00005 meter.

Gill's Formula

The Gills method (1980), called "Computer Generated Intraocular Lens Power equation Formula for the Binkhorst two-loop lens" is as follows:

P_{lens} = 129.404739 + (-1.08023 x K) + (-2.793507 x L eye) + (0.262593 x L_{CL}) + (-0.384961 X Ref)

P_{lens} = lens power needed for desired postoperative refraction (spherical equivalent);

K= refractive power of cornea in diopters;

L_{eye} =axial length of eye in millimeters;

L_{CL} = distance of apex of the anterior corneal surface to the apex of the IOL in millimeters; and

Ref = desired postoperative refraction (spherical equivalent)

This formula takes into account not only the corneal curvature and axial length of the eye, but also the anterior chamber depth.

SRK Formula

Sanders, etal. (1981); Retzlaff, et al(1982); and Retzlaff (1980) have developed a formula that takes into account not only axial length and keratometer readings, but individual specifics of various IOLs, The formula is based on empiric values.

For the application of the SRK formula, we would like to quote from Sanders et. Al(1981);

"The "SRKtm formula," unlike the theoretic formulas, is based on the observed relationship between the preoperative variables (axial length and Keratometer readings) and the actual result (implant power required to achieve emmetropia)"

The SRK tm Formula is:

$P = A - 2.5\,L - 0.9\,K$

Where P = implant power to produce emmetropia (diopters), L = axial length (mm),

K = average keratometer reading (diopters), and

A = the specific constant for each lens type and/or manufacturer.

Clayman's Formula

An interesting practical approach to the intraocular lens power calculation was suggested by Clayman (1981) as a "ready reckon" method.

"Assume as follows:

1. The emmetropizing IOL = 18d (Irrespective of type)
2. The emmetropic axial length is 24.00 mm
3. The emmetropic average keratometer (K) reading is 42,00D.
4. One mm. in axial length = 3D of IOL power
5. Consider keratometry is 1D = 1D.
6. When this method calls for an IOL greater than 21D, deduct 0.25 D for every diopter greater than emmetropia (18.00D).

Mawas Formula (Eureka)

Mawas (Mawas,1984) reported a modification of the SRK formula: "Formule diffentiell basee sur le phenomenee d' emmetropisation (Eureka)".

According to this formula, one calculates the mean "K", considers the results as a normal emmetropic eye: subtracts the individual readings. In the Mawas formula the emmetropic normal eye's axial length L=23.2 mm.

The K-reading using the index number of 1.3376 is 43.25

BINKHORST II AND HOLLADAY FORMULAS

$$IOLam = \frac{1336[1.336-0.3333LC-0.001Tam(16.032R-4LC+LCxR)]}{(LC-CA)[1.336-0.3333CA-0.001Tam(16.032R-4CA=CaxR)]}$$

R : curvature of cornea(mm)

LC: axial length corrected

CA: post operative anterior chamber

SRK-II FORMULAS:

Emmetropic power : P = A-2.5L – 0.9K = C

If L < 20 mm then C = +3

If 20 < L < 21 mm then C = +2

If 21< L < 22 mm then C = +1

If 22< L <24.5 mm then C = 0

If L > 24.5 mm then C = -0.5

SRK-T FORMULAS;

Retinal thickness = o.65696-0.02029 x L

L_{cor} = L except if L > 24.2 then L_{cor} = -3.446 + (1.716 x L) – (0.0237 x L^2)

R_{cor} = 337.5/Kd (with K in diopters)

Crwdest = -5.40948 + 0.58412 x L_{cor} +0.098 x K

SqrootR1 = $(R_{cor})^2$ – $(crwdest)^2/4$

If SqrootR1 < 0 then SqrootR1 = 0

H_{est} = R_{cor} – SQRT(SqrootR1)

ACDT = 0.62467 x A – 68.7470 where A = SRK constant

ACD_{est} = H_{est} + ACDT – 3.3357

na = 1.336

C1 = $337.5/_{Kmm}$

$C2 = 0.3333$

$C3 = L + rethick = 0.97971 \times L + 0.65696$

$C4 = C3 - ACD_{est}$

$C5 = na \times C1 - C2 \times ACD_{est}$

$C6 = na \times C1 - C2 \times C3$

$C8 = 12 \times C6 + C3 \times C1$

$V = 12$ vertex distance : lens/cornea

$C9 = 12 \times C5 + ACD_{est} \times C1$

$$T_{am} = \frac{1336 \times C6 - IOL_{am} \times C4 \times C5}{1.336 \times C8 - 0.001 \times IOL_{am} \times C4 \times C9}$$

$$IOL_{am} = \frac{1336 \times (C6 - 0.001 \times T_{am} \times C8)}{C4(C5 - 0.001 \times T_{am} \times C9)}$$

SOURCES OF ERROR

SOURCES OF ERROR

Even if a given IOL formula were as mathematically accurate as possible however prediction errors would occur because of errors in the measurement of the axial length, the corneal power and in the estimation of the ACD.

I. Axial Length Error.

Measurement of the axial length by ultrasound is the most critical step in any IOL calculation.A general method of estimating measurement errors is to evaluate the error between repeated measurements.

Most A-scan use an overall velocity of ultrasound for the distance from the cornea to the retina and do not measure the lens thickness. Even if the lens thickness were measured in each case errors might arise from uncertainties regarding the precise ultrasonic velocity and density of the Cataract, which may vary considerably from case to case.

II. Corneal Power Error

Although the average power of the cornea changes only slightly after cataract extraction, some variation does exist, partly from surgical flattening (or) steepening of the cornea and partly from measurement error. That is some variability is due to surgical influence and some variation is due to instrument error.

III. Psendophakia Anterior Chamber Depth

The refractive effect of an IOL depends on its position with in the eye. If the implant is placed more anteriorly than expected, the refraction will shift to them yopic side, and if deeper than expected the eye will become more hyperopic than expected. The larger the variation in the postoperative ACD, the larger the eventual prediction error.

PART II
AIM OF THE STUDY

AIM OF THE STUDY

To study the reliability of A –scan biometry in Tertiary Institution where measurements were taken by multiple persons

MATERIALS AND METHODS

MATERIALS AND METHODS

A retrospective series of 110 cases of cataract extraction and in the bag fixation of the IOL done in RIO-GOH were investigated.

Cataract extraction done by

1) extra capsular cataract extraction
2) small incision cataract surgery and
3) phacoemulsification

were included in the study.

Keratometry was performed with the Bausch and Lomb keratometer which uses fictitious index of 1.3375. In the presence of corneal astigmatism the median value reading was taken as the working figure.

The axial length was measured with a Biomedix A – scanner

using an applanation type 10 MHz transducer. The velocity of ultrasound was assumed to be 1,550 m/s for the distance between the cornea and the retina and 1,532 m/s for the anterior chamber.

IOL type included in the study

Single piece, biconvex, Mod C step vault, PMMA, UV absorbing IOL with optic size 6.5mm and length 13.5mm

A constant – 118.2

The pseudophakic refraction was predicted according to SRK- II formula.

All refractions were spherical equivalents of the spectacle corrections recorded four to six weeks after surgery. Only cases with a final visual acuity of 6/9 or better were included because of minimal intended refractive error due to difference between calculated IOL power and implanted IOL power.

Inclusion criteria

1)all uncomplicated cases of cataract surgery.

Exclusion criteria

1) congenital and developmental cataracts
2) cases with postoperative complications
3) patients for whom IOL was not fully in the bag

RESULTS

RESULTS

The keratometry, axial length and IOL powers are detailed in table

Keratometry	Mean	44.57
	Range	41 to 47.52
Axial length	Mean	22.52
	Range	20.17 to 25.2
IOL power	Range	17 to 27

The number of patients who had UCVA of 6/9 or better was 20

Postoperative refractive errors are listed in tables

1) cylindrical errors

Cylindrical power	Number of patients
< -1.00D cylinder	56
-1.00 to –2.00D cylinder	28
> -3.00D cylinder	6

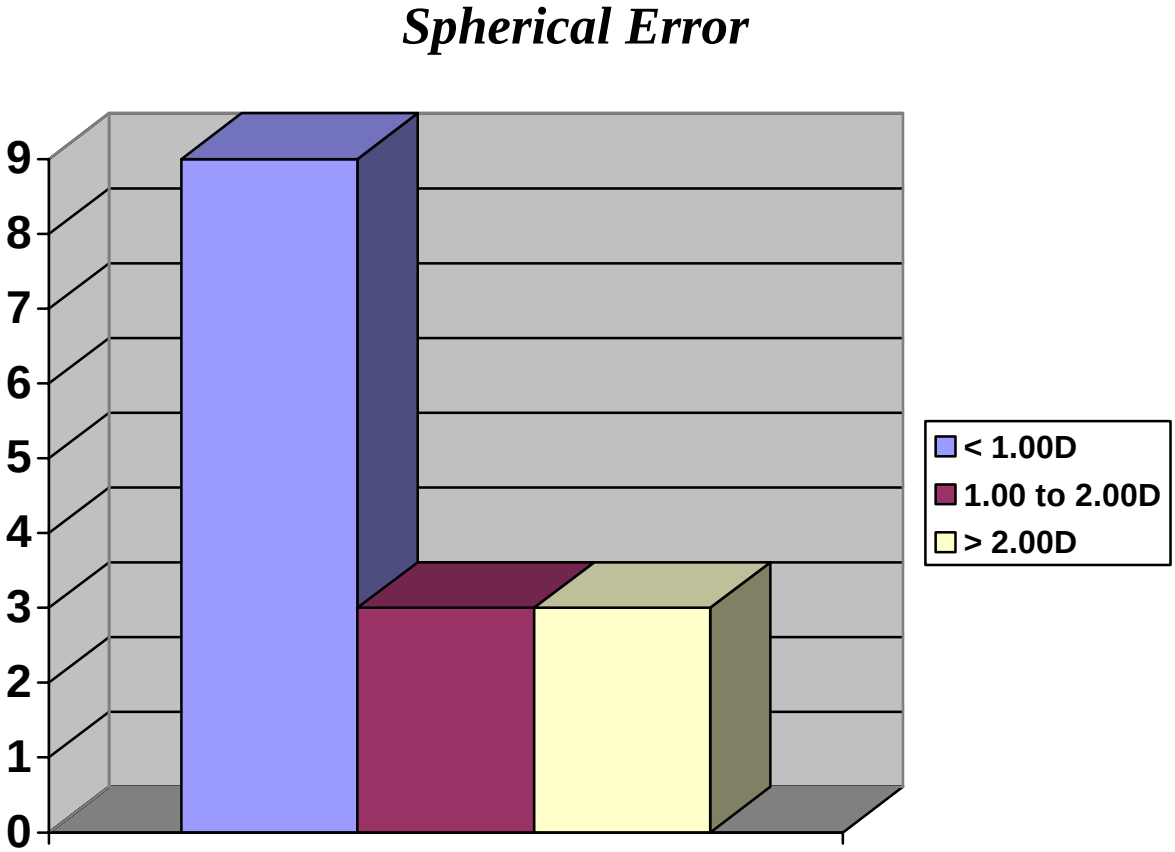
2) spherical errors

Spherical error	Number of patients
< 1.00D	9
1.00 to 2.00D	3
> 2.00D	3

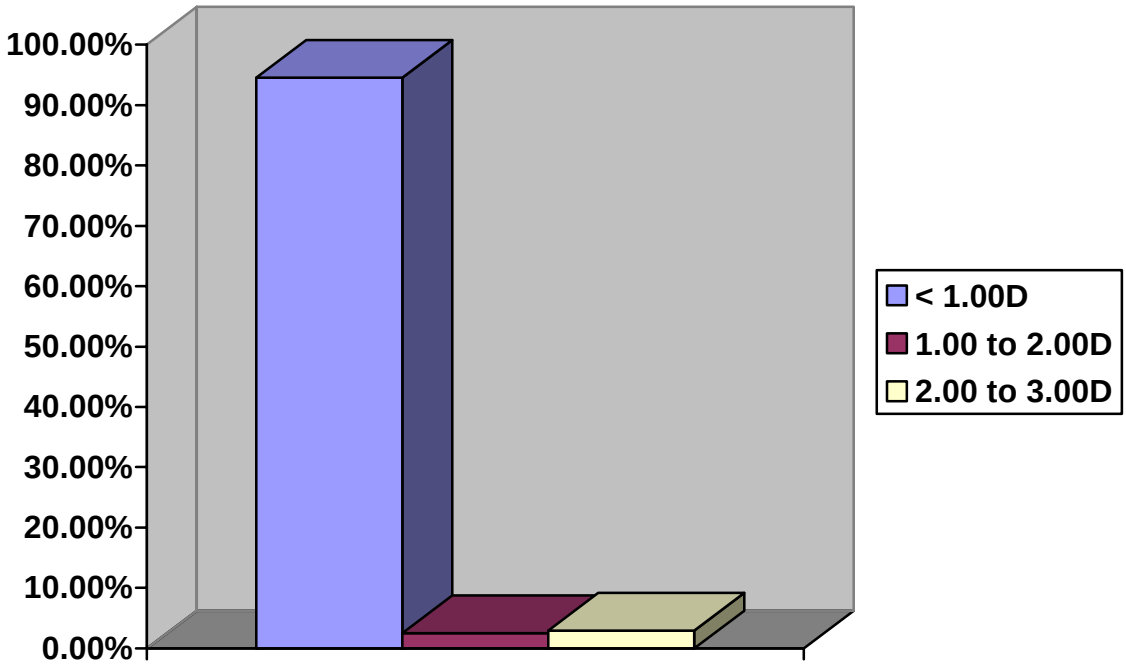
The variance of outcome of spherical equivalence in

percentage

	%
< 1.00D	94.5%
1.00 to 2.00D	2.5%
2.00 to 3.00D	3%


Spherical Error
9
8
7
6
5
4
3
2
1
0
< 1.00D
1.00 to 2.00D
> 2.00D

Percentage of outcome of Spherical Equivalence



All the cylindrical errors are due to surgical incisions. Hence spherical equivalence is not calculated and only spherical errors are taken into discussion.

ANALYSIS AND DISCUSSION

ANALYSIS AND DISCUSSION

The visual results are expressed as the percentage of eyes that achieved UCVA and BCVA of 6/9 or better.

The refractive results are given as percentage of patients with biometry prediction errors of less than 1,2 and 3 D. 94.5% of patients had postoperative refractive error less than -1.00 dioptre of sphere.97% of patients had postoperative refractive error less than –2.00D. The remaining patients had postoperative spherical equivalent up to –3.00 dioptres.

This could be explained by the defective measurements made preoperatively.

Intraocular lens power prediction errors can be divided into

1) measurement errors
2) formula errors

Formula errors can arise as aresult of inadequate mathematical

representation of the optics of the pseudophakic eye or as a result of errors in the prediction of surgical effect.

In this study 97% of patients had postoperative refractive error of less than 2.00 Dioptres which when compared to other studies using same formula (with results of 100% less than 2.00 Dioptres) is slightly lower.

Most of the reference studies used partial coherence interferometry(IOLMaster) for measuring axial length. Measurements were taken by a trained optometrist or two. Whereas in our study it was done by ultrasound biometry and measurements were taken by various persons including trained optometrists, students and Ophthalmologists.

The difference in axial length measured between ultrasound biometry and partial coherence interferometry was upto 0.47mm longer in partial coherence interferometry which corresponds to around 1.5 Dioptres.

Reasons for difference in length are

1) pressure exerted by ultrasound probe

2) in partial coherence interferometry light is reflected at the retinal pigment epithelium whereas ultrasound is mainly reflected at the internal limiting membrane, thus resulting in difference that corresponds to the retinal thickness of the fovea, which is about 130μm

CONCLUSION

CONCLUSION

With the evolution of small incision techniques that minimize surgically induced astigmatism, IOL power selection becomes a crucial step for the refractive outcome of cataract surgery.

The present study has shown that in Institution where multiple persons perform Biometry chances of postoperative refractive error can be minimized if precise and proper technique is followed and it is possible to have prediction errors below1.00 D on the average.

The chance of postoperative refractive error could be further reduced if SRK T formula is used for IOL power calculation.

PART III

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BIBLIOGRAPHY

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PROFORMA

PROFORMA

Patient Name:

IP NO:

Age / Sex:

Keratometry reading:

Axial length:

IOL Power:

Date of surgery:

Post operative period:

Post operative refraction:

MASTER CHART

S.No	IP No	Age	sex	K reading	Axial length	IOL power	post op refraction
1	395201	60.00	F	46.5	21.38	23.5	_-0.50D cyl
2	395266	74.00	F	45	22.59	21	n
3	395300	65.00	F	44.25	20.17	26	_-1.50Dcyl
4	395259	58.00	M	46.25	21.92	22.5	_-0.50D cyl
5	395316	45.00	M	45	22.05	23	_-2.00Dcyl
6	395337	75.00	F	45.25	22.45	21.5	_-0.75Dcyl
7	395282	78.00	M	44.25	23.36	20	n
8	395210	84.00	M	44.5	22.72	21	_-1.00Dsph-1.00dcyl
9	395400	60.00	F	44.25	22.49	22	_-0.50D cyl
10	395353	87.00	F	45.75	20.8	25	_-0.75Dcyl
11	395204	60.00	M	44.25	22.95	21	_-0.50D cyl
12	395216	45.00	M	42.25	25.27	17	n
13	395362	55.00	F	41.25	21.89	27	_-1.50Dcyl
14	395372	40.00	F	44.75	22.53	21	_-0.50D cyl
15	395248	53.00	M	46.5	22.52	20	_-3.00dsph-1.00dcyl
16	395242	65.00	F	45.25	21.71	23.5	n
17	395320	75.00	F	47	20.63	25	_-0.75Dcyl
18	395328	46.00	M	44.25	22.84	21	_-0.50D cyl
19	395289	37.00	M	41	21.29	17.5	_-2.00Dsph-1.50Dcyl
20	395251	60.00	M	42.75	23.48	21	_-3.50Dcyl
21	395226	48.00	F	44.5	24.61	20	_-0.50D cyl
22	395313	68.00	M	47.25	21.31	23	n
23	395341	67.00	M	43.25	23.36	20.5	_-2.50Dsph-1.00dcyl
24	395214	70.00	M	45.25	23.4	19	n
25	395207	60.00	M	43.25	23.45	20.5	_-1.00dcyl
26	395306	82.00	M	45	22.54	21	_-0.75Dcyl
27	395354	77.00	M	43.5	22.32	23	_-2.00Dsph-2.00Dcyl
28	395344	57.00	M	43.5	22.62	22	_-0.50D cyl
29	395378	42.00	F	44.75	23.28	23	_-1.00dcyl
30	395259	58.00	M	46.25	21.92	22.5	_-0.50D cyl
31	395291	54.00	M	43	23.82	20.5	n
32	395268	65.00	F	44.75	23.03	20.5	_-1.50Dsph-1.50Dcyl
33	395388	40.00	F	45	21.35	25	_-2.00Dcyl
34	395261	75.00	M	43	24.22	19	_-0.50D cyl
35	395239	75.00	M	44.25	22.34	22.5	_-1.50Dcyl
36	395348	70.00	M	44.5	22.84	21	_-1.00dcyl
37	395325	60.00	M	45.25	22.84	21	n
38	395342	70.00	F	44.25	21.9	24	_-1.00Dsph-1.00dcyl
39	395350	80.00	M	43.5	22.52	22	_-0.75Dcyl
40	395263	70.00	F	45	22.91	20	_-3.00Dcyl

41	395244	61.00	M	44.75	21.63	23	_-2.00Dcyl
42	395250	60.00	M	47	22.17	20.5	n
43	395245	50.00	M	45	23.44	19.5	_-0.75Dcyl
44	393308	54.00	M	43.75	23.51	21	_-3.50Dcyl
45	395254	65.00	M	47.25	22.38	20	_-1.50Dcyl
46	395369	58.00	F	45.25	22.44	21	n
47	395352	57.00	M	42.25	23.38	21	_-2.00Dcyl
48	395241	45.00	M	46	21.81	23	n
49	395249	65.00	M	46.5	21.69	23	_-0.75Dcyl
50	395225	57.00	M	44.75	22.45	22	_-1.00dcyl
51	395247	70.00	M	43.75	22.66	22	_-2.00Dcyl
52	395252	62.00	M	44.5	22.54	21.5	_-0.50D cyl
53	395370	55.00	F	43.5	22.43	22	_-1.00Dsph-1.50Dcyl
54	395343	70.00	F	43.25	22.83	22	_-0.50D cyl
55	395271	60.00	M	43.5	22.24	23	_-1.00dcyl
56	395108	60.00	M	44.5	22.46	21.5	_-1.00Dsph-2.50Dcyl
57	395361	45.00	F	45	21.6	24.5	_-0.50D cyl
58	395301	60.00	F	43.75	23.5	20	n
59	395319	50.00	M	44.75	22.23	22	_-2.00Dcyl
60	395326	68.00	M	45.75	23.44	19.5	_-0.75Dcyl
61	395339	69.00	F	46.5	22.43	18	_-3.00Dcyl
62	395288	60.00	M	45.75	22.72	20	_-0.50D cyl
63	395302	56.00	M	43.25	23.35	20.5	_-1.50Dcyl
64	395385	50.00	F	46	22.2	21	_-0.50D cyl
65	395398	53.00	M	47.52	21.59	22.5	_-1.00dcyl
66	395202	43.00	M	44.25	22.03	23	n
67	395221	54.00	M	44.25	23.22	20	_-0.50D cyl
68	395212	65.00	F	45.75	21.4	23.5	n
69	395209	75.00	M	43.75	23.09	21	_-2.00Dcyl
70	395287	67.00	F	45.25	24.19	17	_-3.00Dcyl
71	395276	65.00	F	42.75	22.43	23	_-0.50D cyl
72	395260	65.00	F	43	22.87	22.5	n
73	395255	70.00	M	44.5	22.35	22	_-0.75Dcyl
74	395298	65.00	F	43.5	23.13	21	_-2.00dsph-1.00dcyl
75	395399	52.00	M	43.5	22.07	23.5	n
76	395380	50.00	M	42.5	23.1	22.5	_-3.50Dcyl
77	395290	52.00	M	46	21.44	23	_-0.50D cyl
78	395256	60.00	F	45.75	21	21	n
79	395292	47.00	M	41.75	23.59	21.5	_-0.75Dcyl
80	395208	53.00	M	41.5	23.2	22.5	_-2.00Dcyl
81	395222	70.00	M	46.25	21.81	23	_-0.50D cyl
82	395213	65.00	M	43	22.74	22.5	_-1.00dcyl
83	395203	58.00	M	43	21.98	24	_-4.00Dcyl
84	395422	60.00	M	43.75	23.5	20	_-0.50D cyl
85	395408	65.00	M	44.75	22.23	22	_-2.00Dcyl
86	395452	72.00	M	45.75	23.44	19.5	_-1.00Dsph-

							1.00dcyl
87	395427	52.00	M	46.5	22.43	18	_-3.50Dcyl
88	395522	58.00	M	45.75	22.72	20	_-0.50D cyl
89	395536	64.00	F	43.25	23.35	20.5	n
90	395544	57.00	F	46	22.2	21	_-3.00Dsph-1.00dcyl
91	395555	61.00	M	47.52	21.59	22.5	_-0.50D cyl
92	395502	63.00	F	44.25	22.03	23	_-3.00Dcyl
93	395562	85.00	M	44.25	23.22	20	n
94	395573	75.00	M	45.75	21.4	23.5	_-1.00dcyl
95	395581	78.00	F	43.75	23.09	21	_-0.50D cyl
96	395487	50.00	F	45.25	24.19	17	_-1.00Dsph-0.50Dcyl
97	395433	54.00	F	44.25	20.17	26	_-1.50Dcyl
98	395601	62.00	M	46.25	21.92	22.5	_-2.00dsph-2.00Dcyl
99	395595	67.00	F	45	22.05	23	_-0.75Dcyl
100	395603	68.00	M	45.25	22.45	21.5	_-1.00dcyl
101	395611	78.00	M	44.25	23.36	20	_-0.50D cyl
102	395636	79.00	M	44.5	22.72	21	_-1.00Dsph-1.50Dcyl
103	395624	45.00	F	44.25	22.49	22	_-0.50D cyl
104	395628	48.00	M	45.75	20.8	25	_-2.50Dcyl
105	395630	52.00	F	44.25	22.95	21	_-0.75Dcyl
106	395633	65.00	M	44.5	22.72	21	_-1.00dcyl
107	395672	68.00	F	41.25	21.89	27	_n
108	395685	72.00	F	44.75	22.53	21	_-0.50D cyl
109	395690	58.00	F	43.75	22.66	22	_-2.00Dcyl
110	395698	52.00	M	44.5	22.54	21.5	_-0.50D cyl