A STUDY ON COMPARISON OF CENTRAL CORNEAL THICKNESS IN NORMALS, PRIMARY OPEN ANGLE GLAUCOMA AND OCULAR HYPERTENSIVES

DISSERTATION SUBMITTED FOR

MASTER OF SURGERY DEGREE

BRANCH – III - OPHTHALMOLOGY

APRIL 2012

THE TAMILNADU
DR.M.G.R. MEDICAL UNIVERSITY
CHENNAI, TAMILNADU

Dept. of Ophthalmology,
Govt. Rajaji Hospital,
Madurai.

CERTIFICATE

This is to certify that this dissertation entitled **"A STUDY ON COMPARISON OF CENTRAL CORNEAL THICKNESS IN NORMALS, PRIMARY OPEN ANGLE GLAUCOMA, AND OCULAR HYPERTENSIVES**" has been done by **DR. M. SHERIN HAROON** under my guidance in DEPARTMENT OF OPHTHALMOLOGY, Madurai Medical College, Madurai.

I certify regarding the authenticity of the work done to prepare this dissertation.

DR. P.THIYAGARAJAN. M.S., D.O.,

PROFESSOR & H.O.D.
DEPARTMENT OF OPHTHALMOLOGY
GOVT. RAJAJI HOSPITAL &
MADURAI MEDICAL COLLEGE
MADURAI.

DECLARATION

I, **Dr. M. SHERIN HAROON,** solemnly declare that the dissertation titled **"A STUDY ON COMPARISON OF CENTRAL CORNEAL THICKNESS IN NORMALS, PRIMARY OPEN ANGLE GLAUCOMA AND OCULAR HYPERTENSIVES"** has been prepared by me.

This is submitted to The Tamil Nadu Dr. M.G.R. Medical University, Chennai, in partial fulfillment of the requirement for the award of M.S.,(Ophthalmology) Branch-III degree Examination to be held in APRIL 2012.

Place : Madurai

Date : **Dr.M. SHERIN HAROON**

ACKNOWLEDGEMENT

I am deeply indebted to **Dr. P. THIYAGARAJAN. M.S., D.O, Professor and Head of the department of Ophthalmology, Madurai Medical college, Madurai** for the able guidance, inspiration and encouragement he rendered at every stage of this study.

I am extremely thankful to **Prof. Dr. G.S. SRINIVASAN, M.S., DO.,** for his immense support and guidance in doing this study.

I acknowledge with gratitude the dynamic guidance and persistent encouragement given to me by my guide **Dr. N. PARVATHA SUNDARI, M.S., DO, Assistant Professor in Ophthalmology, Department of Ophthalmology, Madurai Medical College, Madurai** for having taken keen interest in sharing her ideas throughout the study period.

I thank all my **Assistant Professors** for their encouragement, advice and guidance.

My Sincere thanks to **Dr.A. EDWIN JOE, M.D (FM) B.L.** ., **Dean, Madurai Medical College, & Govt Rajaji Hospital, Madurai** for permitting me to utilize the clinical materials of the hospital.

Last, but not the least, my profound gratitude to all the ‘patients’, to whom I owe everything because, this venture would not have been possible with out them.

CONTENTS

PART ONE PAGE NO

PART TWO

APPENDIX

A STUDY ON COMPARISON OF CENTRAL CORNEAL THICKNESS IN NORMALS, PRIMARY OPEN ANGLE GLAUCOMA AND OCULAR HYPERTENSIVES

ABSTRACT

AIM:

To compare the central corneal thickness (CCT) and determine the range and distribution in controls, primary open angle glaucoma (POAG) patients and ocular hypertensives. Also to predict any differences in central corneal thickness in relation to age and sex variation.

METHODS :

One hundred and fifty patients (50 controls, 50 POAG patients, 50 ocular hypertensives) aged 40 years or more were enrolled in our study and all subjects underwent a complete ophthalmic examination that included applanation tonometry and CCT measurements with an ultrasonic pachymeter.

RESULTS :

Mean central corneal thickness in 50 control subjects was 533µm (SD 29µm) , 50 POAG patients was 536µm (SD 29µm) , 50 ocular hypertensives was 561µm (SD 28µm).There were no differences between sexes in our study in

POAG and ocular hypertension ,though CCT was higher in females in control group.

CONCLUSION :

Mean central corneal thickness was similar to that found in clinical studies, and was significantly higher in patients with ocular hypertension. A negative association with age and a positive association with intraocular pressure were seen. CCT can be a confounding factor in the measurement of intraocular pressure.

KEY WORDS: central corneal thickness, applanation tonometry, primary open angle glaucoma, ocular hypertension.

INTRODUCTION

Glaucoma is one of the most important causes of irreversible bilateral blindness. Its estimated prevalence in India is about 3% to 4%. Because early detection and treatment may slow the rate of visual field loss and consequent blindness, there have been efforts to develop screening methods for the early diagnosis of the disease.

Screening for glaucoma is however a daunting problem. Patients need to be screened appropriately referred, advised and treated if glaucomatous optic disc damage and field loss has to be avoided. The traditional approaches to screening include Tonometry, optic disc evaluation, assessment of nerve fiber layer and visual field tests, all of which have marked limitations. Goldmann applanation Tonometry is the current gold standard for the measurement of IOP.

Various studies have shown that variations in central corneal thickness affect the accuracy of measurement in intraocular pressure by applanation Tonometry. The present study is aimed at comparing central corneal thickness in open angle glaucoma, ocular hypertension and controls.

TONOMETERS AND TONOMETRY

IOP MEASUREMENT

DIRECT METHOD

To measure IOP directly in a living eye using a manometric technique.

A needle is inserted into anterior chamber via paracentesis site and is connected to fluid filled tubing. The height of fluid in tube corresponds to IOP. Needle can also be connected to fluid filled reservoir with pressure sensitive membrane. Movement of membrane recorded optically or electronically is a measure of IOP. Not applicable clinically.

INDIRECT METHOD

- Based on eye response to an applied force
- IOP measurement is performed by deforming the globe and correlating the force responsible for it to the pressure in the eye.

Palpation Method:

IOP estimated by response of eye to pressure applied by finger pulp (indents easily / firm to touch).

CLASSFICATION OF TONOMETERS

All clinical tonometers measure the intraocular pressure by relating a deformation of globe to the force responsible for deformation. Two basic types differ according to the shape and magnitude of the deformation.

1. Indentation tonometry and
2. Applanation (flattening) tonometry.

Indentation Tonometers

The shape of the deformation with this type of Tonometer is a truncated cone (fig 1A). The precise shape, however is variable and unpredictable. In addition, these instruments displace a relatively large intraocular volume. As a result of these characteristics conversion tables based on empirical data from in vitro and in vivo studies must be used to estimate the IOP. The prototype of this group, the **Schiotz Tonometer**, was introduced in 1905.

Applanation Tonometers

The shape of the deformation with these tonometers is a simple flattening (fig 1B), and because the shape is constant, its relationship to the IOP can, in most cases, be derived from mathematical calculations. The applanation tonometers are further differentiated on the basis of the variable that is measured.

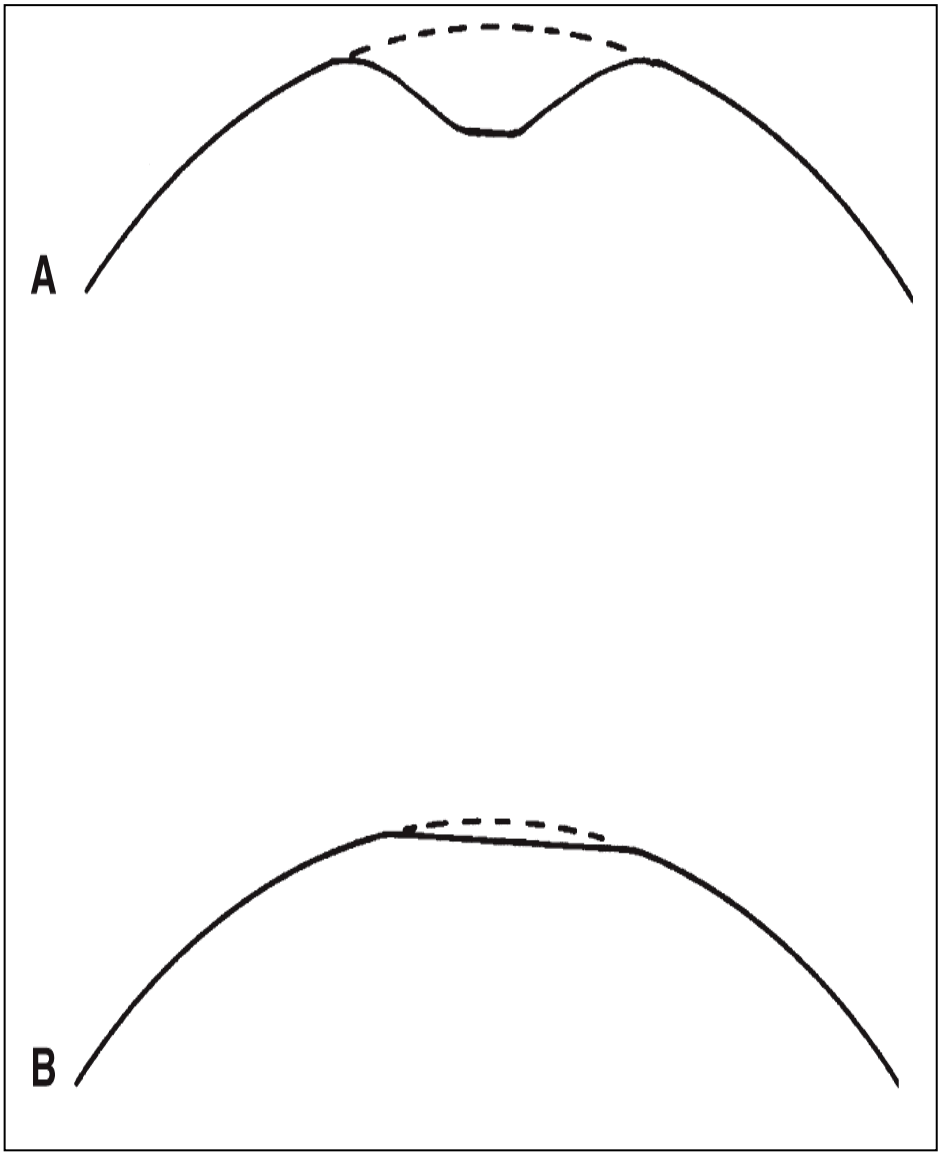


Fig 1.Corneal deformation created by (A) indentation tonometers (a truncated cone) and (B) applanation tonometers (simple flattening)

Variable force

This type of Tonometer measures the force that is required to applanate (flatten) a standard area of the corneal surface. The prototype is the *Goldmann* applanation Tonometer, which was introduced in 1954. Others include:

1. Hand held Goldmann type tonometers
    - Perkins
    - Draegers
2. Mackay marg tonometer
3. Tonopen
4. Pneumatic tonometer.

Variable area

Other applanation tonometers measure the area of cornea that is flattened by a known force (weight). The prototype in this group is the *Maklakov* Tonometer, which was introduced in 1885.

Others include: 1. Applanometer
2. Tonomat
3. Halberg tonometer
4. Glaucotest.

The division between indentation and applanation Tonometers, however, does not correlate entirely with the magnitude of intraocular

volume displacement. Goldmann type tonometers have relatively minimal displacement, whereas that with Maklakov-type tonometers is sufficiently large to require the conversion tables.

Non contact Tonometer

A third type of Tonometer uses a puff of air to deform the cornea and measures either the time or force of the air puff that is required to create a standard amount of corneal deformation. The prototype was introduced by *Grolman* in 1972. Eg. Pulsair tonometer.

GOLDMANN APPLANATION TONOMETRY

Basic concept

Goldmann applanation Tonometry is the international clinical standard for measuring intraocular pressure. Goldmann based his concept of Tonometry on a modification of the Maklakov-Fick law (also referred to as the Imbert-Fick law).[1,2]

This law states that an external force (W) against a sphere equals the pressure in the sphere (P_t) times the area flattened (applanated) by the external force (A) (fig 2A) $W = P_t \times A$

The validity of the law requires that the sphere be a) perfectly spherical, b) dry, c) perfectly flexible, and d) infinitely thin. The cornea fails to satisfy any of these requirements, in that it is aspherical and wet, and neither perfectly flexible nor infinitely thin. The moisture creates a surface tension (S), and the lack of flexibility requires a force to bend the cornea (B), which is independent of the internal pressure. In addition because the cornea has a central thickness of approximately 550µm, the outer area of flattening (A) is not the same as the inner area (A1) It was, therefore, necessary to modify the Imbert-Fick law in the following manner to account for these characteristics of the cornea.(fig 2 B) $W + S = P_t A1 + B$

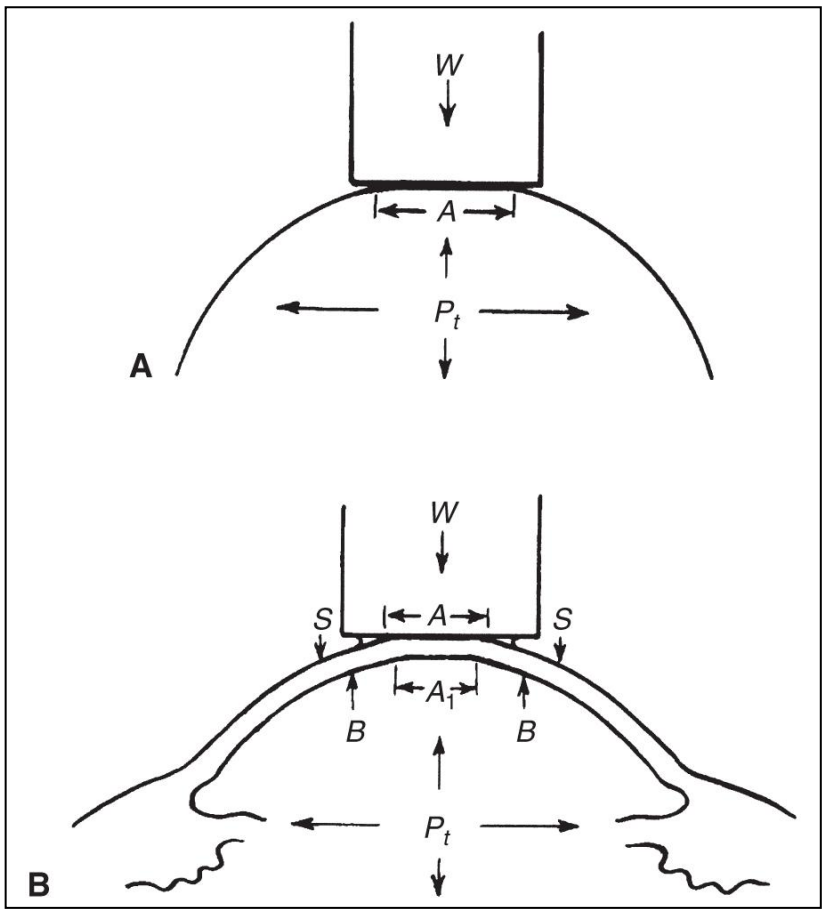


Fig 2 A: The Imbert – Fick law ($W = P_t \times A$)
B: modification of Imbert-Fick law for cornea
($W+S = P_t \times A_1 + B$)

When A1 = 7.35mm^2 S balances B and W = P_t This internal area of applanation is obtained when the diameter of the external area of corneal applanation is 3.06 mm, which is used in the standard instrument. The volume of displacement produced by applanating an area with a diameter of 3.06mm is approximately 0.50mm^3 so that P_t is very close to P_0 and ocular rigidity does not significantly influence the measurement.

Description of Tonometer

The instrument is mounted on a standard slit-lamp in such a way that the examiner's view is directed through the center of a plastic biprism, which is used to applanate the cornea. Two beam-splitting prisms with in the applanating unit optically convert the circular area of corneal contact into semicircles. The prisms are adjusted so that the inner margins of the semicircles overlap when 3.06 mm of cornea is applanated. The biprism is attached by a rod to a housing, which contains a coil spring and series of levers that are used to adjust the force of the biprism against the cornea.(Fig 3)

Technique

The cornea is anesthetized with a topical preparation, and the tear film is stained with sodium fluorescein. The tonometer tip is cleaned with a sterilizing solution[3,4-7] and the tip and prism are set in correct position on the slit lamp. Sterile tonometer tip covers may be used rather

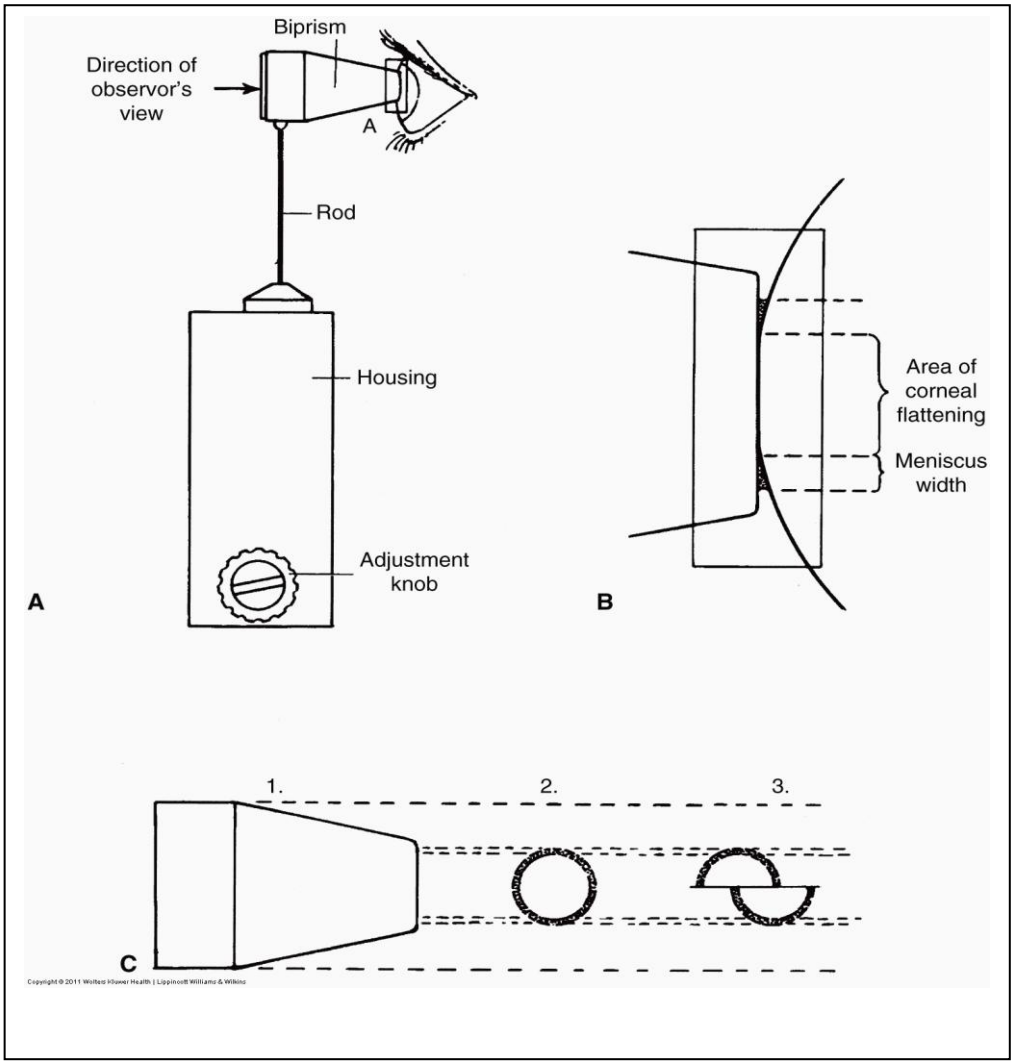


Fig 3 Goldmann-type applanation tonometer

A: Basic features of tonometer shown in contact with patients cornea
B: Enlargement shows tear film meniscus created by contact of biprism and cornea
C: View through biprism (1) reveals circular meniscus (2),which is converted into semicircles (3) by prisms

than a disinfecting solution, if preferred[8]. The tension knob is set at 1g. If the knob is set at 0, the prism may vibrate when it touches the eye and damages the corneal epithelium. The 1g position is used before each measurement. As a rule, it is more accurate to measure IOP by increasing rather than decreasing the force of applanation.

The 0 graduation mark of the prism is set at the white line on the prism holder. If the patient has more than 3D of corneal astigmatism, the area of contact between the cornea and the prism is elliptic rather than circular. In this situation the prism should be rotated to about 45 degrees from the long axis of the ellipse that is, the prism graduation corresponding to the least curved meridian of cornea should be set at the red mark on the prism holder[9]. An alternative approach is to average the IOP readings obtained with the axis of the prism horizontal and then vertical[10,11]. The cobalt blue filter is used with the slit beam opened maximally. The angle between the illumination and the microscope should be approximately 60 degrees. The room illumination is reduced. Biprism is brought into gentle contact with the apex of cornea. The clinician observes the applanation through the biprism at low power. A monocular view is obtained of the central applanated zone and the surrounding Fluorescein stained tear film. Semicircles touch when 3.06 mm area is applanated. Using the control

MEASUREMENT OF IOP WITH APPLANATION TONOMETER

stick the observer raises lowers and centers the assembly until two equal semicircles is seen in the center of the field of view. If two semicircles are not equal in size IOP is over estimated. The clinician turns the tension knob in both directions to ensure that the instrument is in good position. If the semicircles cannot be made too small the instrument is too far forward. If the semicircles cannot be made too large the instrument is too far from the eye. The Fluorescein rings should be approximately 0.25 to 0.35 mm in thickness or about one- tenth the diameter of the flattened area. If the rings are too narrow, the patient should blink two or three times to replenish the Fluorescein, additional Fluorescein may be needed if necessary. If the Fluorescein rings are too narrow, IOP is underestimated. If the Fluorescein rings are too wide, the patient's eyelids should be blotted carefully with a tissue, and the front surface of the prism should be dried with lint free material. An excessively wide Fluorescein ring is less of a problem than a very narrow ring, but can cause IOP to be over-estimated. The Fluorescein rings normally undergo a rhythmic movement in response to the cardiac cycle. The tension knob is rotated until the inner borders of the fluorescein rings touch each other at the mid point of their pulsations.

IOP is measured in the right eye until 3 successive readings are within 1 mmHg. IOP is then measured in the left eye. The reading

obtained in grams is multiplied by 10 to give the IOP in millimeters of mercury. The value is recorded along with the date, time of day, list of ocular medications, and time of last instillation of ocular medication.

Calibration

It is essential that Goldmann applanation tonometer be calibrated periodically at least monthly.

Sterilization

It is possible to transfer bacteria, viruses, and the other infectious agents with the Tonometer head[12] including such potentially serious infections as epidemic keratoconjuctivitis, hepatitis B, and theoretically, acquired immunodeficiency syndrome. The biprism should be rinsed and dried immediately after use. Between uses, the prism head should be soaked in a solution such as diluted bleach or 3% hydrogen peroxide. 70% ethanol and 70% isopropanol are effective as sterilizing solutions but were shown in one study to cause mild damage to the Tonometer tip after one month of immersion[13,14].

Sources of error with Goldmann Tonometry

Although the Goldmann Tonometer is reliable and accurate through a wide range of IOP's, errors in measurement can arise from a number of factors, including those that follow:

1. The alignment and thickness of the mires affects the reading as thin mires overestimate IOP and thick mires underestimate IOP.
2. Inadequate Fluorescein staining of the tear film causes an underestimation of IOP. This commonly occurs when too much time elapses between instillation of fluorescein and the measurement of pressure. To avoid this problem the IOP should be measured within the first minute or so after instilling the Fluorescein.
3. Elevating the eyes more than 15 degrees above the horizontal causes an over estimation of IOP.
4. Widening the lid fissure excessively causes an over estimation of IOP.
5. Repeated Tonometry reduces IOP, causing an underestimation of the true level. This effect is greatest between the first and second readings, but the trend continues through a number of repetitions. A scarred, irregular cornea distorts the Fluorescein rings and makes it difficult to estimate IOP.
6. The thickness of the cornea affects IOP readings[15]. If the cornea is thick because of edema, IOP is underestimated[15]. If the cornea is thick because of additional tissue, IOP is overestimated[15,27]. The Goldmann Tonometer is accurate after epikeratophakia[37]. Central corneal pressures

have been shown to be lower than peripheral corneal readings following Photorefractive keratectomy[38].

7. Decreased corneal thickness leads to underestimation of the IOP. This is seen following excimer laser ablation (LASIK, PRK etc). Correction nomograms have been developed to correct for the same. In general a decrease in the corneal thickness by 100 microns will lead to an underestimation of the IOP by 5-7mmHg.

8. If the examiner presses on the globe, or if the patient squeezes his eyelids, IOP is overestimated. Taking a time to assure the patient and taking care to avoid causing pressure against the globe can help guard against these problems.

9. If corneal astigmatism is greater than 3 D, IOP is underestimated for with- the- rule astigmatism and overestimated for against- the - rule astigmatism[10]. The IOP is inaccurate 1mmHg for every 3D of astigmatism[39].

11. Goldmann applanation tonometer can also be used over a soft (high water content) contact lens, but the lens power is a factor in the readings taken, and conversion tables are required. Hyperopic lenses causing the maximum variation.

12. Factors that alter the ocular rigidity affect the indentation tonometry readings, and to a lesser extent the applanation readings also.

Falsely Low IOP

Too little fluorescein

Thin cornea

Corneal edema

With the rule astigmatism > 1 mmHg per 3D.

Prolonged contact

Inaccurate with irregular corneal surface.

Falsely High IOP

Too much fluorescein

Thick cornea

Steep cornea

>l mmHg per 3 D of against the rule astigmatism

Merits of Goldmann applanation Tonometry

Gold standard

Accurate

Reproducible

Ease of use

Demerits of Goldmann applanation Tonometry

Expensive

Needs slit lamp

COMPARISON OF TONOMETERS

	Type	Advantages	Disadvantages
Schiotz	Indentation	Simple construction Extensive clinical use Portability Ease of application Low cost	Affected by ocular rigidity Corneal curvature and thickness Conversion nomograms Reads lower than Goldmann Supine Position Instrument error Multiple reading required Contact method Sterilization, Mose effect
Goldman	Applanation (Variable force)	Independent of corneal curvature, ocular rigidity, Most accurate clinical measure of IOP Slit lamp required	Subjective (Technical expertise required) Sitting position Ocular pulsation Corneal thickness and Irregularities Calibration required Squeezing, lid touch contact method, Sterilization
Non Contact	Applanation	Non contact with eye Reliable with the physiologic range No anaesthesia Mass screening	Ocular pulsation Abnormal cornea Poor fixation Variable reading in glaucomatous eyes Multiple reading required Subepithelial bubbles
Tonopen (Mackay marg type)	Applanation	Portable Irregular corneas Soft CL	Overestimates low IOP Under estimates high IOP Contact method
Pneumo tonometer	Modified applanation	Diseased corneas, Soft CL Continuous monitoring	May overestimate IOP
Mackay marg	Modified applanation	Instantaneous recording Most accurate in scarred and edematous corneas, Soft CL	Reads higher (Less reliable than Goldmann) No longer available
Perkins	Applanation	Portable, in any position Pediatric use, correlates well with Goldmann	As for Goldmann (Except position)

The Pascal Dynamic Contour Tonometer

The Dynamic contour tonometer (DCT, Pascal tonometer) is a new digital contact tonometer designed to measure intraocular pressure independent of corneal properties. The slit-lamp mounted device furnishes a numeric output of intraocular pressure and of ocular pulse amplitude upon touching the cornea for a few seconds. It measures pulsatile IOP directly and continuously (dynamically).

The Pascal Dynamic Contour Tonometer utilizes a curved tip to match the corneal surface, thereby minimizing corneal distortion. This device is based on Pascal's Law of Pressure, which states that pressure applied to a confined fluid is transmitted undiminished throughout the confining vessel of the system. The concave shape of the tip generates minimal corneal distortion and theoretically eliminates errors in measuring IOP induced by ocular rigidity when the cornea is applanated with a flat- tipped tonometer.

The Pascal Dynamic Contour Tonometer is a slit-lamp mounted device that is operated in a fashion similar to a Goldmann applanation tonometer. A microchip enabled, solid-state sensor embedded within the tip records 100 IOP measurements per second and averages them over fluctuations in ocular pulse amplitude (ie, the range in IOP change during the cardiac cycle). Auditory feedback provides the operator with instant

clues about the quality of the measurements, and a digital display shows the final averaged IOP as well as a Q-value that may be used objectively to judge the quality of the final measurement.

Distinctive features of the PASCAL Dynamic Contour Tonometer:

- Unlike applanation tonometers, which are influenced by corneal thickness and other characteristics of the cornea and hence may produce misleading estimates of IOP, a contour tonometer provides an accurate direct measurement of true IOP, which is independent of inter-individual variations in corneal properties.
- PASCAL detects and accurately measures the dynamic pulsatile fluctuations in IOP and thus permits a more detailed assessment of the pressure range to which the eye is subjected due to pulsatile ocular blood flow.
- No fluorescein staining is required for the measurement.
- Convenient documentation with optional wireless printer: Prints all the values shown on the LCD display and the actual IOP curve.

CENTRAL CORNEAL THICKNESS AND APPLANATION TONOMETRY

Because the mathematical calculation for Goldmann applanation Tonometry is based on a presumed average Central corneal thickness (CCT), variations in this parameter can lead to errors in this measurement.

Ehlers and co-workers noted that corneal thickening due to edema causes an underestimation of true IOP higher pressure, whereas variations of CCT in normal corneas can lead to falsely higher readings with thicker corneas and falsely lower with thinner corneas [15.]

The clinical importance of the latter observations has subsequently been highlighted by numerous studies, which have also attempted to answer several questions.

What is the mean and range of CCT's in general populations and in subgroups, including various glaucoma groups?

What correction factor for the adjusted IOP measurement should be used when the CCT deviates from the mean?

And, how does refractive surgery influence the IOP measurements?

In their modification of the Imbert-Fick Law, Goldmann and Schmidt assigned an average corneal thickness of 520µm. More recent studies have provided slightly higher mean values of 537µ to 554µ in

normal subjects[16,17] with a wide range of 427µ to 620µ in one study[16]. These values may be influence by ethnicity, with thinner mean CCTs of 530µ to 53lµ in one African-American population[18] and 495µ to 514µ in a Mongolian population[19], whereas a study in Japan revealed a mean of 552µ among normal subjects[20]. Of even greater clinical importance is the observation that individuals with ocular hypertension have significantly thicker CCTs , with reported means ranging from 570µ to 606µ[21-25], whereas patients with Normal tension glaucoma have thinner mean CCTs of 514µ to 521µ[17,22]. Patients with chronic open angle glaucoma, pseudoexfoliation syndrome and chronic angle-closure glaucoma appear to have mean CCTs similar to that in the normal population[17].

There is a lack of agreement regarding the correction factor that should be used for adjusting the IOP, measured by Goldmann Tonometry, when the CCT deviates from the normal. Ehlers and colleagues have published a table in which the average error is 0.7 mm Hg per 10µ of deviation from the mean of 520µ[15], which has been supported by others[27]. Still other studies, however, have revealed smaller errors of 0.19 mm Hg per 10µ[16], which is consistent with a direct canulation study[28]. IOP measurements with another applanation tonometer, the Tono-pen,

have also been shown to be influenced by CCT, with reported errors of 0.29mmHg per 10μ in men and 0.12 mmHg per 10μ in women[29].

Refractive surgery for Myopia, which produces a thinning of CCT, also influences IOP measurements and must be considered when following up the patients after the surgery. This is true for both photorefractive keratectomy[30-32] and laser assisted in-situ keratomileusis (LASIK)[33-36]. Both procedures may lead to underestimation of the IOP because of central corneal thinning.

A critical amount of thinning may be necessary to have a clinically significant influence on the measured IOP[36], although there is no reliable correction factor for adjusting the post-operative pressure measurements, and it may be best to use the difference between the preoperative and postoperative readings as the correction factor for each patient.

PACHYMETRY

Corneal thickness is shown to influence the accuracy of applanation Tonometry[28]. Corneal thickness can be measured with an optical device called pachymeter. The normal cornea has a central thickness of about 0.52mm and becomes thicker in the paracentral zone (from about 0.52mm inferiorly to 0.57mm superiorly) and peripheral zone (from 0.63 mm inferiorly to 0.67mm superiorly). The thinnest zone is about 1.5mm temporal to the geographic center.

Currently, the most common approaches to corneal thickness measurement include optical and ultrasound pachymetry.

Methods of Pachymetry

Various methods of pachymetry include

- Optical pachymetry
- Ultrasound pachymetry
- Specular microscopy
- Confocal microscopy
- Ultrasound Biomicroscopy
- Scanning Slit topography system and
- Anterior Segment OCT

Optical Pachymetry

Optical methods of pachymetry were first described as early as 1951 by Maurice & Giardini[41].

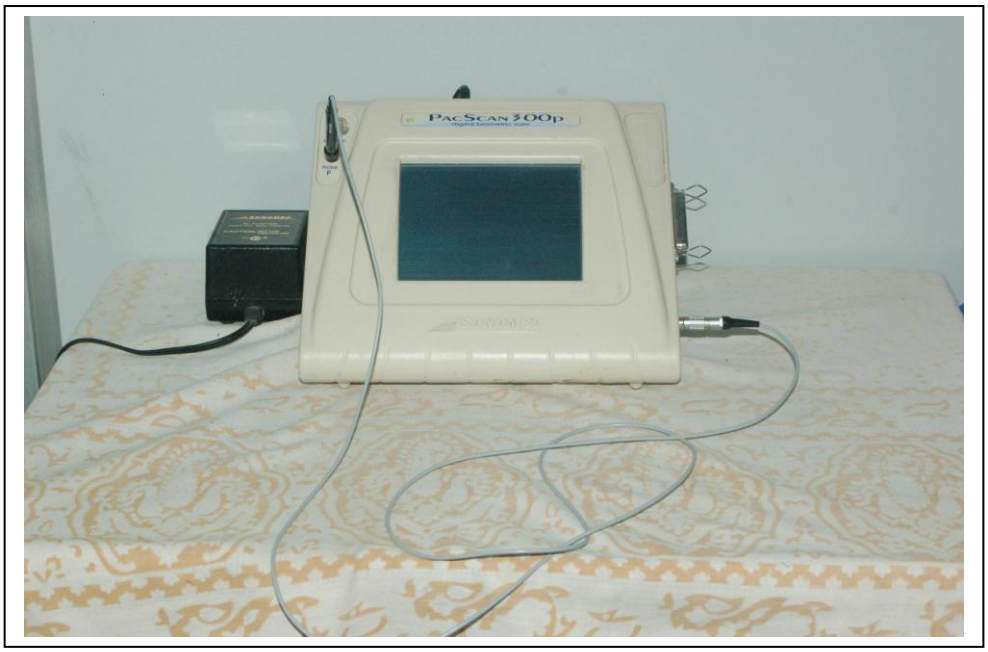
Optical Pachymetry can be performed using a device that attaches to the slit lamp beam. It consists of measuring the oblique section of the cornea by means of a split prism and aligning the split images so the epithelial layer coincides with the endothelial layer.

While the Haag-Streit pachymeter achieves alignment by manual control, automated instruments such as specular microscope and orbscan obtain a digitalized image and calculate the number of pixels.

Ultrasound pachymetry

The first ultrasound pachymtery was introduced by Kremer in 1980[42]. Ultrasound pachymetry is the most efficient and accurate way to measure corneal thickness. Ultrasound pachymetry uses high-frequency sound waves to detect the epithelial and endothelial layers, both of which are highly reflective surfaces. Knowing the velocity of sound in corneal tissue, the distance between the 2 reflecting surfaces can be calculated by detecting the time lapse between the reflected sound waves from the 2 surfaces.

ULTRASOUND PACHYMETER



Pachymeter is calibrated at the beginning of each session. Unlike the optical Pachymeter, it must touch the corneal surface and thus requires topical anaesthesia. The applanating tip must be perpendicular to the surface because tilting induces errors. This was confirmed by an audible beep produced by the instrument.

Ultrasound pachymetry is precise, easy to use, and relatively inexpensive. Traditionally, optical pachymetry had been performed using the Haag-Streit pachymeter, whose measurements are reported to be less reproducible and less reliable than the ultrasound pachymeter[43]. Ultrasound pachymetry measurements have demonstrated high intraobserver reproducibility[44]. However results among observers vary significantly[45].

A new high frequency ultrasound technique incorporating digital signal processing is non -invasive and can measure both epithelial and corneal thickness with precision. A speed sound of 1640 m/sec was used.

Disadvantages

- Requirement of physical contact with the cornea
- Technician error

Specular microscopy

Pachymetry can also be obtained with specular microscopy. Some specular microscopes designed to evaluate the corneal endothelial

cell count also measures corneal thickness using electromechanical devices. These are designed to measure central and apical readings only.

The measurement derived is based on the distance from the posterior surface of the tear film to the posterior surface of the descemet's membrane, thus reducing the error of as much as 20 to 30μm. In the contact mode, corneal touch is involved and compression may be another source of error.

Because the specular microscope functions as an optical pachymeter, it requires clear reflections of the epithelial and endothelial surfaces to obtain a reliable thickness instrument. As such, its clinical use is limited to corneas that are free of edema, scarring, deposits or opacities that may distort light transmission.

Although the machine automated the process of centralizing the image for the measurement, there was no means to ensure perpendicularity.

However, it has the distinct advantages of being operator independent and noninvasive. Improved signal processing and other methods such as Laser interferometry allow the examiner to map the corneal thickness very precisely.

Ultrasound Biomicroscopy

Though it operates by same principle as ultrasound pachymetry, it affords a higher resolution at a transduction frequency of 50MHZ than conventional ultrasound pachymetry at 20MHZ.

UBM transducer fluid is immersed in transduction fluid and is not in contact with cornea. An advantage of this measurement method is the ability to visualize the reflecting surfaces easily. However, it is also a much more lab- intensive procedure for the operator , who must manually adjust the transducer head centrally and perpendicularity of the image.

For the subject, it means a longer time for the procedure, discomfort from the eye cup, and the transiently blurred vision from the transducer gel.

The Scanning Slit topography system

The Scanning slit topography system is an optical scanning-slit instrument that provides topographic analysis and pachymetry measurements of the cornea. Scanning-slit topography requires the patient to fixate for 1 .0 to 1 .5 seconds.

Orbscan elevation topography techniques, recently introduced into wider clinical practices allow the creation of pachymetry maps obtained by a slit-scanning optical device.

Orbscan pachymetry overestimates corneal thickness compared to ultrasound pachymetry. The noncontact Orbscan system measures the hydrated mucous component of the tear film over the cornea; contact ultrasonic pachymetry does not. Thus, Orbscan readings are higher than ultrasonic readings and require the use of the acoustic equivalent correction factor (0.92). Nonetheless, a major advantage of this technique is the creation of an instantaneous picture of "wide-field" corneal thickness that allows for classification of different corneal patterns. Advantages over ultrasound are that it is non-invasive and non-contact.

Instantaneous results are accessible for up to 9600 points on the cornea, a global or wide-field representation of corneal thickness is provided as a colour map, and there are several analysis and presentation options from proprietary software.

The option of a 3-dimensional representation of acquired data and digital storage of images for comparison over time is clearly advantageous.

The main disadvantage of elevation- based pachymetry, in addition to the overestimation of the corneal thickness compared to ultrasound, is dependence on various optical phenomena.

Orbscan readings are higher than ultrasonic readings and require the use of the acoustic equivalent correction factor (0.92). If the cornea is

unusually thick (>600 microns) or thin (less than 500 microns) as measured with ultrasonic pachymetry, then an Orbscan could be performed to confirm the measurements.

Anterior Segment Optical coherence Tomography (OCT)

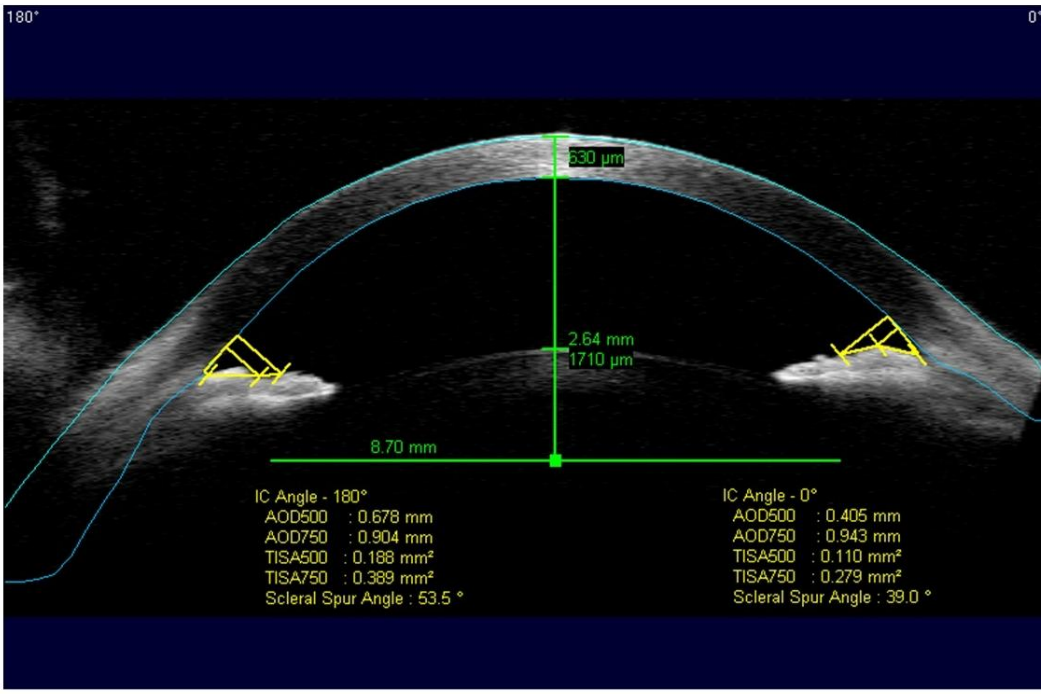
OCT is a relatively newer technique used to measure corneal thickness. OCT is a non- invasive, non-contact imaging technique that uses infrared light to obtain high-resolution cross-sectional images in vivo. Although the technology has been used primarily in the diagnosis of optic nerve and retinal pathology, more recently it has been shown to be valuable for study of the cornea.

Advantages over ultrasound

- Direct
- Non-invasive
- Non-contact

Another advantage is the ability to fixate the patient's gaze during testing. In vitro video monitoring of the scanned surface allows for more accurate placement. Precision of placement is further enhanced with patient's fixation on a light target. In contrast, Ultrasound pachymetry lacks a method to fixate the patient's gaze during repeated measurements. Probe placement is therefore difficult to reproduce and is affected by the test operator. In addition to corneal thickness, OCT measurement also provides high resolution cross-sectional imaging of the

CCT MEASUREMENT WITH ANTERIOR SEGMENT OCT



cornea in vivo. UBM and confocal microscopy also provides high-resolution images in vivo. However UBM requires immersion in saline solution and confocal microscopy requires direct contact with transducer.

THE IMPORTANCE OF CENTRAL CORNEAL THICKNESS IN GLAUCOMA

Glaucoma is defined as an optic neuropathy characterized by typical appearance of optic nerve head and characteristic visual field loss[40]. The diagnosis of glaucoma is based on a combination of factors including IOP (intraocular pressure), optic disc (and nerve fibre layer) damage and specific field defects. Raised IOP is the only known causal risk factor. IOP is the only factor that is accessible for manipulation by the ophthalmologist to treat glaucoma. In routine practice IOP is one of the most important factors in gauging the progression of the disease, the response to treatment and possibly still used in the diagnosis of glaucoma.

Goldmann applanation Tonometry, the current gold standard for the measurement of IOP[46], is based on Imbert -Fick law. Goldmann observed that when the area applanated was 7.35mm^2 the surface tension due to the tear film counterbalanced the resistance to indentation of the cornea, thus making it unnecessary to consider the rigidity of the globe and the surface tension of the tear film in applanation Tonometry[47]. More recent evidence indicates that these, as well as a number of other

factors (e.g. Significant astigmatism, corneal curvature) do affect the accuracy of applanation Tonometry.

Variations in corneal thickness change the resistance of the cornea to indentation so that this is no longer balanced exactly by the tear film surface tension. This may affect the accuracy of the measurement of IOP. A thinner cornea may require less force to applanate it, leading to underestimation of true IOP. While a thicker cornea would need more force thus giving an artifactually high lOP reading. Goldmann himself discussed the influence of variations of CCT on IOP measured by applanation[9]. However, he felt that significant variations in CCT occurred only rarely and hence assumed a "normal" CCT of 520μm for his instrument.

A positive correlation between increased corneal thickness and IOP has been reported earlier[15,27,48]. Studies in eyes with manometrically controlled IOP have demonstrated a significant disparity between the actual IOP and simultaneous applanation Tonometry readings. This disparity was related to the CCT. The underestimation of IOP was as much as 4.9mmHg in thin corneas, while thick corneas produced an overestimation of about 6.8mmHg.[16,21,22] Accordingly it has been suggested that measurement of corneal thickness is necessary for the accurate interpretation of applanation Tonometry.

It has been calculated that applanation Tonometry over/ underestimated IOP by 5mmHg for every 70µm corneal thickness[15]. A correction factor for IOP, to adjust for CCT measurements that differ from "Normal CCT" was proposed as follows:

Corrected IOP = Applanation IOP + [5mmHg × (Mean normal CCT - measured CCT/ 70µm)]

Since a cornea can only be so thin before it becomes pathological, the normal variation of CCT in the population (like the IOP) is skewed to the right. The possibility exists that the measured IOP in patients at either end of the spectrum could be an under/over estimation of the actual hydrostatic IOP and this could be a confounding factor in the terminology of glaucoma based only on the cut-off value of 21mmHg.

This study was undertaken to determine whether, in our population, patients classified as "Ocular Hypertensives" did indeed have thicker corneas compared to normal subjects or true glaucoma patients.

The role of CCT in glaucoma is still confounding and is under scrutiny. CCT is important in glaucoma by two means: 1) by altering the accuracy of applanation Tonometry readings and 2) as a predictive factor in the development of POAG as shown by the OHTS (ocular hypertensive study).

CENTRAL CORNEAL THICKNESS IN NORMALS

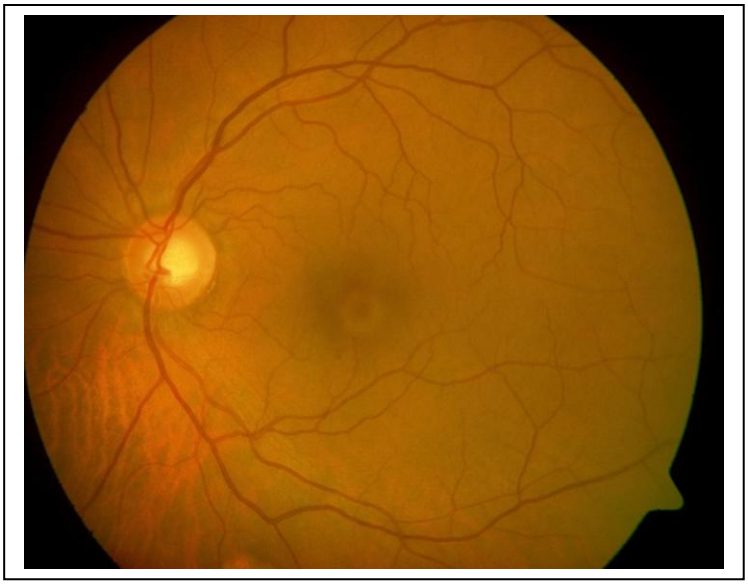
Various studies have estimated the central corneal thickness in normal subject as a control population. The number of control subjects belong to different population depending on where the study was done.

In 2000, Doughty and Zaman[49] presented an extensive review, including a meta-analysis, on the subject of human corneal thickness and its impact on tonometry. They found a significant association between CCT and IOP readings using GAT. They found that the average CCT measured by optical methods was 530 µm and that the average normal CCT measured using ultrasound was 544 µm.

The Rotterdam study performed a cross-sectional study on the distribution of central corneal thickness and its association with intraocular pressure . The Rotterdam study itself is a population-based cohort study of 7,983 residents, aged 55 years and more, of a suburb of Rotterdam, the Netherlands, which aimed at investigating determinants of chronic disabling ophthalmologic, cardiovascular, neurogeriatric and locomotor disease.

The study enrolled 352 control subjects all aged more than 55 years, with normal corneas on slit lamp examination and having had no previous eye surgery. The mean central corneal thickness in the control

NORMAL OPTIC DISC



subject was 537.4µm (95% confidence interval 533.9 to 540.9µm, range 427 to 620µm).

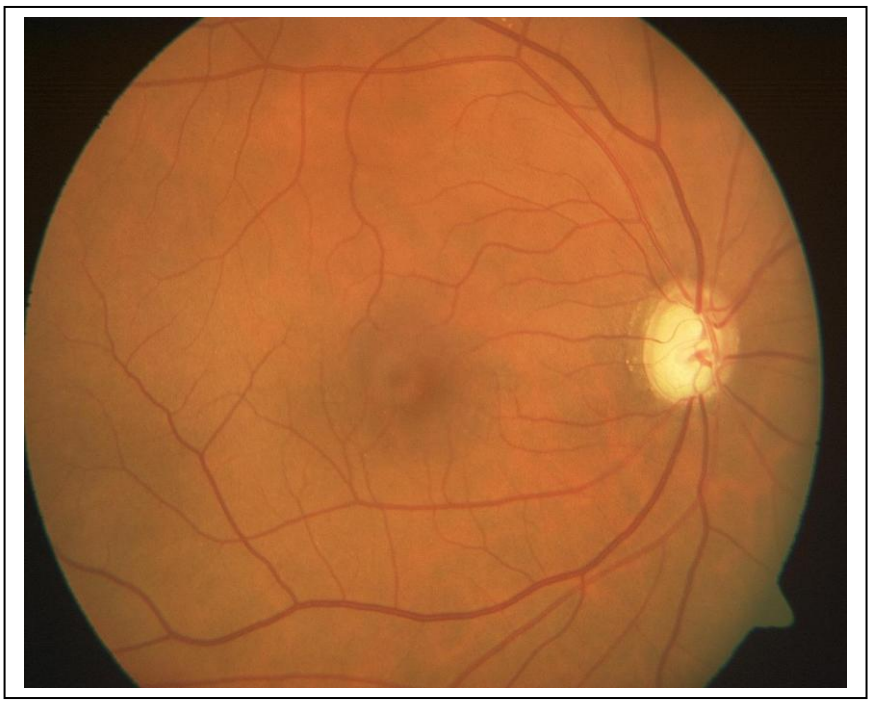
There was no significant difference between right and left eyes or between men and women. Central corneal thickness did not change significantly with age, and it was similar for right and left eyes and for men and women. There was no association between central corneal thickness and time of examination[16].

The Chennai glaucoma study , a population-based study of adults aged 40 years and older residing in the southern Indian state of Tamil Nadu found that the mean CCT for the population was 511.4 ±33.5µm (range, 376–826 µm). Males (515.6 ±33.8µm) had significantly (P = 0.0001) thicker corneas than females (508.0±32.8 µm)[26].

CENTRAL CORNEAL THICKNESS IN PRIMARY OPEN ANGLE GLAUCOMA

Primary open angle glaucoma (POAG) is a chronic progressive condition with characteristic changes at the optic disc (glaucomatous excavation), where it is usually possible to identify reduced visual function related to the disc changes. In most patients, the IOP is above the normal range (i.e. over 21 mmHg) at some time of the day, usually being highest in the morning. In addition, there is a

ADVANCED GLAUCOMATOUS CUPPING



gonioscopically open angle indistinguishable from normal and, in those eyes with elevated IOP, a reduced facility of outflow.

Numerous studies of central corneal thickness in glaucomatous patients have suggested that the central corneal thickness in ocular hypertensives is thicker than in normals and in Normal tension glaucoma thinner than in normals. Most studies have reported there is no significant difference between primary open angle glaucoma and normals.[24, 50,51]

The Rotterdam study enrolled 30 patients of Primary open angle glaucoma to study central corneal thickness and its association with IOP. It was found that the mean central corneal thickness was significantly lower than in the control subjects (21.5µm; 95% confidence interval, 34.1-8.8µm; P=. 001)

Past surgical or different medical treatments in the primary open angle glaucoma group had no effect on the central corneal thickness. The central corneal thickness being significantly lower in Primary open angle glaucoma in this study in contrast to finding in other studies was attributed to too low a power or the use of less accurate optical pachymetry in those studies[16].

The central corneal thickness of patients with POAG was 515µm (range 454-581µm) in a study using optical low coherence

reflectometry, which is a new and more precise method than ultrasonic pachymetry. The design of the optical reflectometer is based on a Michelson reflectometer.

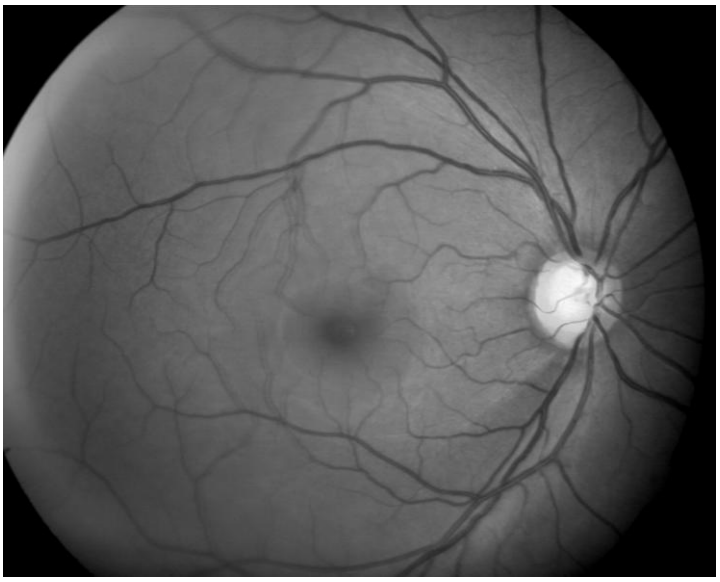
The criterion for inclusion for primary open angle glaucoma in this study was an untreated IOP of 22 mm of Hg or higher, an open angle, a glaucomatous optic disc and visual field defects. Patients with primary open angle glaucoma and controls were included in this observational, concurrent case-control study. The mean central corneal thickness of normals in this study was found to be 524µm (range 483-570µm). The sample size being relatively low, it is difficult to rule out if any differences could have become manifest with a larger sample size[53].

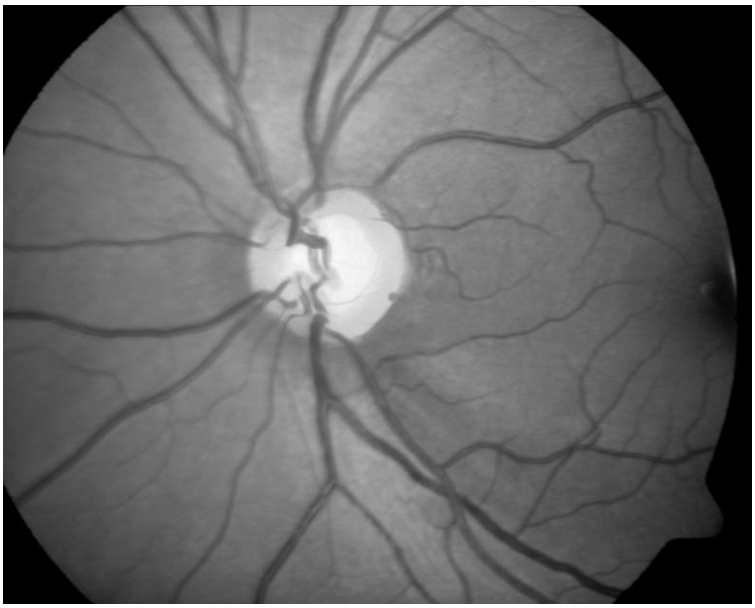
In the Chennai glaucoma study the mean CCT in glaucoma subjects was 514.1±33.6 µm (range, 417.0–616.0 µm) and was similar to the population mean.

CENTRAL CORNEAL THICKNESS IN OCULAR HYPERTENSION (OHT)

Ocular hypertension (OHT) is a term reserved for eyes in which the intraocular pressure (IOP) lies above the normal population range, the optic nerve and visual field show no signs of glaucomatous damage, and there is no ocular co-morbidity.

RED FREE IMAGE SHOWING
NERVE FIBRE LAYER DEFECT





Excluded from this definition are eyes with raised IOP from demonstrable causes such as pseudoexfoliation and pigment dispersion syndrome.

Most population studies on the over 40-year age group indicate that IOPs measured with Goldmann Tonometry are distributed in a manner similar to a normal distribution (mean Approximately 16 mmHg). Persons with IOPs greater than two standard deviations above the mean can be labelled Ocular Hypertensive. This gives an upper limit for "normal" IOPs in Caucasians of 21 mmHg. It is of note however that this figure is statistically derived and does not imply that disease is present if measured IOP levels exceed this value.

Risk factors for the development of OHT

Epidemiological studies have identified those individuals in a population most at risk: -

1. Increasing age
2. Individuals of black African or Caribbean origin.
3. Female gender
4. Systemic hypertension
5. Current use of oral and/or inhaled corticosteroids
6. Diabetes (especially those on insulin)
7. Family history of glaucoma

Risk factors for conversion to glaucoma

Estimates vary as to the conversion rate from OHT to POAG, depending on subject selection and diagnostic criteria. It is likely that approximately 10% of individuals with persistent OHT will convert to POAG over a ten-year period. Risk factors for the conversion of OHT to POAG can be divided into ocular and systemic. The most important are listed below.

A. Ocular risk factors

- Height of the IOP - the greater the IOP the greater the risk
- Large vertical cup/disc ratio (indicating reduced neuroretinal rim area/volume)
- Cup/disc (C/D) ratio asymmetry >0.2
- Previous history of disc hemorrhage
- Retinal nerve fibre layer defect in the absence of morphometric optic nerve head changes
- Thinner than average central corneal thickness (note excimer laser procedures on the cornea can result in artifactually lowered IOPs on measurement)

B. Systemic risk factors

- Increasing age
- Family history
- Individuals of black African or Caribbean origin

OHT was defined as IOP greater than 21 mmHg or use of IOP lowering medications, with a cup-disc ratio of less than 0.5, and with no glaucomatous visual field defect in the base line phase of the Rotterdam study.

The Rotterdam study enrolled 13 patients of OHT to study CCT & its association with IOP. It was found that mean CCT was slightly, not significantly higher than in the control subjects (=l6µm; 95% confidence limit, - 2.6 to + 34.6µm; P = 0.093) which has also been found by others. CCT of patients with OHT was 553µm in a study using optical coherence reflectometry.

CCT as a predictive factor in the development of POAG as shown in the OHTS (Ocular hypertensive treatment study)[23,56]

The OHTS was a multicentric randomized trial designed to evaluate the safety and efficacy of topical ocular hypotensive medications in delaying or preventing the onset of POAG in individuals with OHT. In this study a thinner CCT measurement predicted the development of POAG in both univariate and multivariate models.

Among participants who developed POAG, the mean CCT was 553.lµm ± 38.8µm when compared to 574µm ± 37.8µm among those who did not develop POAG. The entire participants were divided into three groups. CCT < 555µm; CCT 555-588µm and CCT > 588µm. Compared with the

participants with the thickest corneas (>588µm), participants with intermediate thickness (555-588µm) had a hazard ratio of 1.7 and participants with the thinnest CCT (<555µm) had a hazard ratio of 3.4.The risk of developing POAG was found to be highest among participants with the thinnest corneas in any IOP range and also in any range of C/D ratios.

The OHTS is the first study to prospectively document that a thinner CCT measurement predicts the development of POAG. Corneal thickness appears to be strong predictive factor for the development of POAG even after adjusting for the effects of baseline age, IOP, vertical C/D ratio & PSD, which are the other risk factors identified in the OHTS. Participants with a CCT of less than 555µm had a three fold greater risk of developing POAG compared to participants with CCT> 588µm. The predictive power of CCT may be due to its effect on the measurement of IOP. However the OHTS study states that the possibility that CCT is related to other factors affecting susceptibility to glaucomatous damage cannot be excluded.

The OHTS concludes that CCT provides new information about the risk of developing POAG and recommends its measurement in the clinical evaluation of patient with OHT.

A REVIEW OF LITERATURE

A literature search using Pubmed was performed using the key words “central corneal thickness” and “primary open angle glaucoma’. There were 40 results out of which the important ones are highlighted below.

The ocular hypertension treatment study aimed to describe baseline demographic and clinical factors that predict which participants in the ocular hypertension treatment study (OHTS) developed primary open glaucoma. This was based on the background that the ocular hypertension study (OHTS) has shown that topical ocular hypotensive medication is effective in delaying or preventing the onset of primary open angle glaucoma in individuals with elevated intraocular pressure (ocular hypertension) and no evidence of glaucomatous damage.

Univariate and multivariate analyses showed that thinner central corneal measurements were an important predictor for the development of primary open angle glaucoma. It was concluded that the central corneal thickness was found to be a powerful predictor for the development of primary open angle glaucoma[50].

Wu L et al in their study on corneal thickness and intraocular pressure in case with ocular hypertension and glaucoma concluded that there is a large variation in central corneal thickness of normal subjects,

which is significantly positively correlated with intraocular pressure. The central corneal thickness is significantly thicker in ocular hypertension subjects, which should be considered as an important variable in follow up.

No significant differences in central corneal thickness are shown among normal tension glaucoma, primary open angle glaucoma and normal groups. It is suggested that central corneal thickness has little influence on the diagnosis of normal tension glaucoma and primary open angle glaucoma[52].

Singh RP, Goldberg L et al studied central corneal thickness, Tonometry, and ocular dimensions in glaucoma and ocular hypertension and concluded that in primary open angle glaucoma and healthy eyes, the central corneal thickness was not very different when compared to eyes with ocular hypertension which had thicker corneas and eyes with normal tension glaucoma which had thinner corneas[24].

Central Corneal Thickness was significantly higher ($p \leq 0.001$) in patients with ocular hypertension than in normal individuals or in subjects with either normal tension glaucoma, primary open angle glaucoma, or pseudoexfoliation glaucoma, there being no significant differences between the latter four groups in a study by Ventura AC et al of the University of Berns, Switzerland[53].

Central corneal thickness was significantly higher in ocular hypertensive subjects [593 (SD 35) microns, p<0.0001] than in the controls [530 (SD 32) microns] whereas patients with Normal tension glaucoma [482 (SD 28) microns, p<0.000l], Pseudoexfoliation glaucoma [493(SD 33) microns, p < 0.0001], and primary open angle glaucoma [512 (SD 30) microns, p<0.05] showed significantly lower reading in study of central corneal thickness determined with optical coherence tomography in various types of glaucoma[51].

A study comparing the relationship between corneal thickness and measured intraocular pressure in a general ophthalmology clinic concluded that in glaucoma suspect eyes with modest elevation of intraocular pressure and thick cornea may be at low risk of progression to primary open angle glaucoma as in this study most glaucoma suspect eye had thick corneas, which would tend to increase the tonometrically recorded IOP. Thus many patients with "high intraocular pressure" and a thick central corneal thickness do not necessarily have high intra ocular pressure and may not need to be followed as Glaucoma suspect eye[17].

The Rotterdam study performed a cross-sectional study on the distribution of central corneal thickness and its association with intraocular pressure. The mean corneal thickness was significantly lower in POAG subjects than in the control subjects (-21.5m thinner, 95%

confidence interval, -34.1 to -8.8m ; p=0.001) in the Rotterdam study as mentioned previously[16].

The Chennai glaucoma study reports the distribution and factors associated with CCT among individuals from a rural and an urban south Indian population. In this the mean CCT for the population was 511.4 µm, and male corneas were 8µm thicker than female corneas. The CCT was 18µm greater in the urban population & Central corneal thickness was negatively correlated with increasing age and positively with intraocular pressure[26].

AIMS AND OBJECTIVES

The main objectives of this study comparing central corneal thickness in primary open angle glaucoma, ocular hypertension and control group was to

1. Determine the range and distribution of central corneal thickness in normals, primary open angle glaucoma (POAG) and ocular hypertension (OHT) in South Indian population.
2. Determine if there were significant differences in central corneal thickness measurement in normals, POAG and OHT.
3. Predict if there were differences in central corneal thickness in relation to age and sex variation in controls, POAG and OHT.

MATERIALS AND METHODS

The design of the study was a prospective, masked, controlled study. A total of 150 patients were enrolled in this study during the period from July 2010 to July 2011. There are three groups of patients, controls, primary open angle glaucoma (POAG) and ocular hypertension. All patients were aged 40 and above keeping in mind the age distribution in POAG and ocular hypertension. A total of 50 controls were enrolled in the study after getting informed consent. Patients who met the inclusion criteria were chosen in consecutive manner from the ophthalmology outpatient department of our hospital. Controls were matched for age and other demographic factors like gender and ethnicity.

The inclusion criteria for Control group included

1. Intraocular pressures < 21mm Hg in both the eyes measured by Goldmann's applanation Tonometer.
2. Normal optic discs
3. Normal visual fields
4. Open angles on Gonioscopy and
5. No family history of glaucoma, no suspicion of any form of glaucoma, or any other eye disease.

Inclusion criteria for POAG included the following

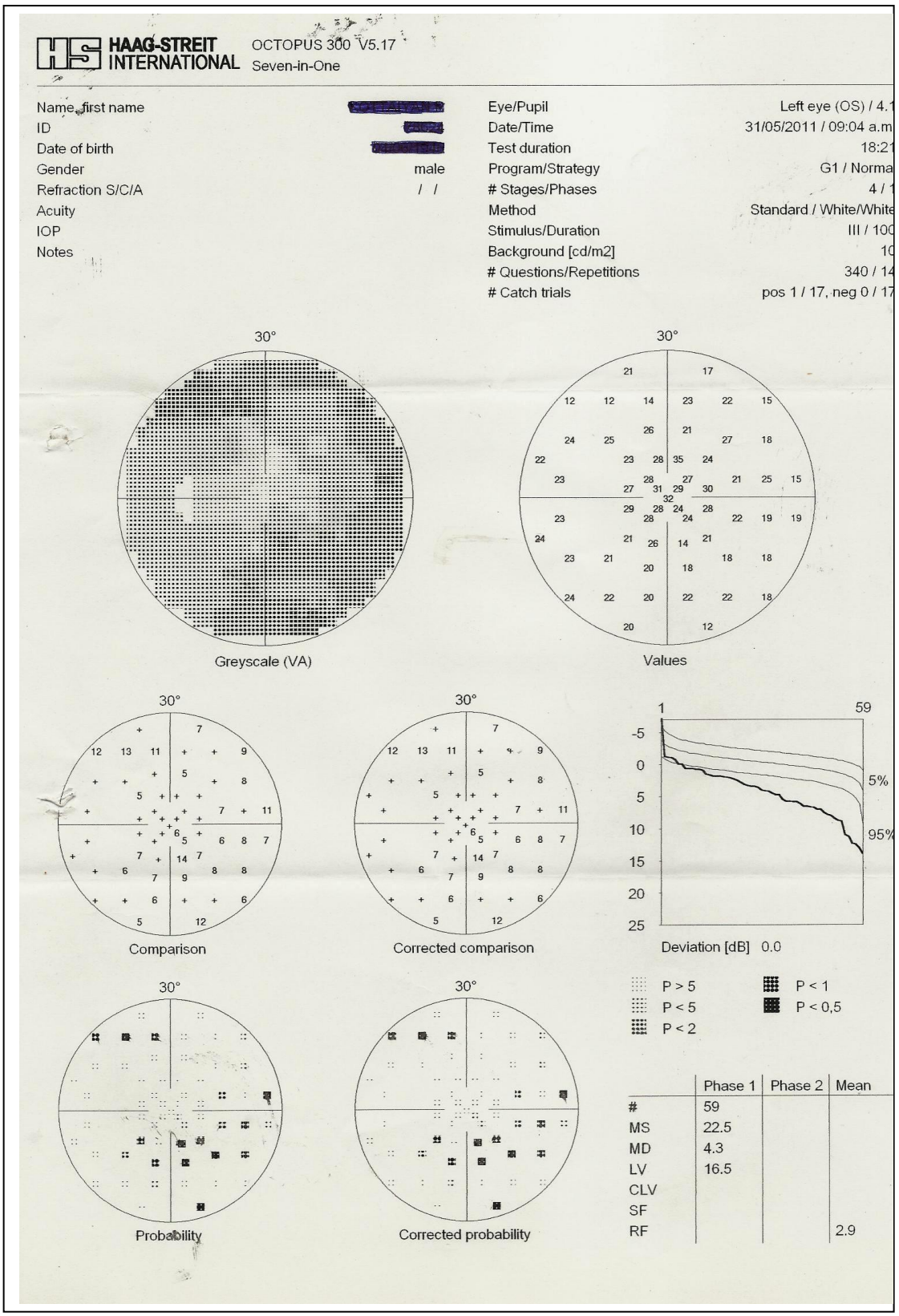
1. Intraocular pressures (IOP) prior to treatment > 21mmHg or current IOP on treatment < 21mmHg measured by Goldmann's applanation Tonometer.
2. Glaucomatous optic disc with or without nerve fiber layer defects.
3. Glaucomatous visual field defects atleast in one hemifield not within 5 degrees of fixation OR field defects in both hemifields and / or loss within 5 degrees of fixation in atleast one hemifield (As per Preferred Practice Pattern POAG AAO Guidelines)[65]
4. Open angles on Gonioscopy

Inclusion criteria for ocular hypertension included the following

1. IOP > 21 mmHg on atleast 2 occasions
2. Healthy optic discs with no glaucomatous features
3. No field defects and
4. Open angles on Gonioscopy.

50 POAG and 50 ocular hypertension patients were enrolled in the study period after informed consent. Patients who met the inclusion criteria were screened in a consecutive manner from glaucoma clinic of ophthal OPD in our hospital. Both newly diagnosed cases and those on treatment were included as the use of topical glaucoma medications were

FIELD DEFECTS IN THE ARCUATE AREA



not found to cause any significant changes in central corneal thickness in clinical studies.

Exclusion Criteria were as follows

1. Evidence of any anterior segment pathology including corneal opacities
2. Previous intraocular or corneal surgery
3. Diabetes mellitus, use of contact lenses or any other conditions that may affect corneal thickness
4. Corneal edema
5. Corneal astigmatism > 2 D and sphere > 4D
6. Any Retinal, optic nerve or intracranial disease
7. Evidence of pseudoexfoliation
8. Angle closure and secondary open angle glaucomas

METHODS

All patients enrolled in this study underwent

1. Determination of best corrected visual acuity
2. Slitlamp Biomicroscopy to exclude corneal pathology
3. Applanation Tonometry
4. Gonioscopy

5. Dilated fundus examination and stereoscopic examination of the optic discs and the nerve fiber layer using +90D lens with the slit lamp.

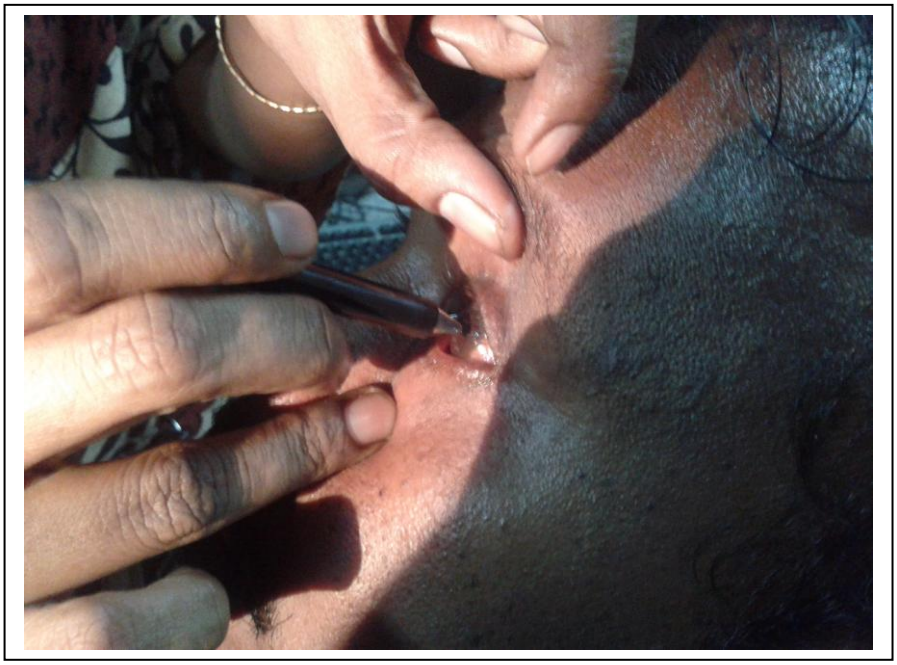
All glaucomatous patients underwent automated perimetry prior to dilatation using G1 Normal program of the Octopus 300 Field Analyzer if it had not been done within three months of the study.

Central corneal thickness was measured in both the eyes of all the patients after informed consent. The readings were taken using PACSCAN 300P model of SONOMED Inc. The corneal velocity was preset at 1636ms. A calibration check was performed before actual measurements. A measurement accuracy test is also performed to ensure the functionality of PACSCAN. This performs an internal calibration check, which should generate a reading of 500 = / - 1m.

Topical proparacaine 0.5% was instilled in both the eyes. The patients were seated, erect and were all asked to look at a target fixed 3m away when the measurements were made.

Three consecutive readings were taken for each eye by a single observer, an ophthalmologist, who was masked to the diagnosis. The observer was not aware of the group to which the patient belonged and the numerical value of the readings taken which was recorded silently by a technician to avoid any bias. All readings were taken between 9 am and

MEASURING CCT WITH ULTRASOUND PACHYMETER



12 noon. Though some studies report a slight variation in the central corneal thickness during a 24 hour period, some studies like the Rotterdam study that studied this aspect concluded that there was no association between central corneal thickness and time of examination.

STATISTICAL ANALYSIS

The student ‘t’ test linear regression test were used for comparing means between groups. For categorical data, chi-square test was used.

The effect of central corneal thickness on intraocular pressure was evaluated with linear regression analysis.

All analyses were performed with the Stata 8.1 software (Stata Corporation, College Station, Texas, USA)

‘p’ value < 0.05 was considered to be statistically significant.

RESULTS AND OBSERVATIONS

The following observations were made from measurements taken in the three study groups.

Table 1 A

AGE WISE DISTRIBUTION OF THE SUBJECTS

Age in years	Number of Controls	Number of POAG patients	Number of OHT patients
40 – 50	18	13	19
51 – 60	21	20	22
61 – 70	10	15	8
71 – 80	1	2	1

Studying the age distribution in the study groups, it was found that the maximum numbers of patients in all three groups were between the ages of 51 to 60 years. Maximum number of patients in controls also fell between 40 to 60 years and this was purely incidental. Thus three groups were comparable.

AGE WISE DISTRIBUTION

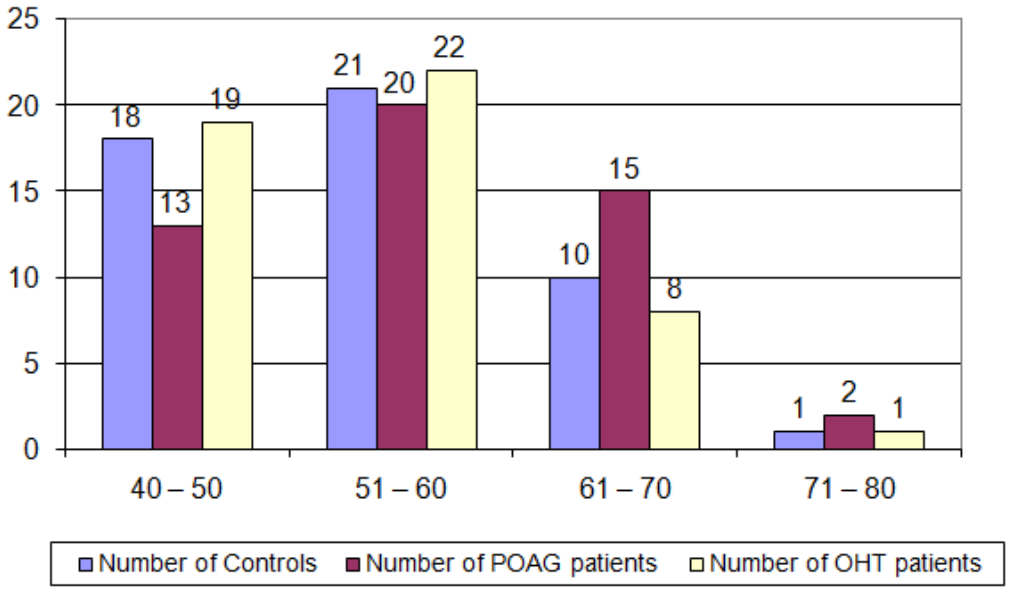


Table – 1B

AGE RANGE

	Age in years	
	Minimum	Maximum
Controls	41	72
POAG	40	80
OHT	40	80

Controls ranged between 41 to 72 years, in POAG and OHT ranges were 40 to 80 years and are thus comparable.

Descriptive Statistics (p = 0.130)

Group	N	Range	Minimum	Maximum	Mean	SD
Control Age	50	31	41	72	53.76	8.57
POAG Age	50	40	40	80	56.56	8.87
OHT Age	50	40	40	80	53.26	8.78

Table – 2

SEX DISTRIBUTION AMONG STUDY GROUPS

	Number of Subjects	
	Males	Female
Controls	28	22
POAG	30	20
OHT	30	20

The gender distribution with in the study group showed a near equal distribution among the POAG and OHT, but slightly lesser number of males in control group. No measures were taken to ensure that equal number of males and females participated in the study.

SEX DISTRIBUTION

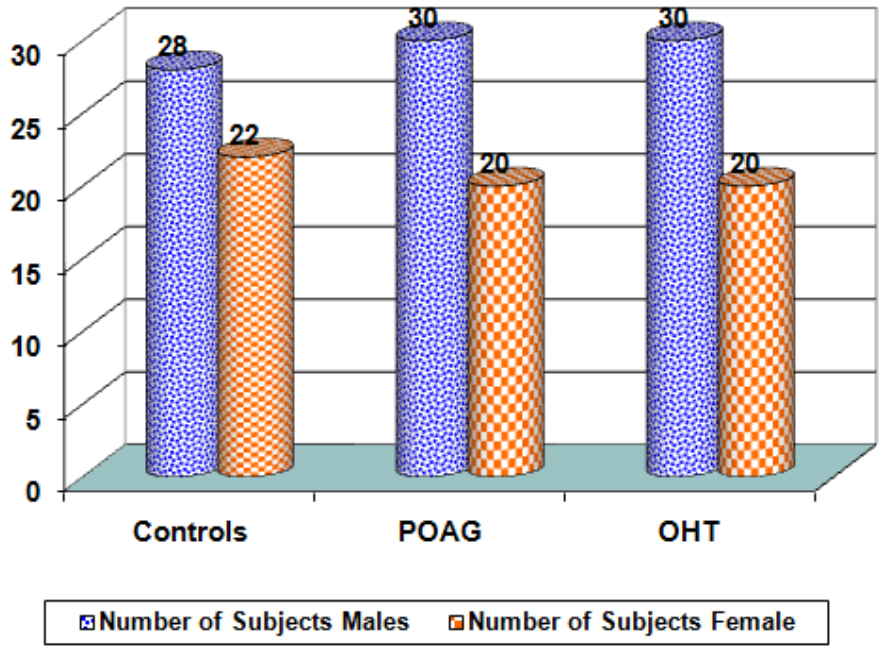


Table – 3

MEAN CCT AND MEAN IOP

	CCT Mean (µm)	IOP Mean (mmHg)
Normal	533	14
POAG	536	19
OHT	561	24

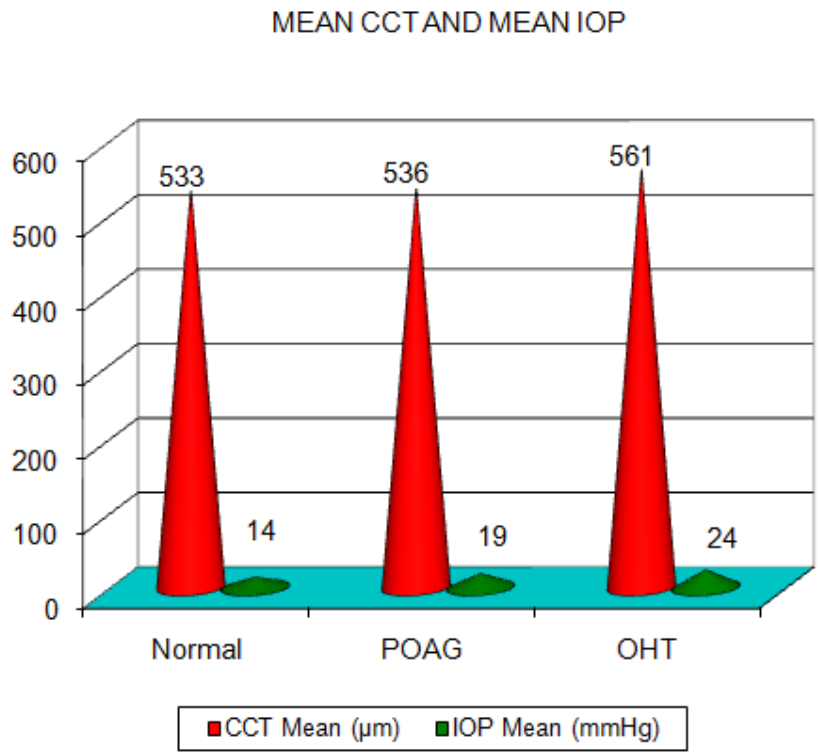
T – Test

Group		Number of eyes	Mean	SD	P value
CCT	Controls	100	533.05	29.40	0.448
	POAG	100	536.17	28.66	
CCT	Controls	100	533.05	29.40	<0.001
	OHT	100	561.23	28.09	
CCT	POAG	100	536.17	28.66	<0.001
	OHT	100	561.23	28.09	

Using t test, there was no statistically significant difference of mean CCT of POAG when compared to control. ($p = 0.448$)

In the ocular hypertension group, we saw a significantly higher central corneal thickness than in the control subjects. ($p<0.001$)

Comparing OHT with POAG group, OHT group was found to have significantly higher CCT than in POAG ($p < 0.001$)


MEAN CCT AND MEAN IOP
600
500
400
300
200
100
0
533
536
561
14
19
24
Normal
POAG
OHT
CCT Mean (µm)
IOP Mean (mmHg)

T – Test

Group		Number of eyes	Mean	SD	P value
IOP	Controls	100	13.97	1.87	<0.001
	POAG	100	18.97	4.27	
IOP	Controls	100	13.97	1.87	<0.001
	OHT	100	23.68	3.08	
IOP	Controls	100	18.97	4.27	<0.001
	OHT	100	23.68	3.08	

Using T test, mean IOP was found to be significantly higher in POAG group when compared to controls ($p < 0.001$)

Mean IOP was significantly higher in OHT group when compared to controls ($p<0.001$)

Mean IOP was significantly higher in OHT group when compared to POAG. ($p<0.001$)

Table – 4

MEAN CCT AND RANGE

	Central Corneal Thickness (µm)	
	Mean	Range
Normal	533	472 - 605
POAG	536	470 – 609
OHT	561	452 - 618

The mean CCT in the control group was 533 µm with a range 472 – 605 µm

In the POAG group, the mean was 536 µm with a range of 470 – 609 µm

And in the OHT group, the mean was 561 µm with a range 452 – 618 µm, which were again comparable.

Table – 5

COMPARISON OF MEAN FOR MEN AND WOMEN

	Men	Women
Controls	527	541
POAG	534	540
OHT	561	568

T – Test

Group	Sex	Number	Mean	SD	P value
Controls CCT	Male	28	526.59	26.81	0.012
	Female	22	541.27	30.78	
POAG CCT	Male	30	533.72	31.60	0.297
	Female	20	539.85	23.46	
OHT CCT	Male	30	561.23	28.09	0.179
	Female	20	568.08	24.35	

There was no statistical difference in CCT values between men and women in POAG & ocular hypertension group. In controls group CCT of women was higher.

Using T test, p value for 3 groups are

Controls - 0.012

POAG - 0.297

OHT - 0.179

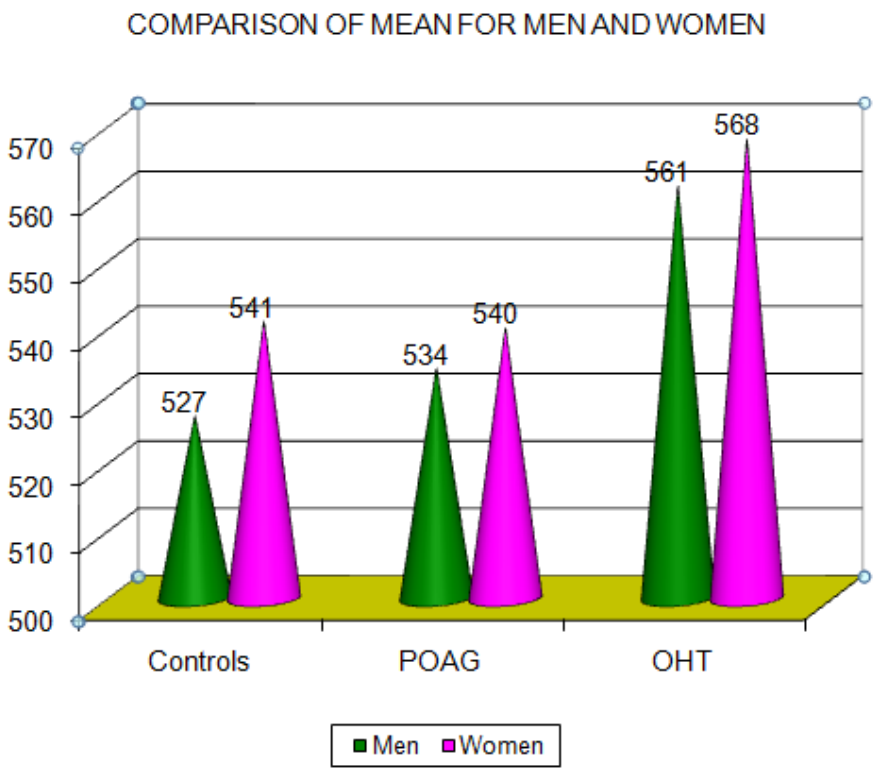

COMPARISON OF MEAN FOR MEN AND WOMEN
570
560
550
540
530
520
510
500
527
541
534
540
561
568
Controls
POAG
OHT
Men
Women

Table – 6

MEAN CCT FOR RIGHT AND LEFT EYES

	Mean Central Corneal Thickness	
	RE	LE
Controls	533	533
POAG	536	536
OHT	561	561

T – Test

Group	Eye	Number	Mean	SD	P value
Controls CCT	RE	50	533.16	29.82	0.970
	LE	50	532.94	29.27	
POAG CCT	RE	50	536.36	29.04	0.948
	LE	50	535.98	28.56	
OHT CCT	RE	50	561.08	28.42	0.958
	LE	50	561.38	28.06	

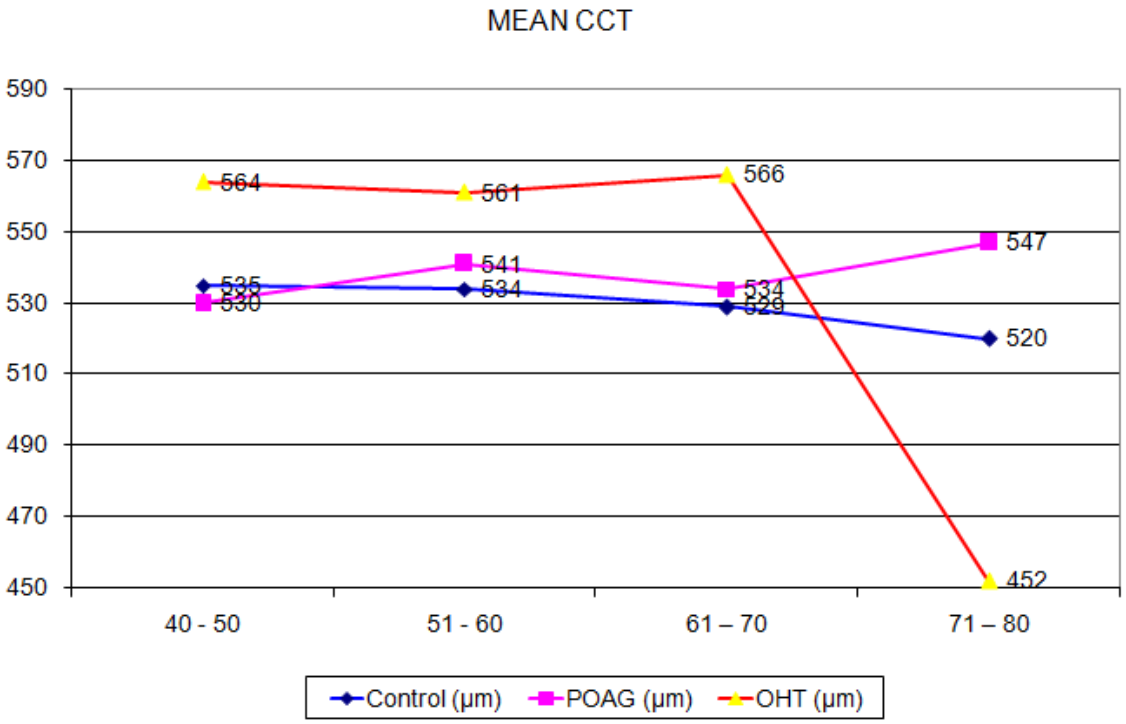
The mean CCT for right and left eyes were 533 µm in controls, 536 µm in POAG, 561 µm in OHT group

There was found to be no statistically significant difference in CCT value of right and left eyes by T testing in the controls (p=0.970), POAG (p=0.948) and in OHT (p = 0.958). thus mean CCT in both the eyes are comparable.

Table – 7

CCT and IOP values for Different Age groups

Age Group	Controls			POAG			OHT		
	No.	Mean CCT (µm)	Mean IOP (mmHg)	No.	Mean CCT (µm)	Mean IOP (mmHg)	No.	Mean CCT (µm)	Mean IOP (mmHg)
40 - 50	18	535	14	13	530	19	19	564	23
51 - 60	21	534	14	20	541	19	22	561	23
61 – 70	10	529	14	15	534	19	8	566	26
71 – 80	1	520	13	2	547	19	1	452	21
81 - 90	0			0			0		


MEAN CCT
590
570
550
530
510
490
470
450
564
561
566
541
534
547
535
530
520
452
40 - 50
51 - 60
61 – 70
71 – 80
Control (µm)
POAG (µm)
OHT (µm)

Age group Crosstabulation

			Group			Total
Age	40 – 50	Count	18	13	19	50
		%within age	36%	26%	38%	100%
	51 - 60	Count	21	20	22	63
		%within age	33%	31.7%	34.9%	100%
	61 – 70	Count	10	15	8	33
		%within age	30.3%	45.4%	24.2%	100%
	71 - 80	Count	1	2	1	4
		%within age	25%	50%	25%	100%
	Total	Count	50	50	50	150
		%within age	33.3%	33.3%	33.3%	100%

Using Chi square test, there was no statistically significant difference of CCT and IOP values among the different age groups in 3 study groups. (p=0.250).

Correlations

		IOP	CCT
IOP	Pearson correlation	1	0.335**
	Sig. (2 tailed)	.	0.000
	N	300	300
CCT	Pearson correlation	0.335 **	1
	Sig. (2 tailed)	0.000	.
	N	300	300

** Correlation is significant at the 0.01 level

Pearson correlation formula showed an increase intraocular pressure with increase in central corneal thickness

Using Regression formula, it was found that there was statistically significant negative correlation of central corneal thickness with age ($p = 0.006$).

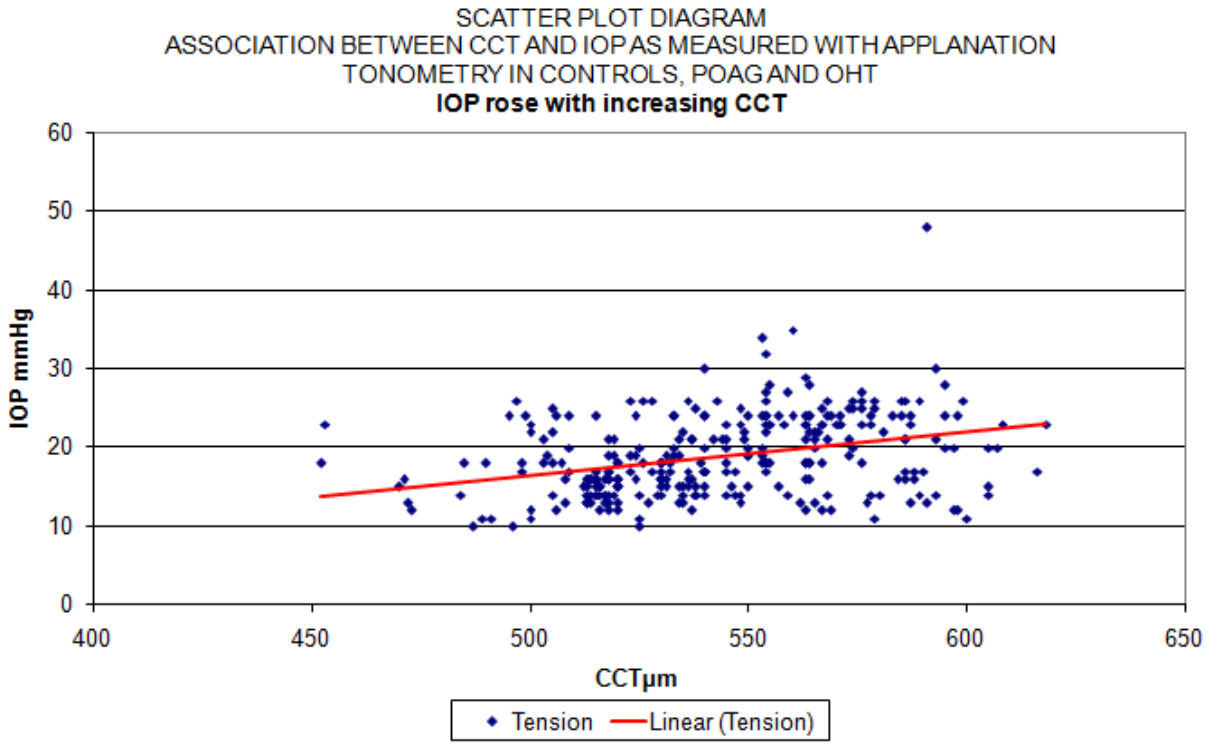
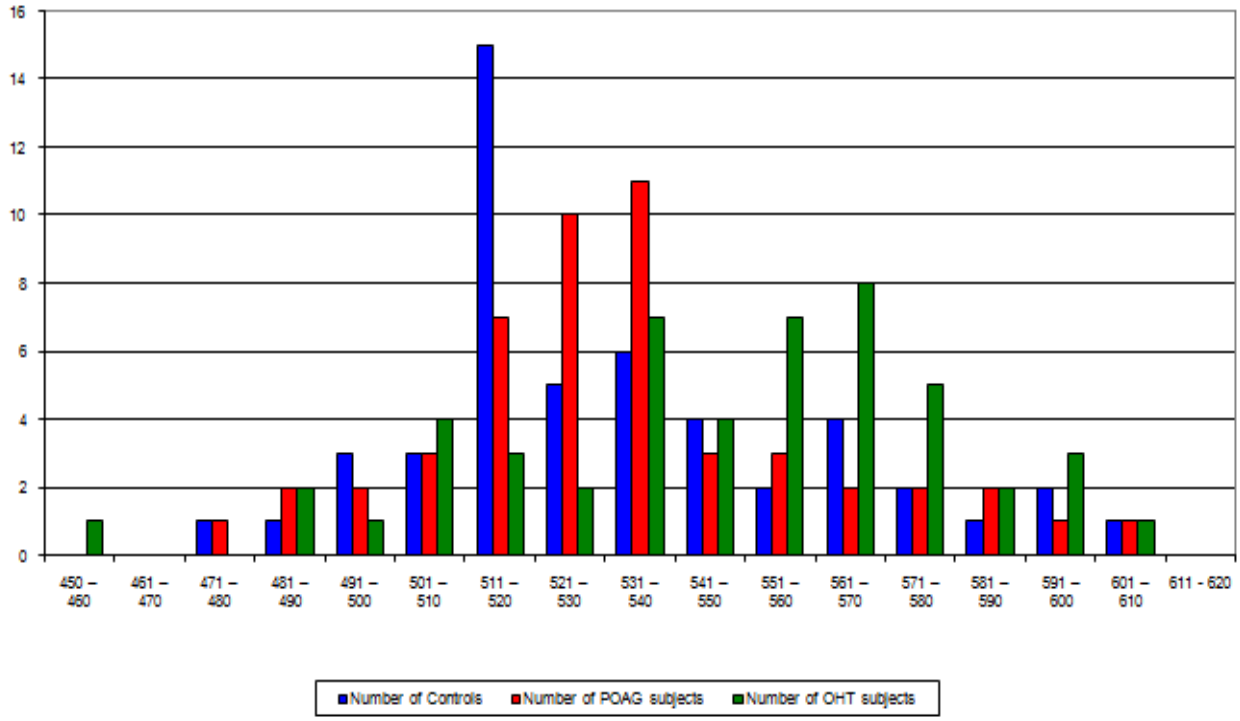

SCATTER PLOT DIAGRAM
ASSOCIATION BETWEEN CCT AND IOP AS MEASURED WITH APPLANATION TONOMETRY IN CONTROLS, POAG AND OHT
IOP rose with increasing CCT
IOP mmHg
60
50
40
30
20
10
0
400
450
500
550
600
650
CCTμm
Tension
Linear (Tension)

Table – 8

DISTRIBUTION OF CCT IN CONTROLS, POAG AND OHT

Central Corneal Thickness (um)	Number of Controls	Number of POAG subjects	Number of OHT subjects
450 – 460	0	0	1
461 – 470	0	0	0
471 – 480	1	1	0
481 – 490	1	2	2
491 – 500	3	2	1
501 – 510	3	3	4
511 – 520	15	7	3
521 – 530	5	10	2
531 – 540	6	11	7
541 – 550	4	3	4
551 – 560	2	3	7
561 – 570	4	2	8
571 – 580	2	2	5
581 – 590	1	2	2
591 – 600	2	1	3
601 – 610	1	1	1
611 - 620	0	0	0

DISTRIBUTION OF CCT IN CONTROLS, POAG AND OHT



The CCT was taken as a range of 10µm and the number of controls, POAG and OHT patients falling into each group was assessed. The right and left eye measurements were taken for this observation. Maximum of 15 patients in the controls group had a CCT between 511 – 520 µm; maximum of 11 patients in POAG group had CCT in the range of 531 – 540 µm, while a maximum of 8 patients in OHT group had CCT in the range of 561 – 570 µm.

DISCUSSION

The distribution of central corneal thickness in the western population has been widely studied[16,57]. There has always been the need to study the same in the Indian population and few population based studies have been published. This study though not a population based one, tries to give a hint by calculating the mean and range within a smaller sample in a tertiary care center.

A recent meta-analysis of corneal thickness literature of 300 articles found that the mean corneal thickness in normals was 544 µm with ultrasonic pachymetry. In our study we found a mean corneal thickness of 533µm normals, which was similar to that reported in clinic based studies and was similar to that of Rotterdam study (mean CCT 537µm). A mean corneal thickness of 515µm was quoted for POAG in the Rotterdam study and this was significantly lower than the normals. Our study found a central corneal thickness of 536µm in the POAG group. Our study does not find any statistically significant difference in the central corneal thickness measurements of the POAG group when compared to the controls.

This result is of significance as the misclassification of patients who truly have "Primary open angle glaucoma" as "normal tension

glaucoma" can be avoided. The approach to treatment options for these two conditions is quite different.

This is in variation with the results of the Rotterdam study which found that the central corneal thickness in Primary open angle glaucoma is significantly lesser than in controls. Though this was different from contemporary studies in the western population, the researchers had attributed them to use of less accurate optical pachymetry. They used ultrasound pachymetry for their study[16]. The ocular hypertension treatment study also showed similar results[50]. Our results are in concordance with various other studies[22,51,52,53].

A mean corneal thickness of 553µm was quoted for OHT in the Rotterdam study and this is slightly higher than in normals. Our study found a mean CCT of 561µm in the OHT group and was significantly higher than in normal (control) individuals and was similar to that of previous study[53].

There is statistically significant negative correlation of CCT with age.

There were no differences between sexes in our study in POAG and ocular hypertension[48,58], which was similar to that found in other studies though CCT was higher in females in control group. The higher

CCT values in control females may be attributed to more number of younger females in control group.

Central corneal thickness was similar in right and left eyes, which was similar to that quoted in Rotterdam study. Previous studies with optical pachymetry[48,59] did show a systematic right-left difference. This may be because of a measurement error in the optical method when the measurement is not perpendicular to the cornea. Such a measurement error does not occur with the ultrasound pachymeter used here because this gives a reading only when the probe is perpendicular to the cornea. Indeed, other studies using ultrasound pachymetry also could not find a right-left difference[60,61].

The ranges of central corneal thickness in all 3 groups were similar. The CCT ranged between 472 and 605µm in the controls, 470 and 609µm in the POAG group and 452 and 618µm in the OHT group. Within this wide range more than 50% of the studied subjects in all three groups had corneal thickness ranging between 501 and 570µm.

As expected from literature[27,48], we found that central corneal thickness and intraocular pressure were positively related. It is still not clear whether the relation between intraocular pressure and corneal thickness is , rather than real. It may be caused by a measurement error in applanation tonometry because of differences in corneal

thickness, as anticipated by Goldmann himself[2]. Another possible explanation is a physiologic effect of intraocular pressure on the cornea, resulting, for example, in an increase of collagen fibers or rigidity in the cornea or a combination of both. Based on our data, we cannot prove or reject any of these possibilities.

Manometric studies, however, disproved this argument and found that the higher pressures obtained by applanation tonometry were in fact due to a measurement error induced by the presence of the thicker corneas, and not accurate representations of the true IOP[27,40] .

We used ultrasound pachymetry for our study as it has shown to have better inter- observer and intra-observer variability than the optical method in several studies[62,63]. The difference between successive measurements in each eye gives an approximate estimation of the error made in measuring a fixed point on the cornea. It is not always possible to measure the exact center of the let alone repeatedly and when successive measurements are being made, paracentral areas of the cornea can be measured. Additionally, readings taken from the central 2-3mm of the cornea have shown to be more replicable than from paracentral or peripheral locations in the cornea[64].

Our study thus confirms that CCT can be a confounding factor while recording intraocular pressure. A patient may be labeled an ocular

hypertensive just because of the error in measuring his applanation IOP, leading to unnecessary prolonged treatment and/ or follow up. The CCT measurement would go a long way in helping us make a clinically relevant decision.

SUMMARY

1. Mean central corneal thickness was significantly higher in patients with ocular hypertension, when compared with the controls. Comparing the central corneal thickness in primary open angle glaucoma and controls, there was found to be no significant statistical difference among the two groups.
2. There was no difference in central corneal thickness between sexes in POAG & ocular hypertension though CCT was higher in females in control group.
3. Central corneal thickness was similar in right and left eyes.
4. There was statistically significant negative correlation of CCT with age.
5. As measured by applanation tonometry, intraocular pressure is positively related to central corneal thickness.

CONCLUSION

The mean Central corneal thickness in normals, primary open angle glaucoma and ocular hypertension was similar to that found in clinical studies. The range of central corneal thickness in our population is comparable to western populations.

The effect of central corneal thickness may influence the accuracy of applanation Tonometry in the diagnosis, screening and management of patients with glaucoma.

The measurement of central corneal thickness though perhaps not necessary in all suspected glaucoma patients, may be of value selected cases in order to improve clinical decision making, especially if the other clinical findings do not seem to correlate with the intraocular pressure. This will help to prevent the erroneous labeling of primary open angle glaucoma patients as “normal tension glaucoma” and normal patients as “ocular hypertensives”. This will help to decide which eyes need aggressive management and which do not need any treatment at all.

The existence of multiple correction formulas does not make reclassification of patients easier due to the inaccuracy of both applanation Tonometry and ultrasonic pachymetry and also the high inter individual variability in corneal thickness.

However, in chronic conditions, a deviation of only 10% from the normal central corneal thickness has a measurable impact on Tonometry, as was confirmed in a recently published Meta analyses[49]. Hence, the measurement of central corneal thickness may be useful in selected cases.

The need for a population-based study to understand the distribution of central corneal thickness in our population exists. The variation in central corneal thickness in glaucoma patients has to be studied to exclude its effect on measurement of intraocular pressure by applanation Tonometry.

Variability in CCT is a profound confounder of most tonometric techniques especially the Goldmann Applanation tonometer. OHTS has shown CCT to be a powerful predictor of glaucoma risk. CCT bears a inverse relationship with the risk of developing POAG damage and just as one would perform baseline Gonioscopy, Optic nerve head and visual field studies, a baseline CCT may be obtained for all patients with glaucoma.

Efforts made to combine Tonometry and pachymetry are thus worthwhile, the accurate measurement of central corneal thickness being important not only for individual patient care, in permitting more precise estimation of intraocular pressures, but also for clinical studies, in assuring a more reliable classification of subjects.

BIBLIOGRAPHY

1. Goldmann MH. Un nouveau tonometre a applanation.Bull Soc Fr Ophthalmol 1954:67:474.
2. Goldmann H. Schmidt TH. Ueber applanations tonometrie. Ophthalmologica 1957 :134:221
3. Baum J,and others : Assessment of intraocular pressure by palpation, Am J Ophthalmol 119:650, 1995.
4. Craven ER , and others : Applanation tonometer tip sterlization for adenovirus type 8 , Ophthalmology 94; 1538, 1987
5. Machesney W, Salz JJ : A simple, convenient tonometer tip disinfection technique, Ophthalmic Surg 19:748, 1998.
6. Pepose JS and others: Disinfection of Goldmann tonometers against human immunodeficiency virus type 1, Arch Ophthalmol 107: 983, 1989.
7. Threlkeld AB, and others: Efficacy of a disinfectant wipe method for the removal of adenovirus 8 from tonometer tips, Ophthalmology 100: 1841, 1993.
8. Maldonado MJ , and others : Goldmann applanation Tonometry using sterile disposable silicone tonometer. shields . Ophthalmology 103:815, 1996.

9. Moses RA : The Goldmann applanation tonometer Am J Ophthal 46: 865,1958.

10. Holladay JT, Allison ME, Prager TC : Goldmann applanation Tonometry in patients with regular corneal astigmatism, Am J Ophthal 96:90,1983

11. Koester CJ, Campbell CJ, Donn A: Ophthalmic optical instruments: two recent developments, Jpn J Ophthalmol 24:1, 1980.

12. Moniz E, and others: Removal of hepatitis B surface antigen from a contaminated applanated tonometer, Am J Ophthalmol 91: 522, 1981.

13. Chronister CL, Russo P: Effects of disinfecting solutions on tonometer tips, Optom Vis Sci 67:818, 1990.

14. Centers for Disease Control: Recommendations for preventing possible transmission of human T-lymphotrophic virus type 3/lymphadenopathy — associated virus in tears, MMW.R Morb Mortal Wkly Rep 34:533, 1985.

15. Ehlers N.Bramsen T.Sperling S .Applanation Tonometry and central corneal thickness. Acta ophthalmol 1975: 53:34.

16. Wolfs CW .Klaver CCW .Vingerling JR .et al. Distribution of central corneal thickness and its association with intraocular pressure: the Rotterdam study .Am J Ophthalmol 1997:123:767-72.

17. Shah S .Chatterjee A.Mathai M et al. Relationship between corneal thickness and measured intraocular pressure in a general ophthalmology clinic. Ophthalmology 1999: 106:2154-60

18. La Rosa FA. Gross RL .Orengo-Nania S. Central corneal thickness of Caucasians and African Americans in glaucomatous and nonglaucomatous populations.Arch Ophthalmol 2001:119:23.

19. Foster PJ . Baasanhu J . Alsbrik PH. Et al. Central corneal thickness and intraocular pressure in a Mongolian population. Ophthalmology 1998:105:969.

20. Wu LL.Suzuki Y. ldeta R.et al .Central corneal thickness of normal tension glaucoma patients in Japan .Jpn J Ophthalmol 2000:44:643.

21. Herdon LW.Choudhri SA. Cox T . et al. Central corneal thickness in normal, glaucomatous and ocular hypertensive eyes. Arch Ophthalmol 1997:115:1137.

22. Copt RP, Thomas R, Mermoud A. Corneal thickness in ocular hypertension, primary open angle glaucoma and normal tension glaucoma. Arch.Ophthalmol 1999:117:14.

23. Brandt JD. Beiser JA. Kass MA .et al . Central corneal thickness in the ocular hypertension treatment study (OHTS) Ophthalmology 2001:108:1779.

24. Singh RP .Goldberg I. Graham SL .et al . Central corneal thickness, Tonometry and ocular dimensions in glaucoma and ocular hypertension J Glaucoma, 2001:10:206-10.

25. Herman DC .Hodge DO .Bourne WM. Increased corneal thickness in patients with ocular hypertension. Arch Ophthalmol 2001:119:334

26. Vijaya L, George R, Arvind H, Ve Ramesh S, Baskaran M, Raju P, Asokan R, Velumuri L. Central corneal thickness in adult South Indians: the Chennai Glaucoma Study. Ophthalmology. 2010 Apr;117(4):700-4

27. Johnson M.Kass MA. Moses RA .et al. Increased corneal thickness simulating elevated intraocular pressure. Arch Ophthalmol 1978:96:664.

28. Whitacre MM . Stein RA. Hassanien K The effect of corneal thickness on applanation Tonometry. Am J Ophthalmol 1993:115:592-96.

29. Dohadwala AA. Munger R .Damji KF .Positive correlation between Tono-pen intraocular pressure and central corneal thickness. Ophthalmology, 1998:105:1849.

30. Mardelli PG .Piebenga LW. Whitacre MM. et al .The effect of excimer laser photorefractive keratectomy on intraocular pressure measurements using the Goldmann applanation tonometer.Ophthalmology 1997:104:945.

31. Chatterjee A.Shah s.Besant DA.et al .Reduction in intraocular pressure after excimer laser photorefractive keratectomy. Ophthalmology 1997:104:355.

32. Abbasoglu OV. Bowmann RW. Cavanaugh HD. et al Reliability of IOP measurements after myopic excimer photorefractive keratectomy. Ophthalmology 1998:105:2193.

33. Price FW. Koller DL. Price MO. Central corneal pachymetry in patients undergoing laser in situ keratomileusis. Ophthalmology 1999: 106:2216.

34. Duch S.Serra A.Casterna J.et al. Tonometry after laser in situ keratomileusis treatment. J Glaucoma 2001: 10:261.

35. Arimoto A. Shimizu K. Shoji N.et al. Underestimation of intraocular pressure in eyes after laser in situ keratomileusis. Jpn J Ophthalmol 2002:46:645.

36. Vakili R.Choudri SA.Taub S. et al. Effect of mild to moderate myopic correction by laser in situ keratomileusis on intraocular pressure measurements with Goldmann applanation tonometer. Tono-pen and pneumatotonometer.J Glaucoma 2002:11:493.

37. Olson PF, and others: Measurement of intraocular pressure after epikeratophakia. Arch Ophthalmol 101:1111 ,1983.

38. Schipper I, and others: (Are we measuring the right intraocular pressure after excimer laser photorefractive laser keratoplasty in myopia?) Klin Mbl Augenheilk, 206:32,1995.

39. Mark HH: Corneal curvature in applanation Tonometry, Am J Ophthalmol 76: 223,1973.

40. Ritch R, Shields MB, Krupin T. The Glauomas, 2 edition.St.Louis : C.V Mosby; 1996.Vol. 1,2. pp 407—29, 615-57, 859- 74.

41. Maurice DM, Giardini AA: A simple optical apparatus for measuring the corneal thickness and the average thickness of the human cornea, Br J Ophthalmol, 35:169-177, 1951.

42. Kremer FB: A new instrument for clinical pachymetry. In Schachar RA, Levy NS, Schachar L, editors: Keratorefractive society meeting on controversial aspects of radial keratotomy, Denison, TX, 1980, LAL.

43. Thornton SR. A guide to pachymeters. Ophthalmic Surg 1984; 15:993-995.

44. Wheeler NC, Morantes CM, Kristensen RM, et al. Reliability coefficients of three corneal pachymeters. Am J Ophthalmol 1992; 113:645-651.

45. Bovelle R, Kaufman SC, Thompson HW, Hamano H. Corneal thickness measurements with the Topcon SP-2000P specular microscope and an ultrasound pachymeter. Arch Ophthalmol 1999; 117:868-870.

46. Duke-Elders S. System of Ophthalmolgy. St Louis : 1976. C.V. Mosby Vol.X1.pp 379- 560.

47. Schmidt TAF . The clinical application of the Goldmann applanation tonometer. Am J Ophthalmol 1960;49:967-78.

48. Hansen FK. A clinical study of the normal human corneal thickness. Acta Ophthalmol 1971 ;49:82-88.

49. Doughty MJ, Zaman ML: Human corneal thickness and its impact on intraocular pressure measures: a review and meta analysis approach. Surv. Ophthalmol. 2000; 44: 367-408.

50. Gordon MO, Beiser JA, Brandt JD: The Ocular hypertension Treatment study:baseline factors that predict the onset of primary open angle glaucoma. Arch. Ophthalmol. 2002 Jun; 120(6) :714-20.

51. Bechmann M, Thiel MJ, Roesen B, Ullrich S:central corneal thickness determined with optical coherence tomography in various types of glaucoma. Br J Ophthalmol. 2000 Nov; 84(11): 1233-7.

52. Wu L, Suzuki Y, Araie M: Corneal thickness and intraocular pressure in cases with ocular hypertension and glaucoma: Zhonghua Yan Ke ZaZhi. 200 Nov; 36(6): 438-41.

53. A.C. Sobottka ventura, M Bohnke, DS Mojon: central corneal thickness measurements in patients with normal tension glaucoma, primary open

angle glaucoma, pseudoexfoliation glaucoma, or ocular hypertension. Br J Ophthalmol; 85: 792-795.

54. Ramakrishnan R, Praveen K, Krishnadas R et al: Glaucoma in a rural population of southern India. The Aravind comprehensive eye survey. Ophthalmology, 2003; 1484- 1490.

55. Rapuano CJ, Fishbaugh JA, Strike DJ: Nine point corneal thickness measurements and keratometry readings in normal corneas using ultrasound pachymetry. Insight 1993: 18; 16-22.

56. OHTS- Baseline factors that predict the onset of POAG. Mae o Gordon, Julian A Besiar et al Arch ophthal, vol 120, June 2002, 714-720.

57. Arkell SM, Lightman DA, Sommer A, et al: The prevalence of Glaucoma among Eskimos Of North-West Alaska. Arch. Ophthalmol. 1987; 105: 482-5.

58. Korey M, Gieser D, Kass MA, Waltman SR, Gordon M, Becker B.Central corneal endothelial cell density and central corneal thickness in ocular hypertension and primary open-angle glaucoma. Am J Ophthalmol 1982;94: 610-616.

59. Ehlers N, Hansen FK. On the optical measurement of corneal thickness. Acta Ophthalmol (copenh) 1971;49: 65-81.

60. Grasson C, Forthomme D. Comparison of central corneal thickness measurements between optical and ultrasound pachometers. Opt Vis Sci 1992;69:236-41.

61. Salz JJ, Azen SP, Berstein J, Caroline F, Villasenor RA, Schanzlin DJ. Evaluation and comparison of sources of variability in the measurement of corneal thickness with ultrasonic and optical pachymeters. Ophthalmic Surg 1983;14;750-754.

62. Giasson C, Forthomme D. Comparison of central thickness measurements between optical and ultrasound pachymeters.Optom Vis Sci 1992;69:236-41.

63. Nissen J,Hjortdal JO, Ehlers N. A clinical comparison of optical and ultrasonic pachometry. Acta Ophthalmol 1991 ;69:659-63.

64. Higgins S E, Fishbaugh JA, Strike DJ, Rapuano CJ. Reproducibility and variation of corneal thickness in different locations in the cornea as measured by an ultrasonic pachymeter. Insight 1993:18:14-18.

65. American Academy of Ophthalmology Glaucoma Panel. Preferred Practice Pattern® Guidelines. Primary Open-Angle Glaucoma. San Francisco, CA: American Academy of Ophthalmology; 2010

PROFORMA

1. Serial Number :
2. Medical Record Number :
3. Name :
4. Age :
5. Sex :
6. Address :
7. Occupation :
8. Medical History : Diabetes Mellitus Yes / No

   Contact Lens Wearer – Yes / No

   Surgical / Laser Interventions – Yes / No
9. Clinical Diagnosis : RE

   LE

Ocular Examination

10. Uncorrected visual acuity : RE

    LE
11. Best corrected visual acuity : RE

    LE
12. Slit Lamp Examination : Anterior segment and detailed Stereoscopic fundus examination with 90D lens

Disc Evaluation : Size/ Shape

Neuroretinal rim

Cup disc ratio

Vessels

Hemorrhage

Parapapillary area

Nerve fibre layer

Macula

Associated findings

13. Tension by applanation tonometry : RE

LE

14.Gonioscopy - Shaffer's grading : RE

LE

15. Central corneal thickness measurement : RE

LE

16. Octopus visual field analysis : RE

LE

KEY TO MASTER CHART

A - SERIAL NUMBER

B - MEDICAL RECORD NUMBER

C - NAME

D - AGE

E - SEX

F - BEST CORRECTED VISUAL ACUITY: RE

LE

G - FUNDUS - VERTICAL CUP DISC RATIO IN PERCENTAGE.

H - TENSION APPLANATION : RE

LE

I - GONIOSCOPY SHAFFER'S GRADING :

RE

LE

J - CENTRAL CORNEAL THICKNESS MEASUREMENT IN µm :

RE

LE

K- OCTOPUS FIELD ANALYSIS G-1 NORMAL

- 1. NORMAL
- 2. ABNORMALITIES WITHIN ONE HEMIFIELD NOT WITHIN 5 DEGREES OF FIXATION
- 3. ABNORMALITIES IN BOTH HEMIFIELDS AND/OR LOSS WITHIN 5 DEGREES OF FIXATION IN ATLEAST ONE HEMIFIELD

CONTROLS

					BCVA		CD Ratio %		Tension Applanation		Gonioscopy Shaffer's Grading		CCT in µm		Octopus Field Analysis	
S.No.	IP No.	Name	Age	Sex	RE	LE	RE	LE	RE	LE	RE	LE	RE	LE	RE	LE
1	471245	MARIMUTHU	41	M	6;6	6;6	25	35	11	10	4	4	489	487	1	1
2	472456	NAGAMMA	55	F	6;9	6;6	20	30	14	13	4	4	580	577	1	1
3	471123	GURUVAMMA	42	F	6;24	6;9	45	45	11	14	3	3	579	578	1	1
4	473323	CHELLAIAH	54	M	6;9	6;9	35	35	10	11	3	3	496	491	1	1
5	474348	KANDASAMY	72	M	6;36	6;6	65	60	15	12	3	4	520	520	1	1
6	475417	NARAYANAN	69	M	6;24	6;6	35	30	11	12	4	4	600	598	1	1
7	474324	NAGALAXMI	65	F	6;24	6;9	65	50	19	14	3	3	523	525	1	1
8	476672	PALPANDI	64	M	6;24	6;9	60	65	13	14	3	4	548	548	1	1
9	470697	MUNEESWARI	43	F	6,24	6;9	60	60	18	16	3	3	505	508	1	1
10	478326	YESUDOSS	46	M	6;9	6;9	50	50	12	13	3	3	563	562	1	1
11	475809	MALAYANDI	66	M	6;6	6;9	30	35	13	15	3	4	527	530	1	1
12	476534	MOOKAIAH	68	M	6;12	6;9	50	45	13	12	4	4	472	473	1	1
13	479867	KANAGA	46	F	6;9	6;9	60	55	13	14	4	4	565	568	1	1
14	480794	PALANIAMMA	48	F	6;9	6;9	60	50	12	12	3	3	569	567	1	1
15	476405	PACKIARAJ	52	M	6;6	6;6	50	50	11	10	3	3	525	525	1	1
16	477890	KUPPAMA	54	F	6;12	6;12	50	50	17	16	3	3	523	524	1	1
17	474789	RAJAVELU	65	M	6;6	6;12	35	40	11	12	4	4	500	500	1	1
18	481980	MEERAN	47	M	6;6	6;6	35	40	19	18	4	4	524	526	1	1
19	483541	MAYIL	55	F	6;9	6;12	40	50	17	16	3	3	586	584	1	1
20	478651	TAMIL	53	F	6;12	6;24	50	50	13	12	4	4	508	506	1	1
21	472387	MOORTHY	64	M	6;12	6;12	45	40	16	16	3	3	530	530	1	1
22	474398	KANNAN	60	M	6;12	6;12	40	50	13	14	4	4	513	514	1	1
23	475193	MAYAN	46	M	6;6	6;6	40	50	12	13	4	4	516	513	1	1
24	489907	LALITHA	48	F	6;9	6;9	35	45	13	14	3	3	520	519	1	1
25	486513	PERIYASAMY	68	M	6;12	6;12	45	55	14	13	4	4	517	518	1	1
26	483278	KURINGI	63	F	6;24	6;12	55	55	13	15	3	3	534	535	1	1
27	480876	SURESH	44	M	6;6	6;6	65	60	17	16	4	4	518	513	1	1
28	472098	SHIEK	49	M	6;12	6;9	45	45	15	14	4	4	540	540	1	1
29	486713	KALYANI	55	F	6;9	6;12	55	55	14	15	4	4	605	605	1	1
30	475612	AYIRATHAMMA	57	F	6;60	6;12	40	35	15	16	4	4	515	515	1	1
31	478809	ALAGAPURI	43	M	6;9	6;12	45	55	14	12	4	4	538	537	1	1
32	474657	NANDINI	57	F	6;9	6;12	60	55	14	15	3	3	547	550	1	1
33	487650	KUPPUSAMY	53	M	6;24	6;12	45	50	13	14	3	4	513	515	1	1
34	475345	KALAN	55	M	6;18	6;12	45	50	14	15	4	4	518	513	1	1
35	475098	MUTHU	44	M	6;9	6;6	40	45	14	13	4	4	589	587	1	1
36	487086	LAXMI	46	F	6;12	6;12	45	55	14	13	3	3	538	535	1	1
37	476378	MAYACHANDRAN	57	M	6;12	6;18	50	55	15	17	3	3	534	536	1	1
38	474552	JOSEPH	52	M	6;9	6;12	45	45	14	14	4	4	515	517	1	1
39	484879	PRIYADARSHINI	41	F	6;9	6;12	50	55	13	14	3	3	517	517	1	1
40	486647	KARUPASAMY	59	M	6;60	6;12	60	50	14	15	3	3	559	557	1	1
41	481230	KATTAN	60	M	6;24	6;18	40	45	15	16	4	4	520	520	1	1
42	484430	GOMATHY	44	F	6;6	6;12	30	30	16	16	3	3	514	515	1	1
43	482094	ARUNA	51	F	6;24	6;12	45	55	14	16	3	3	516	517	1	1
44	473428	SHANMUGAN	43	M	6;12	6;60	45	55	14	15	4	4	538	536	1	1
45	479957	VADIVOO	41	F	6;18	6;24	55	60	15	16	3	3	520	518	1	1
46	474118	VANAN	55	M	6.;12	6;24	45	35	13	12	4	4	514	518	1	1
47	476330	GEETHA	65	F	6;9	6;12	50	60	14	15	4	4	535	538	1	1
48	481220	KANIAMMA	54	F	6;12	6;9	40	45	12	13	4	4	597	591	1	1
49	491150	JESURAJ	57	M	6;12	6;18	50	50	14	15	4	4	513	516	1	1
50	487103	SARIFA	52	F	6;12	6;9	45	50	14	14	4	4	513	515	1	1

POAG

					BCVA		CD Ratio %		Tension Applanation		Gonioscopy Shaffer's Grading		CCT in µm		Octopus Field Analysis	
S.No.	IP No.	Name	Age	Sex	RE	LE	RE	LE	RE	LE	RE	LE	RE	LE	RE	LE
1	474123	MUTUSAMY	45	M	6;12	6;18	60	70	17	19	4	4	530	533	2	3
2	474321	LAKKAMA	65	F	6;36	6;24	65	75	18	19	3	3	530	534	2	3
3	471245	FRANCIS	53	M	6;9	6;12	65	70	20	18	4	3	525	520	2	3
4	476321	SADAIYAPPAN	72	M	6;24	6;36	70	80	20	21	3	3	509	503	3	3
5	474831	SOPHIA	40	F	6;9	6;9	60	70	24	26	3	3	540	536	2	3
6	472761	MAYAN	52	M	6;12	6;24	65	70	16	17	3	3	536	540	2	3
7	474657	PANDARAM	63	M	6;12	6;18	50	60	15	17	3	3	512	518	2	2
8	474234	SOMUTHEVAR	80	M	6;36	6;36	70	70	16	17	3	3	588	590	3	3
9	484672	POTHUMPONNU	46	F	6;12	6;18	60	65	30	21	3	3	540	537	2	3
10	474893	GUNAVATHY	54	F	6;12	6;18	75	75	24	24	3	3	533	533	3	3
11	479870	PONNAIAH	66	M	6;24	6;18	60	65	20	17	3	4	545	540	3	2
12	476990	KANDAIAH	65	M	6;12	6;18	70	70	14	17	3	4	529	528	3	3
13	475231	JEYARAM	57	M	6;12	6;18	50	60	17	19	3	3	509	518	2	2
14	477632	LAXMI	63	F	6;12	6;18	60	65	19	14	3	3	550	530	2	3
15	478320	VIDYA	54	F	6;24	6;24	50	60	15	16	3	3	516	520	2	2
16	480720	RAJAN	45	M	6;12	6;18	50	30	18	18	4	4	490	498	3	1
17	481901	SOOSAI	56	M	6;12	6;9	55	65	18	17	3	3	545	545	2	2
18	473672	MANICKAM	65	M	6;24	6;12	65	70	17	24	3	3	498	495	2	3
19	475230	MARI	68	M	6;12	6;12	50	50	16	17	3	3	586	588	2	2
20	483091	KANAGA	47	F	6;12	6;15	65	70	15	14	3	3	546	545	3	3
21	482346	KUTHALAM	57	M	6;9	6;12	65	95	14	48	4	4	593	591	2	3
22	478126	SARAVANAN	58	M	6;24	6;18	65	65	17	17	4	4	540	540	3	2
23	476112	SAMIKANNU	61	M	6;24	6;12	75	75	26	26	3	4	523	526	2	3
24	473467	KUPPU	65	M	6;12	6;24	75	65	26	22	4	3	497	500	2	2
25	480221	NAYAGI	46	F	6;9	6;9	50	50	18	18	4	3	564	563	3	2
26	481007	RAMAR	54	M	6;12	6;9	50	55	16	16	4	4	530	537	2	2
27	480887	VEDANTHAM	56	M	6;12	6;12	65	60	20	21	4	4	595	593	3	2
28	489001	SUNDARI	64	F	6;24	6;9	60	60	18	16	4	3	564	563	3	3
29	481330	PUNITHA	42	F	6;18	6;6	50	50	16	16	4	4	518	514	2	2
30	477890	KOTTARAM	56	M	6;24	6;12	50	55	17	18	4	3	554	553	2	2
31	476234	KOMBAIAH	68	M	6;12	6;18	55	65	16	18	4	3	564	563	2	2
32	484701	GANESAN	59	M	6;12	6;24	50	30	18	14	4	4	507	505	3	1
33	479907	SAMIPONNU	57	F	6;12	6;24	65	70	16	18	4	3	531	530	2	2
34	471388	GAYATHRI	41	F	6;12	6;24	60	70	18	19	4	4	555	550	2	3
35	483402	GEETHA	57	F	6;12	6;18	55	60	15	17	4	4	531	532	2	2
36	482661	ANNAMALAI	67	M	6;12	6;18	60	80	21	24	4	4	518	515	3	3
37	479956	SARMILA	48	F	6;24	6;18	75	75	21	23	4	3	573	571	3	3
38	480078	SUJATHA	53	F	6;9	6;12	60	60	18	19	4	3	530	531	2	2
39	478551	JEYAKANT	67	M	6;12	6;24	50	60	17	18	4	4	540	539	2	2
40	476102	KALAM	47	M	6;9	6;18	55	70	15	16	4	4	470	471	2	3
41	474992	KUMARI	58	F	6;12	6;18	70	70	18	19	4	4	503	504	3	2
42	359956	PUSPHA	64	F	6;24	6;18	65	60	19	17	3	3	519	515	3	2
43	484886	PUNITHAN	46	M	6;12	6;9	50	50	18	14	3	4	485	484	2	2
44	480445	LALI	57	F	6;12	6;6	70	75	20	23	3	4	607	608	3	3
45	490061	KUMAR	47	M	6.;9	6;18	65	80	20	22	3	4	533	535	3	3
46	482992	JEYA	59	F	6;36	6;12	65	45	21	18	3	4	519	520	2	2
47	478112	SUDALAI	64	M	6;12	6;18	50	60	18	19	3	3	554	553	2	2
48	490102	JAFAR	56	M	6;12	6;18	65	50	21	18	3	4	534	532	3	2
49	485897	SHAKEENA	43	F	6;9	6;12	55	50	21	21	3	4	545	544	2	2
50	483214	MARIAPPAN	55	M	6;12	6;6	50	60	20	22	3	3	565	566	2	2

OCULAR HYPERTENSION

					BCVA		CD Ratio %		Tension Applanation		Gonioscopy Shaffer's Grading		CCT in µm		Octopus Field Analysis	
S.No.	IP No.	Name	Age	Sex	RE	LE	RE	LE	RE	LE	RE	LE	RE	LE	RE	LE
1	478801	MANIKAM	45	M	6;9	6;6	30	40	23	23	4	4	558	554	1	1
2	478766	MANTHIRAM	55	M	6;9	6;9	40	40	24	24	3	3	564	568	1	1
3	488796	SUBBULAXMI	67	F	6;6	6;6	60	65	26	26	4	4	576	579	1	1
4	474467	THANGAVEL	43	M	6;6	6;12	40	45	24	20	4	4	595	597	1	1
5	474667	JOHARA	63	F	6;12	6;18	55	30	27	35	4	4	559	560	1	1
6	477789	AKILAN	56	M	6;12	6;18	40	30	24	18	3	3	550	554	1	1
7	477688	GANAPTHYAMMA	54	F	6;12	6;9	40	35	23	20	3	3	608	605	1	1
8	472889	JANAGIRAM	42	M	6;6	6;9	25	30	21	23	3	3	565	563	1	1
9	471885	IRULAPPAN	80	M	6;60	6;6	40	50	18	23	3	3	452	453	1	1
10	476955	MEENACHI	40	F	6;12	6;9	50	50	23	20	3	3	571	574	1	1
11	474889	GANDHI	56	M	6;6	6;9	30	30	23	17	3	3	548	547	1	1
12	472776	TAMILARASU	65	M	6;12	6;9	30	40	28	22	4	4	555	554	1	1
13	480112	RADIKA	57	F	6;9	6;12	40	50	24	22	3	3	585	581	1	1
14	472334	VENU	46	M	6;18	6;6	35	40	25	25	3	3	579	576	1	1
15	473478	SADDIQUE	54	M	6;36	6;12	30	30	26	26	3	3	586	585	1	1
16	476722	LILLY	43	F	6;12	6;9	45	40	28	30	3	3	595	593	1	1
17	475003	ABRAHAM	68	M	6;12	6;18	40	40	28	29	4	4	564	563	1	1
18	472560	KANAGARAJ	58	M	6;9	6;12	35	40	22	23	3	3	549	545	1	1
19	480970	POOMAHAL	42	F	6;9	6;12	45	50	18	24	4	4	567	569	1	1
20	481276	OCHAYI	45	F	6;9	6;12	50	45	22	21	4	4	564	563	1	1
21	484889	MADASAMY	56	M	6;12	6;12	45	50	23	23	4	4	578	576	1	1
22	489778	KUPPUSAMY	46	M	6;12	6;9	30	35	19	23	3	3	573	571	1	1
23	482361	DAVID	54	M	6;6	6;12	40	40	26	18	3	3	574	576	1	1
24	480141	RANJANI	63	F	6;12	6;12	40	50	24	26	3	3	598	599	1	1
25	484009	MEENA	57	F	6;12	6;9	35	35	24	23	4	4	583	587	1	1
26	482776	MAYILVAHAN	42	M	6;6	6;9	40	45	17	23	3	3	616	618	1	1
27	486770	PALANIANDI	59	M	6;24	6;12	40	45	34	32	3	3	553	554	1	1
28	487201	KAVERI	43	F	6;12	6;24	35	40	24	25	3	3	571	574	1	1
29	477281	ILAKIYAN	61	M	6;9	6;12	30	30	24	24	3	3	553	554	1	1
30	479902	JEBARAJ	54	M	6;36	6;18	40	40	23	21	3	3	567	568	1	1
31	472774	KUMARI	45	F	6;12	6;18	40	40	24	23	3	3	557	555	1	1
32	487448	KANDAN	58	M	6;18	6;9	30	25	21	26	3	3	542	543	1	1
33	470089	AYYAVOO	41	M	6;9	6;12	25	30	23	24	3	3	567	563	1	1
34	481120	FATIMA	54	F	6;12	6;9	30	30	26	21	4	4	589	586	1	1
35	487200	ABBAS	43	M	6;12	6;6	35	35	25	21	3	3	548	549	1	1
36	484992	SENTAMARAI	67	F	6;6	6;12	40	45	23	27	3	3	555	554	1	1
37	484780	KAMARAJ	58	M	6;9	6;12	45	45	20	24	3	3	553	554	1	1
38	480480	KAMALA	59	F	6;12	6;9	45	40	21	24	3	3	586	587	1	1
39	484110	AVUDAIAPPAN	43	M	6;12	6;9	50	50	24	23	3	3	560	563	1	1
40	474684	PUGALENDI	54	M	6;12	6;9	40	30	23	25	3	3	570	573	1	1
41	490784	POOMARI	65	F	6;12	6;9	50	50	25	26	3	3	567	568	1	1
42	486792	MAYILANDI	57	M	6;9	6;12	40	40	24	27	3	3	578	576	1	1
43	489667	BAMA	54	F	6;12	6;6	35	35	23	24	3	3	500	499	1	1
44	482232	MANNAR	45	M	6;12	6;9	40	40	25	24	3	3	505	509	1	1
45	487999	KUMUTHAM	53	F	6;9	6;12	35	35	20	26	3	3	550	554	1	1
46	477222	GOPAL	58	M	6;9	6;12	45	45	22	24	3	3	505	506	1	1
47	490119	REVATHY	46	F	6;12	6;9	40	30	20	24	3	3	540	540	1	1
48	489110	HYDER	49	M	6;9	6;12	35	35	22	24	4	4	565	564	1	1
49	487761	PANDIAMMA	53	F	6;9	6;12	45	50	21	25	4	4	537	538	1	1
50	491283	KASI	47	M	6;12	6;18	40	40	24	26	3	3	524	528	1	1