# A COMPARATIVE STUDY OF INTRAOCULAR PRESSURE MEASURMENT BY SCHIOTZ, GOLDMANN'S APPLANATION & ICARE TONOMETERS

**Dissertation submitted in**

**Partial fulfillment of the regulations required for the award of**

**M.S. DEGREE**

**In**

**OPHTHALOMOLOGY**

**THE TAMILNADU**

**DR. M.G.R. MEDICAL UNIVERSITY**

**CHENNAI**

**APRIL 2014**

# DECLARATION

I hereby declare that this dissertation entitled **"A COMPARATIVE STUDY OF INTRAOCULAR PRESSURE MEASURMENT BY SCHIOTZ, GOLDMANN'S APPLANATION & ICARE TONOMETERS"** is a bonafide and genuine research work carried out by me under the guidance of Dr A RAJENDRAPRASAD MS DO Professor of Ophthalmology, Coimbatore Medical College, Coimbatore.

Date:

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This is to certify that the dissertation **"A COMPARATIVE STUDY OF INTRAOCULAR PRESSURE MEASURMENT BY SCHIOTZ, GOLDMANN'S APPLANATION & ICARE TONOMETERS"** is a bonafide research work done by Dr GOPINATHAN G S, post graduate in MS Ophthalmology under my direct guidance and supervision to my satisfaction, in partial fulfilment of the requirements for the degree of MS Ophthalmology.

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A COMPARATIVE STUDY OFSCHIOTZ, GOLDMANN'S APPLANATION& ICARE TONOMETERS Dissertation submitted in Partial fulfilment of the regulations required for the award of M.S. DEGREE In OPHTHALOMOLOGY THE TAMILNADU DR. M.G.R. MEDICAL UNIVERSITY CHENNAI APRIL 2014 i DECLARATION I hereby declare that this dissertation entitled “A COMPARITIVE STUDY OF SCHIOTZ,GOLDMANN’S APPLANATION AND ICARE TONOMETERS” is a bonafide and genuine research work carried out by me under the guidance of Dr A RAJENDRAPRASAD MS DO Professor of Ophthalmology, Coimbatore Medical College, Coimbatore. Date: Place: Dr GOPINATHAN G S ii CERTIFICATE This is to certify that the dissertation “A COMPARITIVE STUDY OF SCHIOTZ, GOLDMNANN’S...


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## Abstract:

**Objective**:

To compare the intraocular pressure readings obtained by Goldmann Applanation Tonometer, Icare rebound tonometer and Schiotz indentation tonometer. Also to find the degree of agreement between each tonometers & to study the influence of factors like Age, Sex, Laterality over their measurement.

**Design**:

Cross sectional hospital based study.

**Studypopulation**:

102 patients attending ophthalmology OPD of our hospital.

**Methods**:

Cases were selected on the basis of inclusion and exclusion criteria. Then demographic details of the cases were recorded. All the cases were then evaluated in the following order before subjecting them to IOP measurements.

The protocol is as follows:

1. Visual acuity with pinhole.
2. Detailed anterior segment examination with slit lamp examination
3. Fields charting with Bjerrum screen
4. Then IOP measurement using 3 different tonometers.

5. Followed by that pupil is dilated using 0.5% tropicamide and detailed fundus evaluation is done to rule out glaucomatous changes.

**Results:**

Resultsshowed that most of patients in our study were females. And the average age group was 62 year for males and 58 year for females. The statisticaldifference in IOP between right and left eye was absent. Also there was no significant change in IOP with respect to age in both sexes.

The correlation studies showed that the correlation between schiotz and other two tonometers namely Icare and GAT were weak. But that of GAT and Icare was very strong which was also statistically very significant in both the eyes.

Also the agreement between IOP values of GAT and Icare was very good than the agreement between schiotz and other tonometers.

**Conclusion**:

Accurate IOP assessment is of pivotal importance in glaucoma diagnosis.Schiotz tonometry though cheap, portable, light weight and quick method of IOP assessment it is not an accurate and reliable method of assessment.GAT is the gold standard technique of IOP assessment in glaucoma patients, giving reliable and accurate readings. But it is time consuming, not portable and cumbersome to use.ICARE tonometer is easy to use, comfortable to patients, quick, lightweight and portable. Yet it gives reliable and accurate

IOP readings comparable with GAT.Thus ICARE tonometer can be used as an effective screening tool.

**Keywords**:

Intraocular pressure, tonometry, Schiotz,Goldmann's applanation tonometry,Icare.

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# ABBREVIATIONS

| | | |
|---|---|---|
| GAT | - | Goldmann's applanation tonometer |
| IOP | - | Intraocular pressure |
| NCT | - | Non-contact Tonometry |
| OHT | - | Ocular hypertension |
| POAG | - | Primary open angle glaucoma |
| NPG | - | Normal Pressure Glaucoma |
| RK | - | Radial keratotomy |
| PRK | - | Photorefractive Keratectomy |
| LASIK | - | Laser Assisted In-Situ Keratomileusis |
| CCT | - | Central corneal thickness |
| ORA | - | Reichert Ocular Response Analyser |
| CH | - | Corneal hysteresis |
| CRF | - | Corneal resistance factor |
| DCT | - | Dynamic Contour Tonometer |
| RBT | - | Rebound tonometer |
| OPD | - | Out patient department |

# INTRODUCTION

Glaucoma is the leading cause of irreversible blindness throughout the world. WHO statistics published in 1995 indicate that glaucoma accounts for blindness in 5.1 million persons or 13.5% of global blindness .worldwide it has become the second most common cause of bilateral blindness. Open angle glaucoma and angle closure glaucoma were estimated to affect approximately 66.8 million people by the year 2000, with 6.7 million experiencing bilateral blindness[1].

Prevalence based studies had estimated the prevalence of glaucoma in India to be about 11.9 million and 60.5 million in the world by the year 2010. There have been four prevalence studies from South India: The Andhrapradesh eye disease study (APEDS), the Aravind comprehensive eye survey (ACES), the Chennai glaucoma study (CGS) and the Vellore eye study (VES). Prevalence of POAG in India by APEDS – 2.56%, by ACES- 1.7 % & CGS -1.62% and that of PACG by APEDS- 1.08 % & CGS – 0.87 %.

Glaucoma has been declared to be the second most common cause of blindness in adults in India. The proportion of persons bilaterally blind from POAG has been variably reported to be 11 % (APEDS), 1.6 % (ACES), and 3.2% (CGS). The high rate of blindness in the Indian population is due to high proportion of undiagnosed glaucoma in the

community. Glaucoma was undetected in more than 90 % of individuals identified in the population studies. The ACES also reported that 50 % of persons detected with glaucoma had undergone an ophthalmic evaluation in the previous year and yet glaucoma was undetected in 80 % of individuals identified in this study. Inadequate identification of glaucoma even in population undergoing ophthalmic evaluation continues to be a major determinant of preventable blindness due to glaucoma in India[2].

Once the blindness of glaucoma has occurred, there is no treatment that will restore vision. In nearly all cases, however, blindness is due to glaucoma is preventable. This prevention requires early detection and proper treatment[1].

The important crux of any glaucoma program must be "case detection". When patients come to us for any ocular problem we should use the chance to detect glaucoma in those cases. The idea is to properly diagnose and treat those clearly defined glaucoma cases those which have failed to be properly diagnosed for various reasons[3].

Good case detection depends on using tests with high positive predictive values such as perimetry, tonometry and fundus examination to all the patients who visit our clinic for various eye ailments[4].

For early diagnosis of glaucomatous damage new technologies such as new tonometers, new OCT machines& optic nerve head analysers etc. are of paramount importance[5].

Nowadays even though the diagnosis of glaucoma is done on the basis of structural and functional changes found in retinal nerve fibre layer, intra ocular pressure is the only factor which can be used to titrate the treatment and also the important factor whose reduction can bring about good prognosis and disease slowing. Thus an accurate assessment of IOP is of paramount importance in glaucoma cases[6].

# EVOLUTION OF TONOMETRY

**TONOMETRY**:

Tonometry, or the measurement of intraocular pressure (IOP), is an important procedure in our clinics used for accurate diagnosis of glaucoma cases. Normal IOP is due to a balance between aqueous inflow and its outflow by trabecular and uveal pathways.

Functions of aqueous:

1. Aqueous maintains the normal IOP.
2. Aqueous provides nutrition to lens and cornea.
3. It maintains the shape of the globe.
4. Serves as a transparent medium for the light to pass through.

Non pigmented ciliary epithelium secretes aqueous humor at a rate of 2–3 μL per minute. In humans anterior chamber volume is estimated to be ~250–300 μL. Turnover rate of aqueous humor is ~1% of anterior chamber volume (~2.5 μL per minute).

The mean IOP was found to be around 16 mmhg by various people, but with increasing age it was towards higher pressures. Taking 22 mmhg as abnormal value and using that to diagnose and treat cases would be a grave mistake as damages can occur even at lower IOP'S.

Actually there is no fixed IOP value above or below which it can be said that damages can or cannot occur. But still IOP continues to be

THE ONE factor which can altered to treat this condition of glaucoma in patients.

In normal individuals, IOP varies by 2–6 mmHg over the course of a 24-hour period as aqueous humor production changes. Higher IOP is associated with greater fluctuation and a diurnal fluctuation > 10 mmHg is suggestive of glaucoma. Many people reach their peak IOP in the morning hours, but others do so in the afternoon, in the evening, or during sleep; still others follow no reproducible pattern.

In treatment of glaucoma, reduction of IOP by either surgical or pharmacological means forms the important factor in slowing both structural and functional loss of retinal nerve fibres. So accurate measurement of IOP is of utmost importance in these patients. But still even after reducing IOP to target levels deterioration can occur as it is not the only factor in determining glaucomatous damage. There are many other factors which control IOP and glaucoma based damage to optic nerve head[7].

## EVOLUTION:

**Sir William Bowman** emphasised the importance of intraocular pressure, after that many new technologies have come up to evaluate the intraocular pressure[8].

**Sir William** first explained the importance of IOP measurement by fingers. After that this method of IOP estimation became so popular that even for few years after advent instruments to measure IOP, physicians continued to do IOP estimation by fingers only!!!

### Impression tonometry:

In the early 1860s, **Albrecht von Graefe was** the first one to attempt to build a tonometer, but it was **Donder** who actually built a working tonometer; even though it was not an accurate one. His instrument displaced fluid on contact with sclera, which was the basic principle.

This principle was used to find the IOP by first finding the curvature of the sclera at the point of contact and taking that as a reference plane to measure the depth of indentation.

**Smith and Lazerat** later refined this technology in 1880s, and with the discovery of cocaine in 1884 led way to corneal impression tonometry. With the advent of corneal anaesthesia, corneal tonometry became the choice of IOP measurement.

With impression tonometry major disadvantage was it displaced large amount of fluid that led to invariably wrong readings that were not reproducible[8].

**Indentation (Schiotz) tonometry:**

This was first introduced into practice by **Hjalmar Schiotz** in 1900's. It measured IOP by finding how much cornea is indented by plunger of a fixed weight. Even though it is not used in daily practice nowadays it was a simple, easy to use and cheap instrument in ophthalmology clinics those days[8].

**Applanation Tonometry:**

**Adolf Weber** was the to invent applanation tonometer in 1867 after that it was reinvented by **Alexei Maklakoff** following which many versions of the same has come.

In 1950s Goldmann introduced the adjustment for ocular rigidity, which led to the development of the Goldmann's applanation tonometer. It displaced so small amount of fluid that ocular rigidity was considered negligible[8].

**Goldmann applanation tonometry:**

The Goldmann applanation tonometer (GAT) is called a variable force tonometer because it measures the amount of force required to flatten a fixed area of the cornea. For many years it was considered as

the gold standard of IOP measurement. Goldmann while designing thought that corneal thickness would be a deciding factor in resistance to deformation. So he took an average corneal thickness of 520 micron as standard and estimated that resistance to deformation would be cancelled by precorneal tear film surface tension if the applanating surface diameter was 3.06 mm[8].

**Assumptions in applanation tonometry:**

1. CCT = 520um
2. Consistent Surface tension
3. Consistent Corneal / Scleral rigidity

**Facts in applanation tonometry:**

1. Based on **Imbert-Fick principle:** Pressure = force/area
2. 0.1g force to applanation head 3.06mm = 1 mmHg
3. Surface tension and ocular rigidity negate each other

**Non-contact Tonometry (NCT):**

Non-contact (also called air-puff) tonometers use a puff of air to applanate the cornea. IOP is measured by the amount of force by air puff required to flatten the cornea to a fixed level.

It undergoes the same problems as an applanation does as it also tries to measure IOP by applanation[8].

**Principle of NCT:**

NCT was invented by Grolmanin 1972. It deforms the cornea by a puff of air and that central corneal deformation is used to measure the IOP.

Types of NCT

1. Table mounted – Xpert NCT
2. Hand held -Pulsair tonometer from Keeler

Pneumatic System:

Is the one which generates the air puff. The principle is that maximum rays of light are received when the corneal is flattened; and the time taken for maximum light detection is used for IOP estimation by comparing with Goldmann readings[8].

**Fallacies with NCT:**

The ocular pulses become an important variable since the measurements are not synchronous with the cardiac cycle. Also the IOP varies in some patient's up to 6 mmhg when the choroid fills and empties. And NCT measurements are independent of the cardiac cycle making its readings difficult to reproduce. To overcome these, 3 readings within 3 mmhg range is taken as IOP.

**Accuracy:**

In normal range of IOP it is comparable to Goldmann's. But accuracy decreases in higher IOP ranges and in cases if unsteady fixation and corneal lesions are present.

**Advantages:**

1. Patient comfort.
2. Contamination absent
3. Absent corneal injury
4. No use for topical anaesthetics
5. Useful in mass screening.

Goldmann tonometer was considered gold standard and was not questioned until ocular hypertension studies and refractive surgeries came into existence[8].

**Refractive Surgery and Applanation Error:**

Goldmann tonometer readings were found to decrease by 3-5 mmhg after radial keratotomy (RK) and LASIK procedures. This was associated with decrease in corneal thickness values post-surgery.

But in RK there was no decrease in corneal thickness only an increase was noted, but here also there was a decrease in IOP. Latter in 1950 Goldmann explained in his study that his IOP values were

influenced by many factors one of which is central corneal thickness (CCT).

To overcome this problem of CCT, Ehlers devised a correction formula. This was on the basis that GAT value was higher in thick corneas and low in thin corneas. After that many such correction formulas came below is the one by **Orssengo-Pye**

| Corrected IOP = Measured IOP – (CCT-545)/50 x 2.5 mm Hg |
|---|

According to this IOP correction of 1 mm hg is needed for every 20 microns of thickness Variation.

**Correction values for IOPs based on CCT. Corrections derived from data from Ehlers, et al.**

| CCT in microns | IOP correction in mm Hg |
|---|---|
| 445 | 7 |
| 455 | 6 |
| 465 | 6 |
| 475 | 5 |
| 485 | 4 |
| 495 | 4 |
| 505 | 3 |
| 515 | 2 |

| | |
|---|---|
| 525 | 1 |
| 535 | 1 |
| 545 | 0 |
| 555 | -1 |
| 565 | -1 |
| 575 | -2 |
| 585 | -3 |
| 595 | -4 |
| 605 | -4 |
| 615 | -5 |
| 625 | -6 |
| 635 | -6 |
| 645 | -7 |

But still these correction methods have come into scrutiny and there are few studies to suggest that these formulas are over simplication of the IOP correction. So taking this into account many technologies are tried for accurate assessment, as a result of which two new devices have come into existence which are the Reichert Ocular Response Analyzer (ORA) and The PASCAL Dynamic Contour Tonometer (DCT) [8].

**The Reichert Ocular Response Analyser (ORA):**

Principle behind ORA is that it uses "dynamic bi-directional applanation process" for finding the biomechanical properties of cornea and IOP. ORA measure the IOP which is Goldmann correlated (IOPG) and also corneal hysteresis (CH). Measurement of the later allows ORA to find what is called corneal resistance factor (CRF) and the corneal-compensated intraocular pressure (IOPCC).

Since IOPCC is compensated for corneal biomechanical properties its IOP values are least affected by corneal thickness. Hence its values are stable after refractive surgeries[8].

Overall corneal resistance is given by CRF and so it affects both CCT and GAT.

**Operation of the Ocular Response Analyser:**

The ORA uses an electro optical system to monitor the corneal deformation made by the air pulse.

In ORA, air pulse not only pushes the cornea to the level of applanation but also behind that to make cornea into a concave surface. Then the air pulse slowly withdraws allowing the cornea to take back its shape again. The entire process is monitored by an optical system which then calculates the pressure for both inward and outward process. The pressures for both these process are different as the corneal viscous

damping forces are different for both these process. IOPG is given by the average of these two values. And the different between these values gives the CH[8].

## The Pascal – Dynamic Contour Tonometer (DCT):

DCT uses the principle of contour matching instead of applanation. This removes the problems found in other tonometers due to corneal biomechanical properties.

Even though it looks like Goldmann tonometer PASCAL is not a variable force tonometer.

It has a tip that matches the shape of cornea with a pressure sensor that rests with a constant force of 1 g on cornea. So when the corneal tip of tonometer senses changes in pressure its electrical output changes which is calibrated to give the corresponding IOP.

Tip of the tonometer resting on the cornea has a diameter of 10.5 mm. This tip takes the shape of cornea when the both side pressures are equal. After taking the shape the sensor on the tip takes 1 second to make 100 IOP measurements. Then in 8 seconds a complete measurement cycle is taken[8].

# REVIEW OF LITERATURE

The normal intraocular pressure in man may be considered to be the statistical average pressure which normal eyes have been found to tolerate over a period of time without damage to their integrity. Since the introduction of tonometer there have been number of investigations to record the intraocular tension of the normal healthy eyes. In clinical practice intraocular pressure cannot be measured directly as such but indirectly through the state of tension of the tunics of the eye ball. This indirect deduction often leads to many variations which cannot be always controlled. There has been a constant search to improvise the methods of recording intraocular tension so as to minimize the errors due to many variable factors[9].

## Factors affecting intra ocular pressure:

- **Factors that may increase intraocular pressure[13]:**
    - Elevated episcleral venous pressure:
        - Valsalva manuveur
        - Breath holding
        - Wearing tight collar
        - Bending over
        - Elevated central venous pressure

- Pressure on the eye:
    - Blepharospasm
- Elevated body temperature:
    - Increased aqueous production
- Hormones:
    - Thyroid ophthalmitis
    - Hypothyroid
- Drugs :
    - LSD
    - Topiramate
    - Steroids
    - Ketamine

- **Factors that may decrease intra ocular pressure[13] :**
    - Aerobic exercises :
    - Anaesthetic drugs:
        - Succinyl choline
    - Metabolic / respiratory acidosis:
    - Hormones:
        - Pregnancy
    - Drugs:
        - Alcohol
        - Heroin

- Cannabis

In this study we have compared schiotz tonometer, Goldmann's applanation tonometer and Icare tonometer. Even though Goldmann'sapplanation tonometer is considered to be the gold standard and Schiotz tonometers to be out dated; we have taken schitoz in this study, since it's a cost effective instrument in many parts of this world for early glaucoma screening. Icare being a newer technology was included in the study to see how it can effectively perform as a glaucoma screening device in this part of the world, as not much study was done from this part of the country.

## SCHIOTZ TONOMETER

**Instrument:**

It has a foot plate attached to a plunger which in turn is connected to a needle which moves across a scale through jack hammer arrangement. Because of this arrangement the needle moves across the scale as the plunger indents the cornea. The scale reading is noted which is then converted to IOP.

**Fig. 1 Schiotz Tonometer**

**Standard instrument:**

1. Foot plate: has radius of curvature of15 mm& weight 11 gm.
2. Plunger: diameter is3 mm, weight 5.5 gm.
    - Additional weights are 7.5,10 or 15 gm.
    - Scale reading is zero when plunger moves 0.05 mm beyond foot plate.
    - Each scale unit means 0.05 mm of plunger protrusion.

**Basic concept:**

The weight of the tonometer on the eye increases the actual IOP (P0) to a higher level (Pt). The change in pressure from P0 to Pt is an expression of the resistance of the eye to the displacement of the fluid. Determination of P0 from a scale reading Pt requires conversion which is done according to **Friedenwald** conversion tables.

**Freidenwald** generated empirical formulae for linear relationship between the log function of IOP and the ocular distension. This formula

has “c” a numerical constant, the coefficient of ocular rigidity which is an expression of disdentability of the eye. Its average value is 0.025.

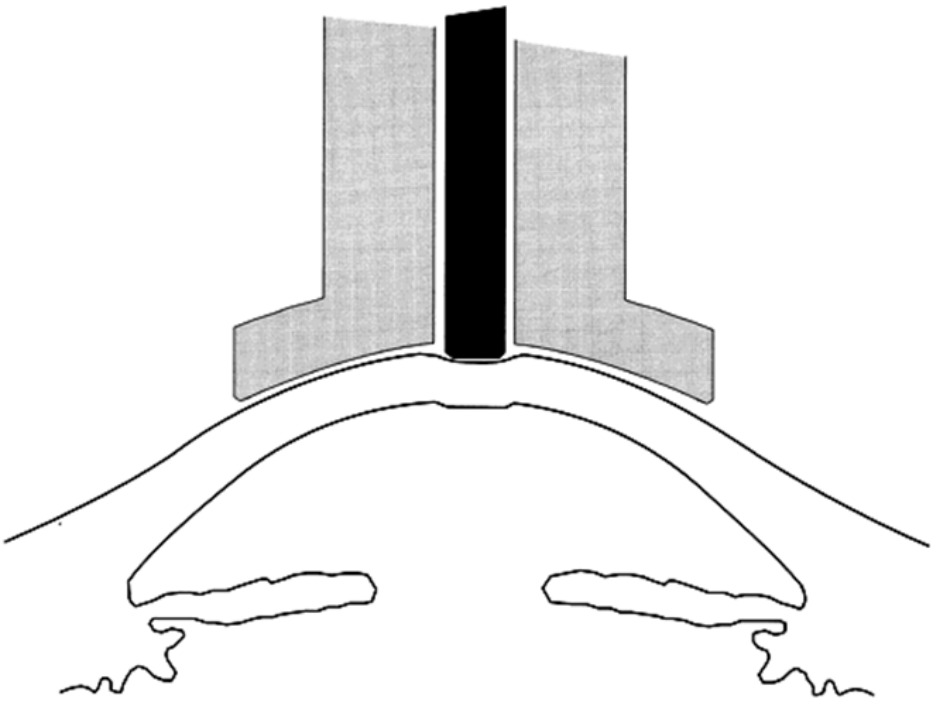


**Fig. 2 Corneal Indendation**

**Source of error:**

- Accuracy is limited as ocular rigidity varies from eye to eye .as conversion tables are based on an average coefficient of ocular rigidity. An eye that varies significantly from this value gives erroneous IOP.
- High ocular rigidity is seen in hypermetropes, long standing glaucoma, and ARMD and vasoconstrictor therapy. High ocular rigidity gives a falsely high IOP.
- Low ocular rigidity is seen in high myopia, increasing age, mioitcs, and vasodilators after Retinal Detachment surgery and intravitreal

injection of compressible gas. Low ocular rigidity gives a falsely low IOP reading.

- The variable expulsion of intra ocular blood during Schiotz tonometery may influence IOP measurements.
- Repeated measurements lower IOP.
- Either a steeper or thicker cornea cause greater displacement of fluid during tonometry giving a falsely high IOP[12].

Schiotz indentation tonometer has remained the most popular instrument for recording intraocular tension. Since its introduction Schiotz himself devised several scales of increasing accuracy. These were further modified by **Friedenwald**. The calibration scale used nowadays is based on the use of the applanation tonometer of Goldman which is considered as the most accurate and near ideal tonometer so far. It is interesting to note the various phases through which these studies have been carried. The average normal intraocular pressure according to Schiotz ranged from 15 - 30 mmHg averaging 20 - 25 mmHg and somewhat less for the same tonometer when calibration is used. With the subsequent calibration of 1955 (and 1957) **Friedenwald** stated that the 1948 calibration scales of Schiotz and McLean are too high - the average pressure was given between 18-19 mmHg rather than 22-24 mmHg as believed by Schiotz and 27 - 28 mmHg as held by McLean. Before the standardization of the tonometer was accomplished by the Committee of

Standardization of Tonometers set up by the American Academy of Ophthalmology and Oto-laryngology, it was discovered that many of the tonometers in common use were practically valueless, since they were of non-standard specifications. **Peter C. Kronfeld** has given a table of the range variation of intra-ocular tension in the normal healthy eyes as determined by Ricci, Sugar, Stine and Bloomfield. The wide variations among the different authors are probably due to different samples of population examined and also because of the lack of uniformity that existed from instrument to instrument. These difficulties have been greatly overcome after the Standardization committee. In recent years the most extensive study has been carried out by **Leydhekar** who has examined 13801 healthy eyes with the Schiotz tonometer. According to his studies the greatest probability curve occurs at 16 mmHg. Leydhekar also suggests that 95.5% of all healthy eyes have an intra-ocular tension within the range - 10.5 to 20.5 mmHg. Between the ages of 10 - 70 years and between two sexes no significant difference exists. According to Adler the range of intraocular tension in the normal healthy eyes extends from 10 to 22mmHg. And points out that this wide range makes it difficult to determine the physiological limit for a particular person. **Becker and Shaffer** have given the average intraocular tension in normal healthy eyes with Schiotz Tonometer as 16.1 mmHg (± 2.5) and with Goldman applanation tonometer as 15.4 mmHg (± 2.5). According to this

study intraocular pressure of over 21 mmHg occurs in less than 2.5% and a pressure above 25 mmHg occurs in less than 0.15%. There was reference from Indian authors in his connection[9].

All tonometers in use today work on the principle of applying a force to the eye and measuring the deformation produced. Since tonometry involves the application of a force to the eye it is inevitably accompanied by a rise of IOP It is this artificially elevated pressure, usually termed Pt, which is measured directly by the tonometer. The pressure which is of clinical interest, however, is the pressure Po which existed in the undisturbed eye before the tonometer was applied. It is important to recognise that for indentation tonometers like Schiotz tonometer, the difference between Po &Pt is large. Nevertheless the most frequently used tonometer worldwide is the Schiotz indentation tonometer despite clear evidence that the problem of ocular rigidity involved in indentation tonometry cause misleading results in the individual eye. When the ocular rigidity differs slightly from normal, the error in deducing the true IOP Po may be negligible, but in a small proportion of eyes, the rigidity may be so far removed from normal that the error becomes clinically significant. It will be remembered that the general effect is that the Schiotz tonometer tends to overestimate the Po in eyes of high rigidity and to underestimate Po in eyes of low rigidity.

In order, to overcome this defect Friedenwald proposed the so-called method of "DIFFERENTIAL TONOMETRY" in which a reading is taken with one weight on the Plunger and then a second reading' in taken with a different weight. By referring the nomogram Po and Ocular rigidity can be determined[9].

Schiotz IOP Values are influenced by two parameters namely scleral rigidity and ocular tension.

Rigidity and elasticity are not the same. Resistance of a body to change shape is rigidity. And ability to change and take back the original shape is elasticity. In our eye rigidity is due to sclera and cornea.

Schiotz when applied on the cornea its plunger indents the cornea and at the same time it causes scleral distension and increase in ocular tension. When additional weights are applied the plunger further indents the cornea. Thus the IOP by two different weights are different; greater the difference in IOP values greater is the scleral rigidity, as it measured by the difference of the two values.

This is given by the **FRIENDENWALD** formulae:

$$\text{Log}\frac{Pt_2}{Pt_1} = K\ (V_2 - V_1$$

Where,

- Pt 1 = tonometric pressure &
- V 1 = indentation volume caused by first weight

- Pt 2 = tonometric pressure&
- V 2 = indentation volume caused by second weight
- K = coefficient of ocular rigidity[10].

Study by **stephanik** shows that the above FREIDENWALD formula is not valid as it is not linear in many eyes. As a result of this nomogram is also considered to be inferior; thus questioning the accuracy of schiotz measurements[11]

## GOLDMAN APPLANATION TONOMETRY

**Basic concept:**

**Imbert- fick law**: pressure (W) required to flatten a sphere by a fixed area (A) is equal to the pressure (P) inside that sphere.

**W=P X A**

**Problems with the equation**:

1. Eyes are spherical.
2. Also there is capillary attraction at the tear film layer to the tonometer head (S).
3. Force is needed to bend the cornea(B)
4. Outer applantion area doesn't always correspond to internal applanating area (A1).

To overcome this **Modified imbertfick law** came:

$$W + S = PAI + B.$$

Here,

A1 = 7.35 mm3

S = B & so W=P .This internal area of applanation occurs when the diameter of the external area of corneal applanation is 3.06 mm .Using this diameter , grams of force required for flattening the cornea is multiplied by ten which gives IOP in mmhg .

**Instrument:**

The instrument is slit lamp mounted. The applanating area has two biprism facing apex to apex, which convert the circular area of contact into two semicircles. This circular area of contact is made visible by applying 2 % fluorescein priorly into the eye and shinning cobalt blue light. Then the dial which controls the force of applanation is rotated until the two semicircles just touch each other. At this point, the area of applanation becomes 3.06mm. The value on the dial multiplied by 10 gives the IOP value directly.

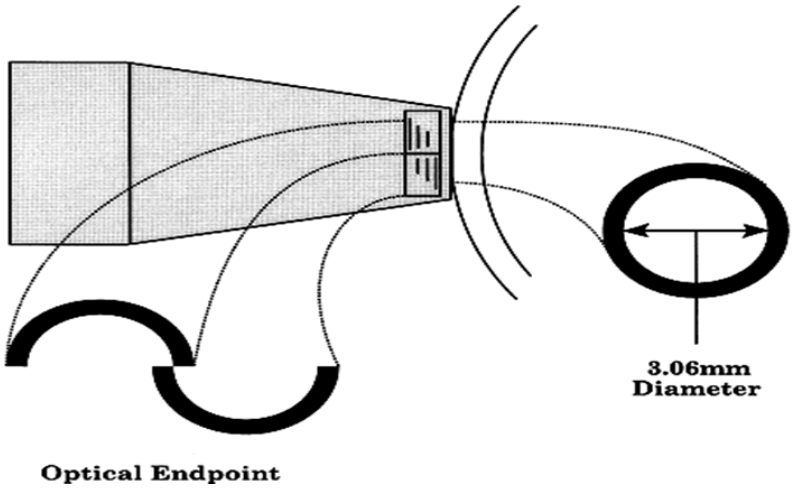



**Fig. 3 Applanation diameter**

**Technique:**

Sodium fluorescein is instilled into the eye after applying local anaesthetics. Cobalt blue light is turned on to visualise the two semicircles made by bi prisms in the appalanating unit. Then the dial controlling the amount of force of applanation is dialled until the two semicircles just touch each other in the inner margins. The value on the dial is read and multiplied by 10 which gives the IOP in mm hg.

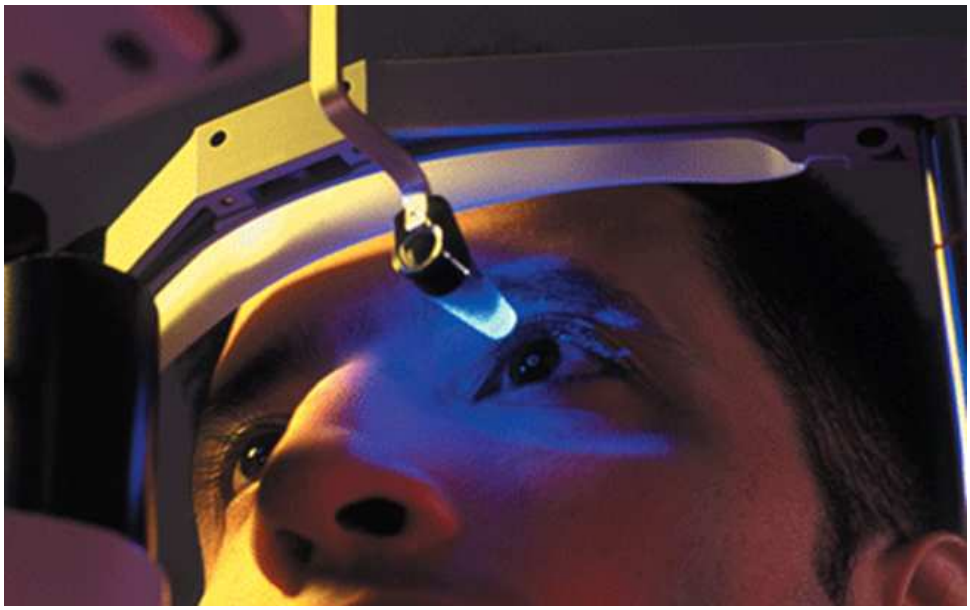


**Fig. 4 Goldman Applanation Unit**

**Error sources:**

1. Inadequate fluorescein gives hypofluroscence.
2. In acidic solution, fluorescein loses fluorescence resulting in under estimation of IOP.
3. Over estimation occurs with wider meniscus.
4. Thick corneas overestimates and thinner ones underestimate the IOP.

5. IOP rises by 1 mm hg for every 3 D increase in corneal curvature.
6. Erroneous IOP is seen in >3 D.
7. Underestimation / over estimation of IOP occur with 4D of with the rule / against the rule of astigmatism.
8. Irregular corneas distort the mires.

**Effect of central corneal thickness (CCT):**

The resistance to applanation changes when corneal thickness changes. So in thin corneas over estimation occurs and vice versa. GAT was based on the assumption of corneal thickness of 520 micron.

So when this CCT changes there is either over estimation or under estimation of IOP. **Ehlers et al** showed that there was an IOP change of 0.7 mm hg for every 10 micron change in CCT [12].

For compensating these thicker and thinner corneas, corneal thickness correction needs to be done for the GAT measured IOP's.

This was emphasised in a study by Joshua R Ehrlich, et al (2012). This says that there is a difference in IOP values of normal / NTG & OHT cases based on CCT. And suggests IOP corrected for corneal thickness is alternative for GAT. And says that CCT corrected IOP is better, especially in normal to low IOP cases[17].

For the above said correction of IOP values with CCT values a formula was proposed by **Wu et al.** The formula was

**Corrected IOP=GAT IOP measurements-(CCT-555) × (1/24).**

But these formulas were not completely error free, asking the researchers to find a better alternative[16].

A study says that larger the difference between the CCT and the assumed 520 micron thickness, greater will be the change in expected IOP. This was given by **Ping-Bo Ouyang, et al (2012)**[16].

But **Kaushik S, et al (2012)** showed that CH and CRF would influence GAT IOP values in a larger way than the CCT values[20].

An exception to use correction formulae was found by **Park SJ, et al (2012)** study. According to this, these formulas can be used in population studies and not for individual cases[18].

Even though the Goldman's applanation was considered to have good reliability, there were studies showing greater IOP diurnal variability when compared with dynamic contour tonometry (DCT) in glaucoma patients.

As both DCT and GAT gave high IOP values in the morning compared to day time readings. This was given by **Carlos Gustavo Vasconcelos de Moraes et al (2009)** in his study[15].

But there were many studies which suggested better or equally good tonometers when compare to GAT.

This was seen in a study by **Martinez-de-la-Casa JM, et al (2006).** According to which RBT and DCT were as reliable and accurate as GAT. And also DCT was independent of CCT[19].

The same was shown in another study **by Ku JY, et al (2006).** According to the study, dynamic contour tonometer (DCT) was equally good as GAT and that it was free from CCT interference in calculating the IOP[21].

A study by **Mangouritsas G et al, (2011)** showed otherwise**.** According to this, both tonometers cannot be used interchangeably[23].

Still, DCT in a study by **Kotecha A, et al (2010)** showed good reliability & agreement with GAT values. Thus not ruling out the possibility of existence of other tonometer's as good as or better than GAT[22].

Finally another tonometer which came close to GAT values of IOP measurement was NCT. This was proven by **Cook JA, et al (2012)**[24].

Tendency of GAT to error by overestimating higher IOP's and underestimating lower IOP's was shown in a study which compared GAT with DCT by **Francis BA, et al (2007)**[25].

A study analysing the influence of age on GAT values was shown by **Jordão ML, et al (2009).** There was no effect of age on IOP measurement by GAT[53].

# REBOUND TONOMETER

ICARE was invented in 1997. It has two coils one for propelling the ICARE probe and the other one for sensing the movement of the probe. The probe has a tip of 1.7mm diameter. It measures IOP by comparing the speed of probe before deceleration by impact on the cornea with the deceleration speed on impact. Main benefit is that it can be used in children without anaesthetics. Also no possibility of infecting a patient as it has disposable probes. Another advantage is that it can be used in home for IOP monitoring of glaucoma patients.


**Fig. 5 Rebound Tonometer**

**Advantages:**

1. Portable
2. Least chance of cross infection
3. Comfortable for children

**Disadvantages:**

1. Values not comparable with GAT[27].

In a study by **LÓPEZ-CABALLERO C, et al,(2007)** showed that even though the measurements obtained with RBT & GAT showed a good correlation, the RBT yields systematically an IOP value greater than the one yielded by the GAT. Also the rebound tonometry reveals a statistically significant relation with the central corneal thickness, exhibiting behaviour similar to applanation tonometry, with higher values in thick corneas and lower in thin corneas[26].

The same was seconded by other studies like:

**Wan-sang Chui et al, (2008)** study, which says that there was over and under estimation when compared with GAT values[29].

**Makoto Nakamura et al, (2006)** showed that ICARE overestimated IOP in thick corneas when compared to GAT[31].

The same was given in a study **by Kyoung Nam Kim et al, (2013) &Suman S et al, (2013).** Former also concluded that it can even replace GAT[32&35].

**Sahin A et al, (2007),** showed that ICARE overestimated GAT values by 0.43 mm hg[34].

But **Detry-Morel M, et al (2006),** showed that ICARE overestimated GAT values by1.5 mmHg when compare to GAT[43].

But in another study it says otherwise, that it did not over or under estimates the IOP values. This was given by **L M Abraham et al, (2008)**[28].

The same was seconded by **Vandewalle E et al (2009) & Brusini P et al (2006),** in their studies[36&42].

**Salim S, et al (2013)** showed that ICARE values were in good correlation with GAT values. And that it can be used in glaucoma routine examination[45].

But the dependency of ICARE on CCT was shown in a study comparing Pascal, Icare and Goldmann applanation tonometry by **Jóhannesson G et al, (2008)**. According to this ICARE was dependent on CCT[39].

The same was again proven in another study by **Nakamura M, et al (2006). It** states that ICARE was influenced by CCT[37].

**Scott R. Lambert et al, (2013) showed** that Rebound tonometry seems to be a reasonably accurate instrument that allows the IOP to be measured in many children without using general anaesthesia[30].

**Matthias et al, (2013)** in his study on oedematous corneas concluded that ICARE can be used for IOP measurements; as it gives accurate results in this condition[33].

In a study on post refractive surgery cases it was found that ICARE was less influenced by corneal oedema that GAT. Study done by **M L Salvetat, et al (2011)**[38].

Interestingly in a study by **Ian G. Beasley et al, (2013)** showed that small angular and lateral deviations of the probe did not significantly change the readings[40].

On performance of ICARE tonometer, a study by Schreiber **W et al, (2007)** showed that it was easy to handle and a reliable tool in glaucoma Assessments[41].

**Munkwitz S, et al (2008)** says that in low to moderate IOP ranges ICARE is a mobile alternative to GAT[44].

ICARE tonometer usage in different age groups is shown in the following studies:

**Lambert SR, et al (2013) &Gandhi NG, et al (2012)** showed that rebound tonometry seems to be a reasonably accurate instrument that allows the IOP to be measured in many children without using general anaesthesia[46&48].

The same above findings were seconded by **Flemmons MS, et al (2011**), but this was in glaucomatouschildren[47].

But a study by **Lundvall A, et al (2012)** shows that even in infants it is easy to use and is well tolerated[52].

But **Dahlmann-Noor AH, et al (2013)** showed RBT and GAT IOP values were not coherent in children with glaucoma[49].

**Sahin A, et al (2007)** showed that there was no difference in IOP measurements between two eyes by ICARE tonometer[50].

In a study comparing with Goldmann's tonometer by **Poostchi A, et al (2009)** showed that the rebound tonometer cannot replace the Goldmann tonometer in the office setting[54].

But in a study by **Scuderi GL, et al (2011)** showed that the Icare tonometer could be considered a valid alternative to GAT when GAT is not available[55].

Finally in a study by **Dusek WA, et al (2012)** showed that males have high IOP values than females irrespective of tonometers. Also age was a factor that influenced the IOP values in males and not in females[51].

# AIM OF THE STUDY

1. To compare the intraocular pressure readings obtained by Goldmann Applanation Tonometer, Icare rebound tonometer and Schiotz indentation tonometer.
2. To find the degree of agreement between each tonometers.
3. To study the influence of factors like Age, Sex, Laterality over the measurement of intraocular pressure.

# MATERIALS AND METHODS

**DESIGN OF STUDY:**

- A cross sectional hospital based study.

**SETTING:**

- Was conducted in the department of ophthalmology, Coimbatore Medical College Hospital, Coimbatore.

**DURATION OF STUDY:**

- From November 2012 to October 2013.

**STUDY POPULATION:**

- People attending the ophthalmology OPD, who are greater than 20 years of age, will be the study subjects.

**INCLUSION CRITERIA:**

- Both male and females.
- Age > 20 years.

**EXCLUSION CRITERIA:**

- Age < 20 years
- History of any previous corneal surgery including refractive surgery
- Scarred or hazy corneas
- Microphthalmos
- Blepharospasm

- Manifest nystagmus
- Keratoconus
- Any current conjunctival or corneal infections
- Known case of glaucoma on treatment

**Study methods:**

- Detailed and Complete history from the patient
- Detailed ophthalmic examination
- Followed by measurement of IOP by Schitoz, Applanation and Icare Tonometer.
- This will be done under topical anesthesia with proparacaine 0.5%.
- Comparative and statistical analysis of the values.

## STUDY DESIGN

Case selection is done using the above inclusion and exclusion criteria. Demographic details of the cases were recorded.

All cases were evaluated with the following protocol before subjecting them to IOP measurements.

The protocol is as follows:

1. Visual acuity with pinhole.
2. Detailed anterior segment examination with slit lamp examination
3. Fields charting with Bjerrum screen
4. Then IOP measurement using 3 different tonometers.
5. Followed by that pupil is dilated using 0.5% tropicamide and detailed fundus evaluation is done to rule out glaucomatous changes.

## IOP MEASUREMENT METHODOLOGY:

IOP is measured first with schiotz then with Goldmann's applanation and then finally with ICARE tonometry in the following manner.

# SCHIOTZ TONOMETER


**Fig. 6 Requisites of schiotz**

## Requisites

1. Schiotz instrument, weights, and nomogram.
2. Anaesthetic eye drops.
3. Cotton swabs.
4. 70 % alcohol for disinfection

## Preparation

- The tonometer is first calibrated with the mould given for that purpose.
- The cleaned with cotton swab and spirit. And then it is wiped dry.
- The patient is made to lie flat with head on pillow.

**Fig. 7 Schiotz Calibration**

**Method**

1. Hands is Washed.
2. We have to stand behind the patient with our hand on his head for support.
3. Anaesthetic eye drops instilled.
4. Patient is then asked to fix at his thumb with hand extended.
5. We have to open the patient's eyes without pressing it.
6. With the other hand, we have to hold the tonometer (with the 5.5 g weight) and then place the schiotz tonometer on the cornea.
7. The scale reading is noted.
8. If tonometer value was 2 or less then we have to change the weight to 7.5 g and then measure.
9. Scale reading is noted and then tonometer is removed.

10. After cleaning the instrument, it is dried and used on the other eye.
11. Using the nomogram card, the scale readings noted are converted to IOP values.

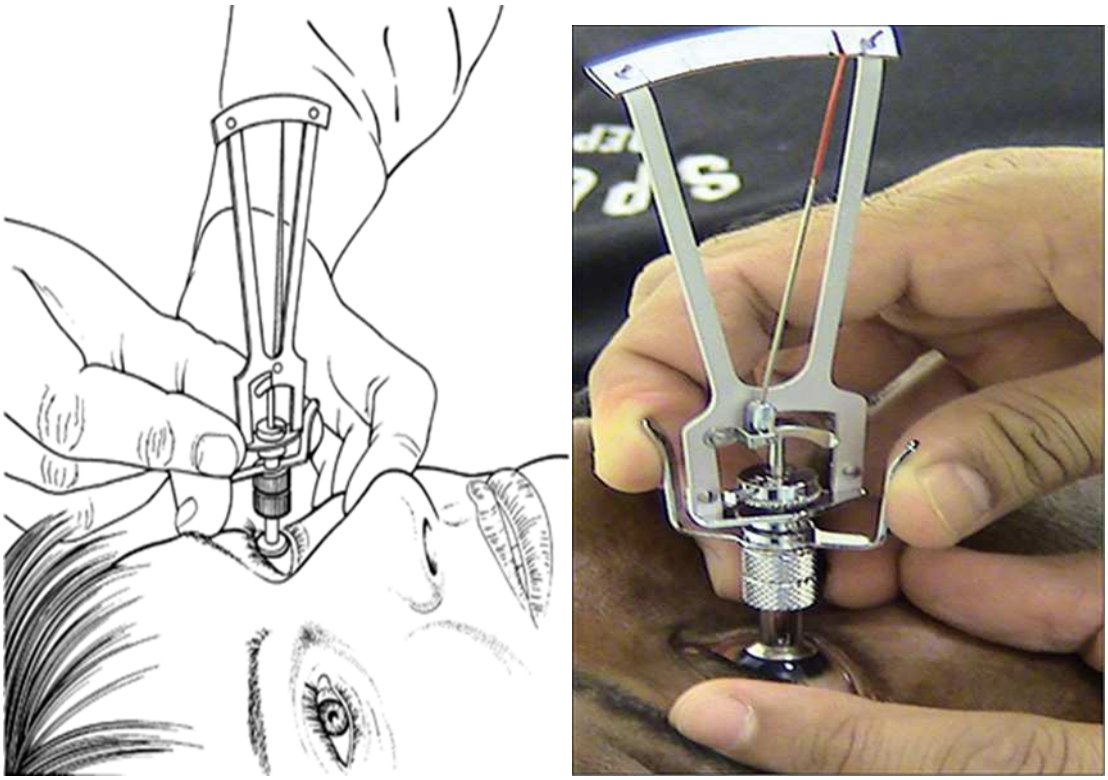


**Fig. 8 IOP Measurement by schiotz**

## GOLDMANN'S APPLANATION TONOMETRY

**Equipment:**

1. Slit lamp mounted Goldmann's tonometer.
2. Applanation prism.
3. 70% alcohol or 1% sodium hypochlorite.
4. Anaesthetic eye drops.
5. Fluorescein strips.
6. Cotton swabs.

**Preparation:**

- Applanating prism is cleaned with70% alcohol or 1% sodium hypochlorite. Then it is wiped dry with a swab.
- "0 "on the dial of prism is set at white mark
- The dial is set at 10 mmHg.
- Patient is made to sit in the correct & comfortable position.
- Slit lamp is set at × 10 magnifications.

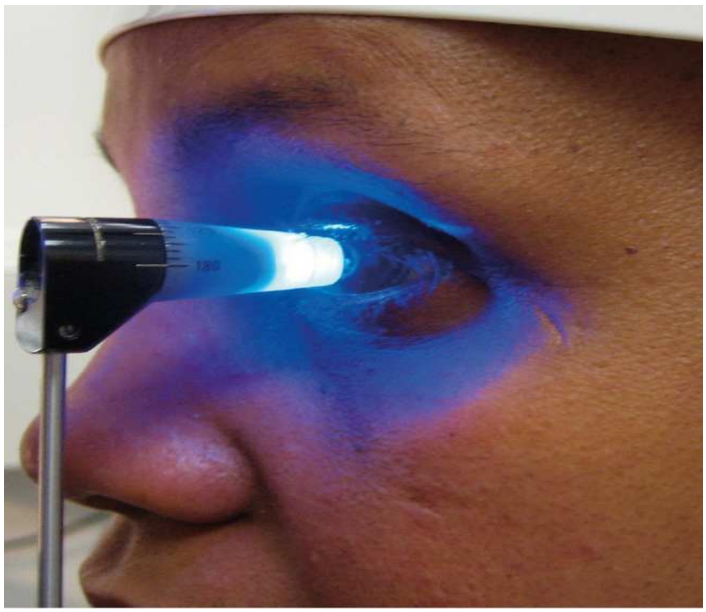


**Fig. 9 IOP Measurement by Goldmann's applanation**

**Method:**

1. After applying fluorescein and anaesthetic eye drops, cobalt blue light is turned on.
2. For measuring right eye, the light is made to come from the patient's right side; for the left eye, the beam is made to come from the patient's left side.

3. Light is kept at maximum.

4. Patient is then asked to sit still with eyes open.

5. The blue light is then directed on the prism head.

6. The tonometer tip is then moved forward to rest on the cornea and then slowly applanate it at its centre.

7. Then the dial is slowly turned until the two semi circles visualised just touch each other at its inner margins.

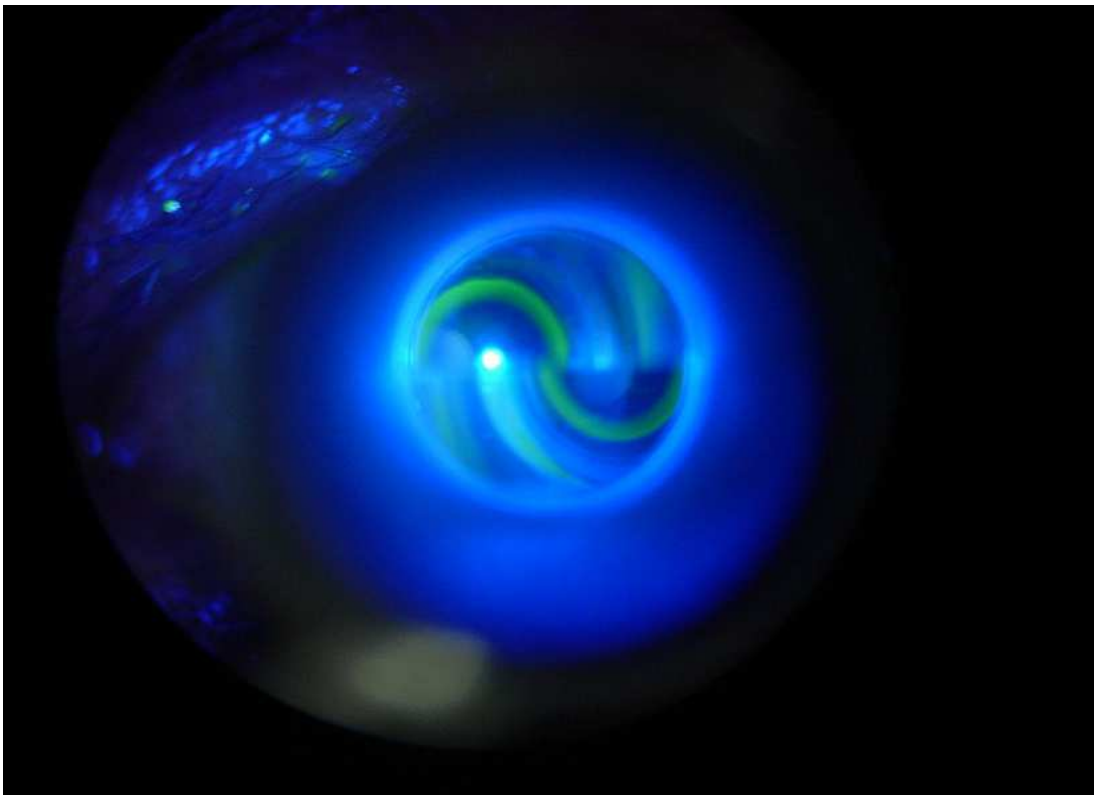


**Fig. 10 Applanation endpoint**

8. The dial reading is noted.

9. The tip resting on the cornea is removed and then washed with disinfectant and dried for using it in the other eye.

10. Same above steps are repeated in the other eye.

## Rebound tonometer (ICARE):

### TURNING THE TONOMETER ON:

- The wrist strap is worn around the wrist.
- The measurement button is pressed to turn ON ICARE.
- After some time it will “LOAD” sign.


**Fig. 11 Turning on and loading the Probe**

**LOADING THE PROBE:**

- The probe is pushed from the tube into the instrument after removing the cap of the tube. Then we have to secure it by pressing the measuring button so that it is magnetised. Then it will show 00.
- The instrument is supported against the forehead of patient which can be adjusted according to the needs.

**MEASUREMENT:**

1. Anaesthetic eye drops not needed.
2. Patient is asked to fix on a distant object steadily.
3. Instrument should be held horizontal to the floor which can be assessed by the central groove. It is kept at a collar length from the eye.
4. Then the measurement button is pressed to take six measurements consecutively.

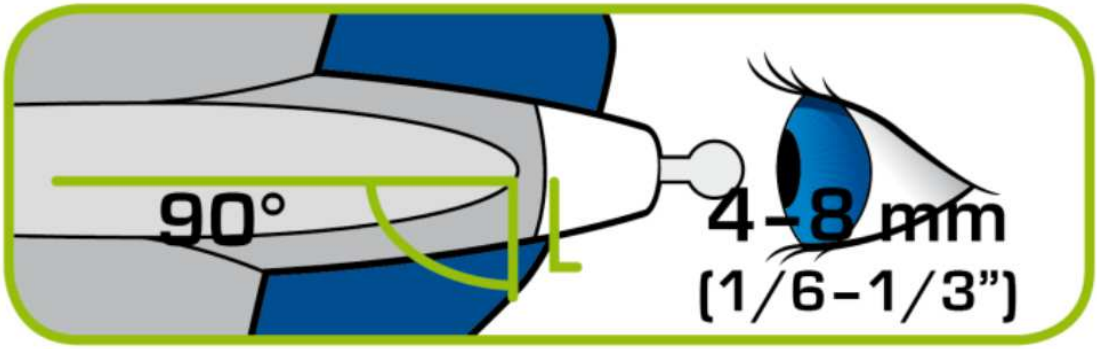



**Fig. 12 Method of using Icare**

A short beep will be heard after each successful measurement. When all six readings are taken a long beep occurs and the IOP will display with the letter P in front of it.

Tonometer will beep twice if a wrong reading is taken and will display error message. To clear the error message, measurement button is pressed.

After taking six successful readings, to start a new set of readings press the measurement button to clear the old IOP value and start fresh.

**DISPLAY AFTER MEASUREMENTS:**

| Before the measurement | After the second measurement | After the sixth measurement |
|---|---|---|
| 00 | 2.13 | P 13 |

The letter P appears on the display after the sixth measurement, followed by IOP value.

**Turning the tonometer OFF:**

'End 'sign will be displayed if the selector button is pressed for 5 seconds. Then measurement button is pressed for 2 seconds until it says 'BYE', following which it will be switched off. The probe then can be taken out easily.

# PACHYMETRY

**Steps:**

1. Cornea is first anaesthetised with Local anaesthetic drops eye drops and then asked to close the eye for 1 min.
2. Pachymeter is turned on and then patient details are entered into it along with the Goldmann's applanation uncorrected IOP value.
3. Patient is asked to open the eyes and asked to look ahead straight.
4. The probe is then brought close to the corneal surface with its tip perpendicular to the corneal surface and a gentle contact with centre of the cornea is made.
5. After a reading is taken the machine gives a beep. Six such readings are needed to give a final Pachymetry and corrected IOP value.
6. The same procedure is repeated for the other eye and final Pachymetry value with corrected IOP for that is also found.
7. The values are then recorded and then the machine is turned off.

# RESULTS AND OBSERVATIONS

In this study a total of 102 patients were subjected to three methods of tonometry – schiotz, Goldmann's applanation and Icare tonometry. Analysis of the data showed the following results:

**Table No. 1 Age Distribution**

The mean age of the participants was 60 years, the youngest participant being 35 years old and oldest being 80 years old.

| **Age Distribution** | | | |
|---|---|---|---|
| Age group (in years) | Sex | | Total No of cases |
| | Male | Female | |
| <40 | 0 | 2 | 2 |
| 41 – 50 | 2 | 13 | 15 |
| 51 – 60 | 17 | 21 | 38 |
| 61- 70 | 14 | 26 | 40 |
| >70 | 7 | 0 | 7 |
| Total | 40 | 62 | 102 |

In our study, majority of males were in 50-60 years age group and in female's majority were in 60-70years age group.

## Chart No. 1 Age Distribution

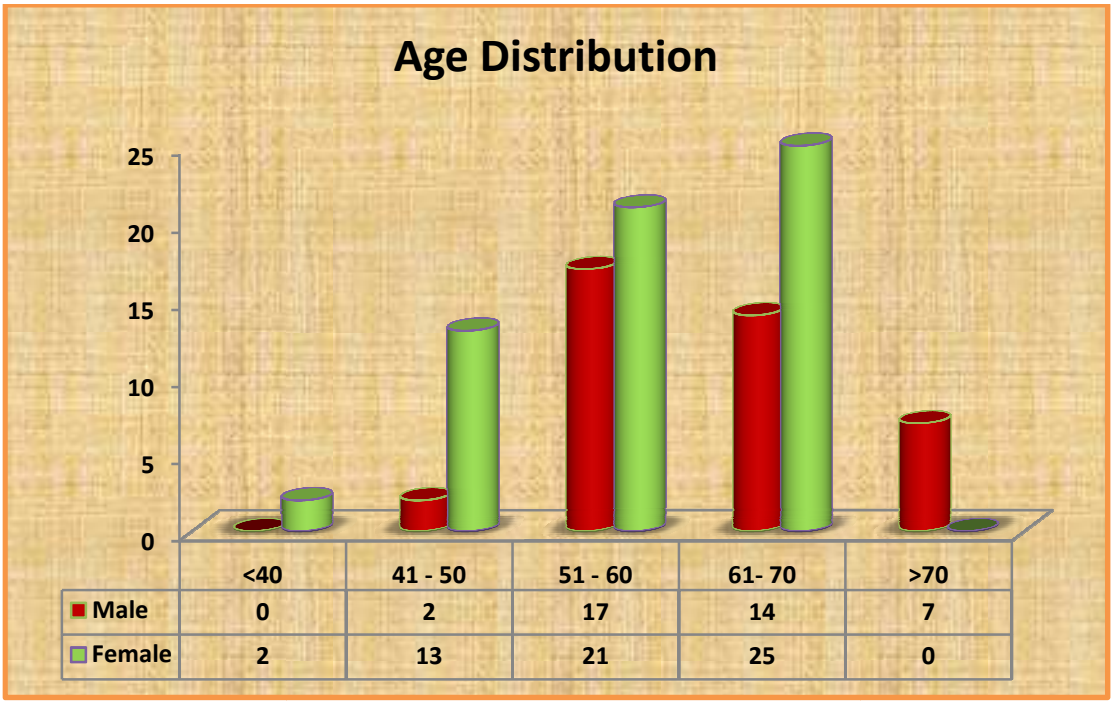
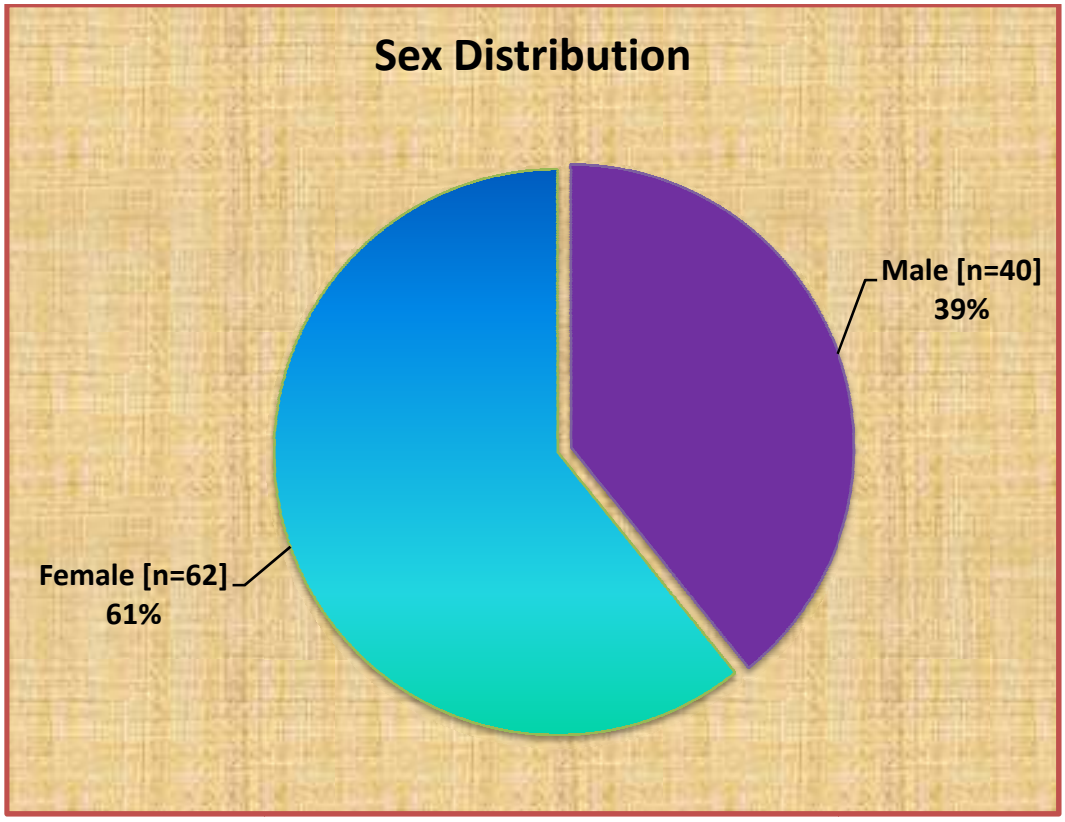


**Table No. 2 Gender distribution:**

From a total of 102 patients 40(39%) were male and 62(61%) were female patients. Hence majority were females.

| | Number of cases | | Minimum age | Maximum age |
|---|---|---|---|---|
| Gender | Male | 40 | 46 | 80 |
| | Female | 62 | 35 | 70 |
| | Total | 102 | 35 | 80 |

**Chart No. 2 Gender distribution:**



## Mean IOP & Age - Right Eye

### Table No. 3 Schiotz tonometer

| NUMBER OF CASES | | | Mean IOP | SD | Minimum IOP | Maximum IOP | p value |
|---|---|---|---|---|---|---|---|
| AGE GROUP | <50years | 17 | 14.5 | 2.8 | 10.2 | 18.9 | 0.714 |
| | >50years | 85 | 14.8 | 3.4 | 8.5 | 22.4 | |
| | Total | 102 | 14.8 | 3.3 | 8.5 | 22.4 | |

With schiotz tonometer, cases were divided in two groups (< 50 &>50 years) for right eye and the significance in the IOP values was found. Statistical significance between these two groups was absent as p value was 0.714.

### Chart No. 3 Schiotz tonometer

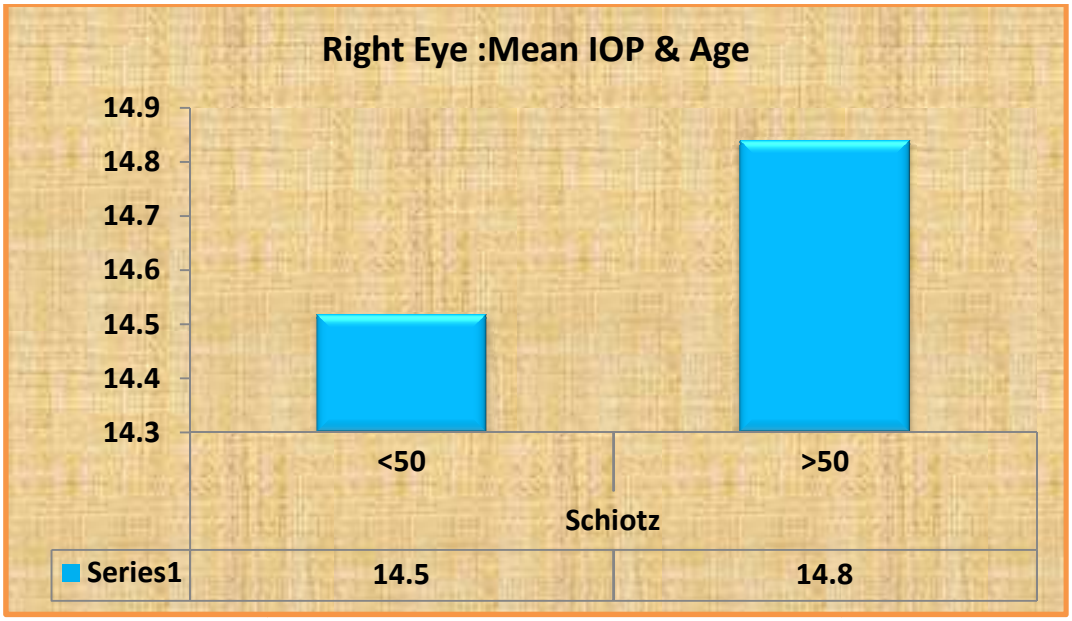


**Table No. 4 GAT**

| NUMBER OF CASES | | | Mean IOP | SD | Minimum IOP | Maximum IOP | p value |
|---|---|---|---|---|---|---|---|
| GAT | <50 YEARS | 17 | 16.1 | 3.5 | 10.0 | 21.9 | 0.405 |
| | > 50YEARS | 85 | 15.4 | 3.3 | 8.1 | 22.7 | |
| | Total | 102 | 15.5 | 3.3 | 8.1 | 22.7 | |

With GAT, cases were divided in two groups (< 50 &>50 years) for right eye and the significance in the IOP values was found. There was no statistical significance between these two groups as p value was 0.405.

**Chart No. 4 GAT**

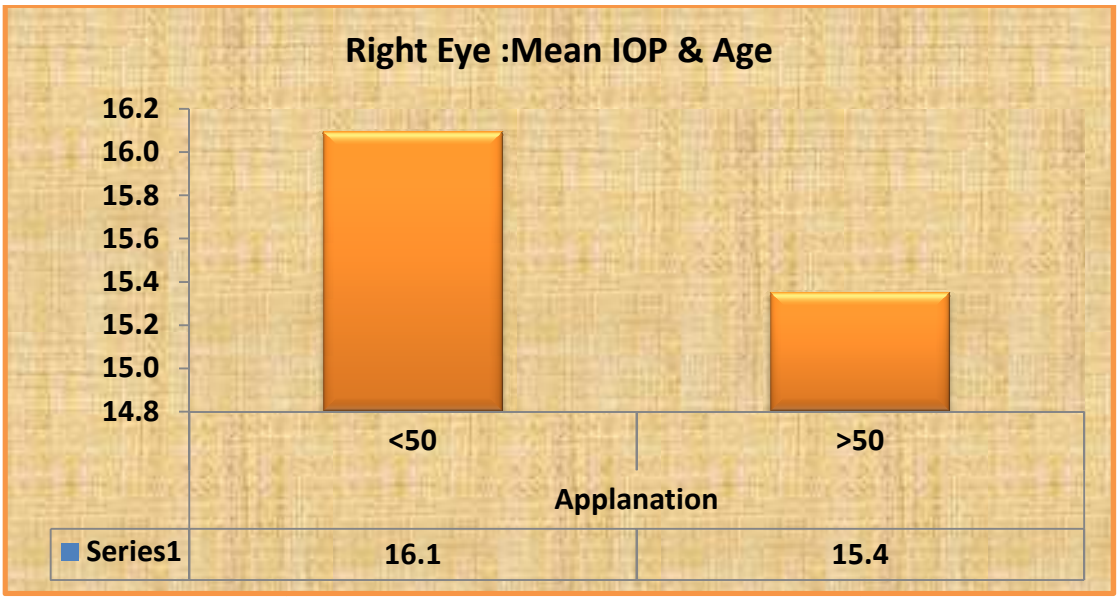
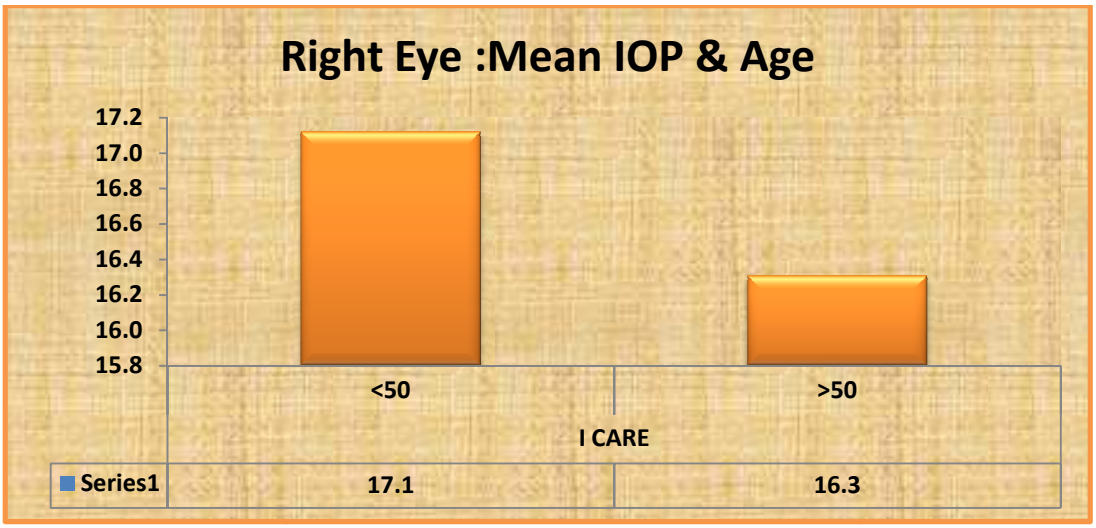


**Table No. 5 ICARE:**

| NUMBER OF CASES | | | Mean IOP | SD | Minimum IOP | Maximum IOP | p value |
|---|---|---|---|---|---|---|---|
| I CARE | <50 YEARS | 17 | 17.1 | 2.8 | 12.0 | 22.0 | 0.284 |
| | >50 YEARS | 85 | 16.3 | 2.8 | 7.0 | 22.0 | |
| | Total | 102 | 16.4 | 2.8 | 7.0 | 22.0 | |

With Icare, cases were divided in two groups (< 50 &>50 years) for right eye and the significance in the IOP values was found. There was no statistical significance between these two groups as p value was 0.284.

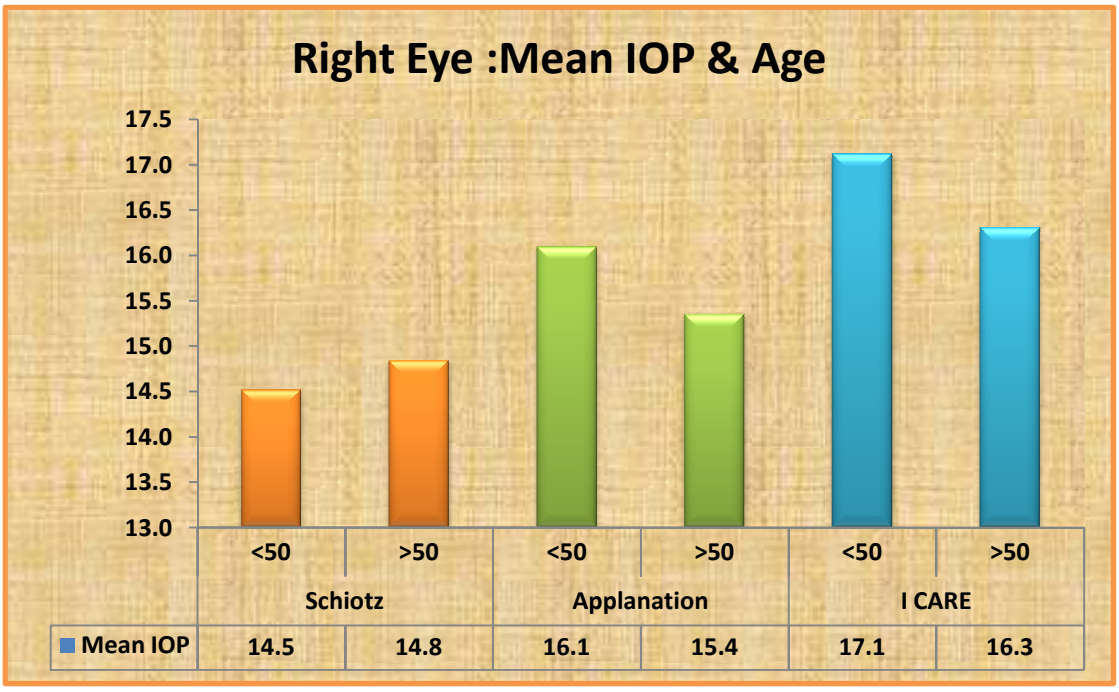
**Chart No. 5 ICare**



## Table No. 6 RIGHT EYE

| Tonometer | AGE (in years) | No. of Cases | Mean | SD | Minimum | Maximum | p value |
|---|---|---|---|---|---|---|---|
| Schiotz | <50 | 17 | 14.5 | 2.8 | 10.2 | 18.9 | 0.714 |
| | >50 | 85 | 14.8 | 3.4 | 8.5 | 22.4 | |
| | Total | 102 | 14.8 | 3.3 | 8.5 | 22.4 | |
| Applanation | <50 | 17 | 16.1 | 3.5 | 10.0 | 21.9 | 0.405 |
| | >50 | 85 | 15.4 | 3.3 | 8.1 | 22.7 | |
| | Total | 102 | 15.5 | 3.3 | 8.1 | 22.7 | |
| I CARE | <50 | 17 | 17.1 | 2.8 | 12.0 | 22.0 | 0.284 |
| | >50 | 85 | 16.3 | 2.8 | 7.0 | 22.0 | |
| | Total | 102 | 16.4 | 2.8 | 7.0 | 22.0 | |

## Chart No. 6RIGHT EYE



# Mean IOP & Age - Left Eye

**Table No. 7 Schiotz Tonometer**

| NUMBER OF CASES | | | Mean IOP | SD | Minimum IOP | Maximum IOP | p value |
|---|---|---|---|---|---|---|---|
| Schiotz | <50 YEARS | 17 | 15.2 | 2.5 | 11.2 | 18.9 | 0.588 |
| | >50 YEARS | 85 | 14.7 | 3.5 | 9.4 | 22.4 | |
| | Total | 102 | 14.8 | 3.3 | 9.4 | 22.4 | |

With schiotz, cases were divided in two groups (< 50 &>50 years) for left eye and the significance in the IOP values was found. Statistical significance between these two groups was absent as p value was 0. 588.

**Chart No. 7 Schiotz Tonometer**

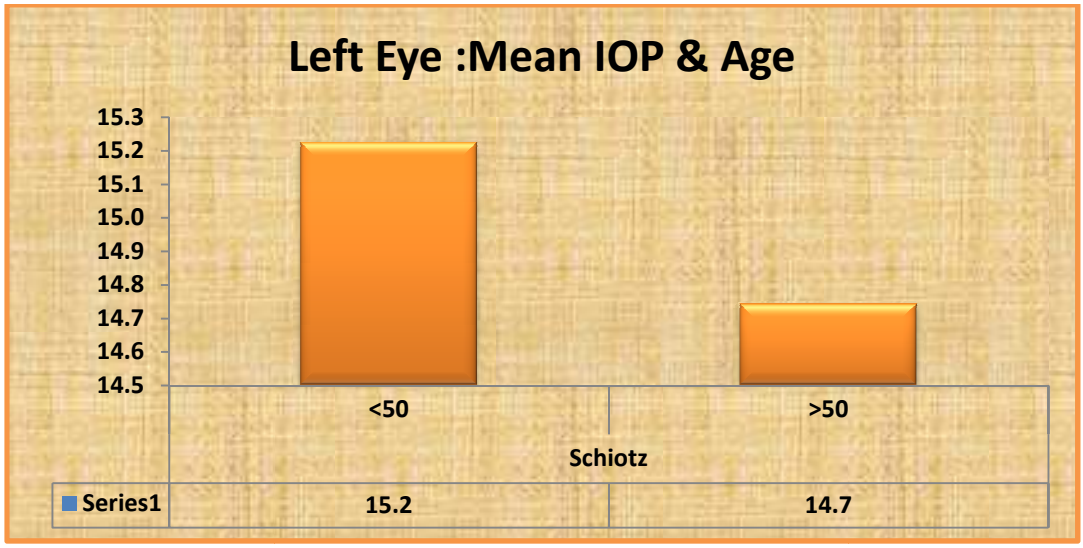


**Table No. 8 GAT**

| NUMBER OF CASES | | | Mean IOP | SD | Minimum IOP | Maximum IOP | p value |
|---|---|---|---|---|---|---|---|
| GAT | <50 YEARS | 17 | 15.3 | 3.6 | 9.2 | 21.8 | 0.690 |
| | >50 YEARS | 85 | 15.7 | 3.6 | 7.1 | 23.9 | |
| | Total | 102 | 15.6 | 3.6 | 7.1 | 23.9 | |

With GAT, cases were divided in two groups (< 50 &>50 years) for left eye and the significance in the IOP values was found. Statistical significance between these two groups was absent as p value was 0. 690.

**Chart No. 8 GAT**

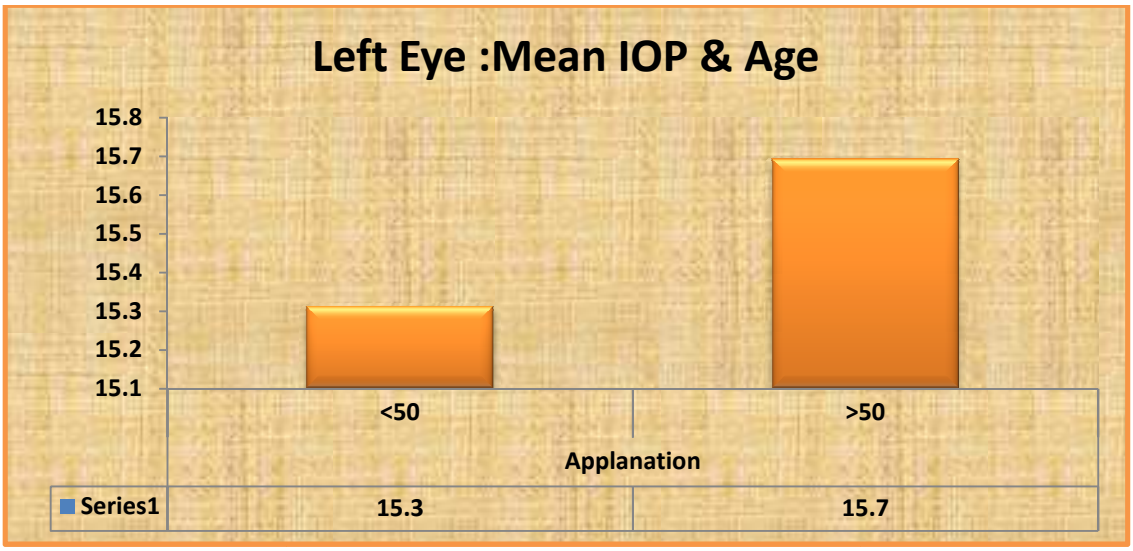
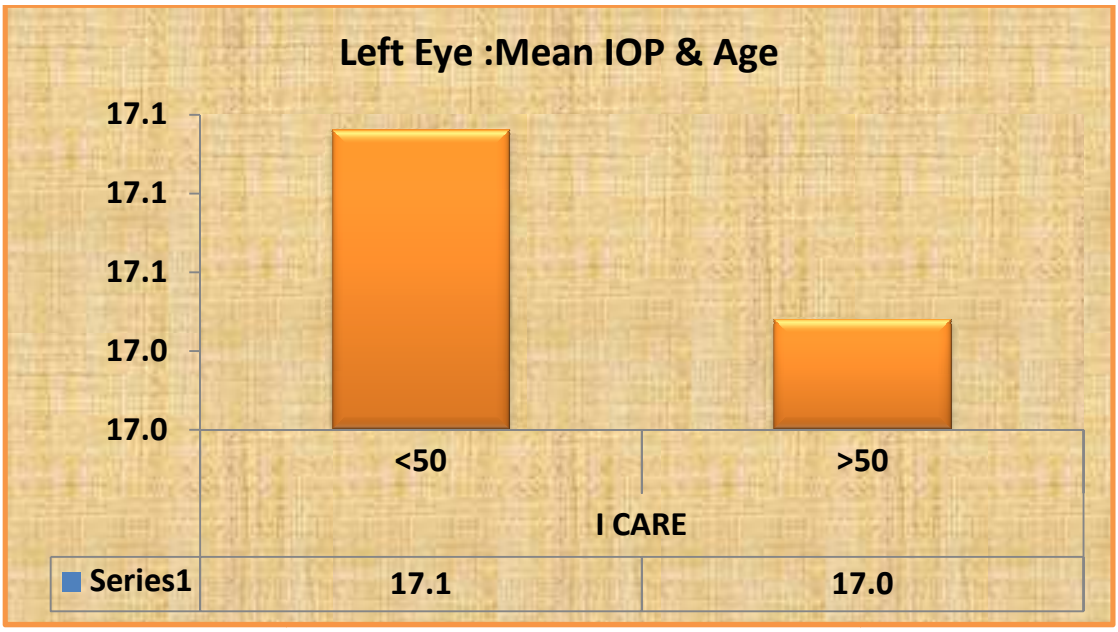


**Table No. 9 ICARE**

| NUMBER OF CASES | | | Mean IOP | SD | Minimum IOP | Maximum IOP | p value |
|---|---|---|---|---|---|---|---|
| I CARE | <50 years | 17 | 17.1 | 3.5 | 10.0 | 24.0 | 0.988 |
| | >50 years | 85 | 17.0 | 2.9 | 10.0 | 24.0 | |
| | Total | 102 | 17.0 | 3.0 | 10.0 | 24.0 | |

With Icare, cases were divided in two groups (< 50 &>50 years) for left eye and the significance in the IOP values was found. Statistical significance between these two groups was absent as p value was 0. 988.

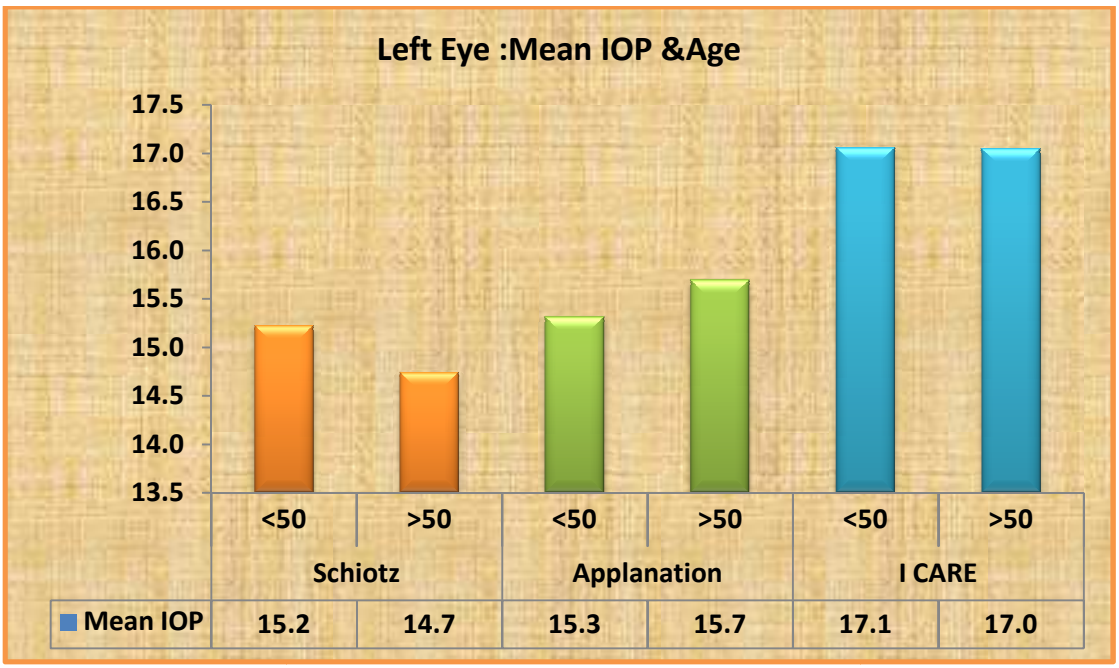
**Chart No. 9 ICARE**



## Table No. 10 Mean IOP & Age - Left Eye

| | | N | Mean | SD | Minimum | Maximum | p value |
|---|---|---|---|---|---|---|---|
| Schiotz | <50 | 17 | 15.2 | 2.5 | 11.2 | 18.9 | 0.588 |
| | >50 | 85 | 14.7 | 3.5 | 9.4 | 22.4 | |
| | Total | 102 | 14.8 | 3.3 | 9.4 | 22.4 | |
| Applanation | <50 | 17 | 15.3 | 3.6 | 9.2 | 21.8 | 0.690 |
| | >50 | 85 | 15.7 | 3.6 | 7.1 | 23.9 | |
| | Total | 102 | 15.6 | 3.6 | 7.1 | 23.9 | |
| I CARE | <50 | 17 | 17.1 | 3.5 | 10.0 | 24.0 | 0.988 |
| | >50 | 85 | 17.0 | 2.9 | 10.0 | 24.0 | |
| | Total | 102 | 17.0 | 3.0 | 10.0 | 24.0 | |

## Chart No. 10 Mean IOP & Age - Left Eye



## Table No. 11 Mean IOP & Gender - Right Eye

| NUMBER OF CASES | | | Mean IOP | SD | Minimum IOP | Maximum IOP | p value |
|---|---|---|---|---|---|---|---|
| Schiotz | Male | 40 | 15.5 | 3.4 | 8.5 | 22.4 | 0.089 |
| | Female | 62 | 14.3 | 3.2 | 8.5 | 22.4 | |
| | Total | 102 | 14.8 | 3.3 | 8.5 | 22.4 | |

For right eye the mean IOP of schiotz was compared between male and female groups to find out whether any statistical difference exists between those groups. It was found that statistically significant difference between those two groups does not exist as p value was 0.089.

## Chart No. 11 Mean IOP & Gender - Right Eye

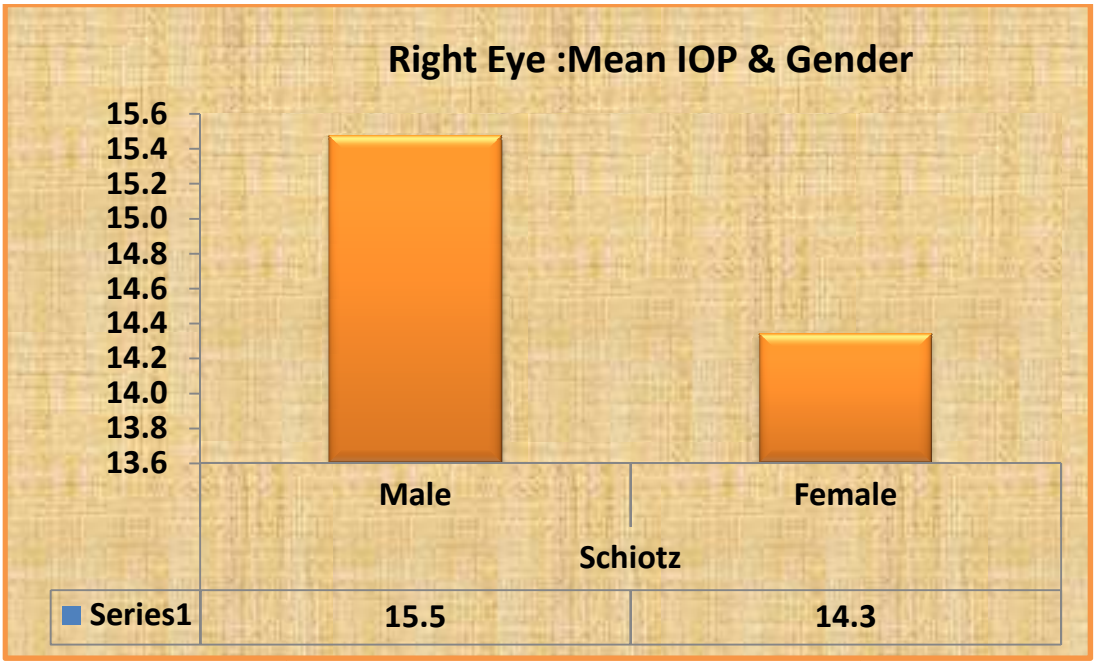


**Table No. 12 GAT**

| NUMBER OF CASES | | | Mean | SD | Minimum | Maximum | p value |
|---|---|---|---|---|---|---|---|
| GAT | Male | 40 | 14.8 | 3.1 | 9.0 | 22.7 | 0.123 |
| | Female | 62 | 15.9 | 3.4 | 8.1 | 22.2 | |
| | Total | 102 | 15.5 | 3.3 | 8.1 | 22.7 | |

For right eye the mean IOP of GAT was compared between male and female groups to find out whether any statistical difference exists between those groups. It was found that statistically significant difference between those two groups does not exist as p value was 0.123.

**Chart No. 12 GAT**

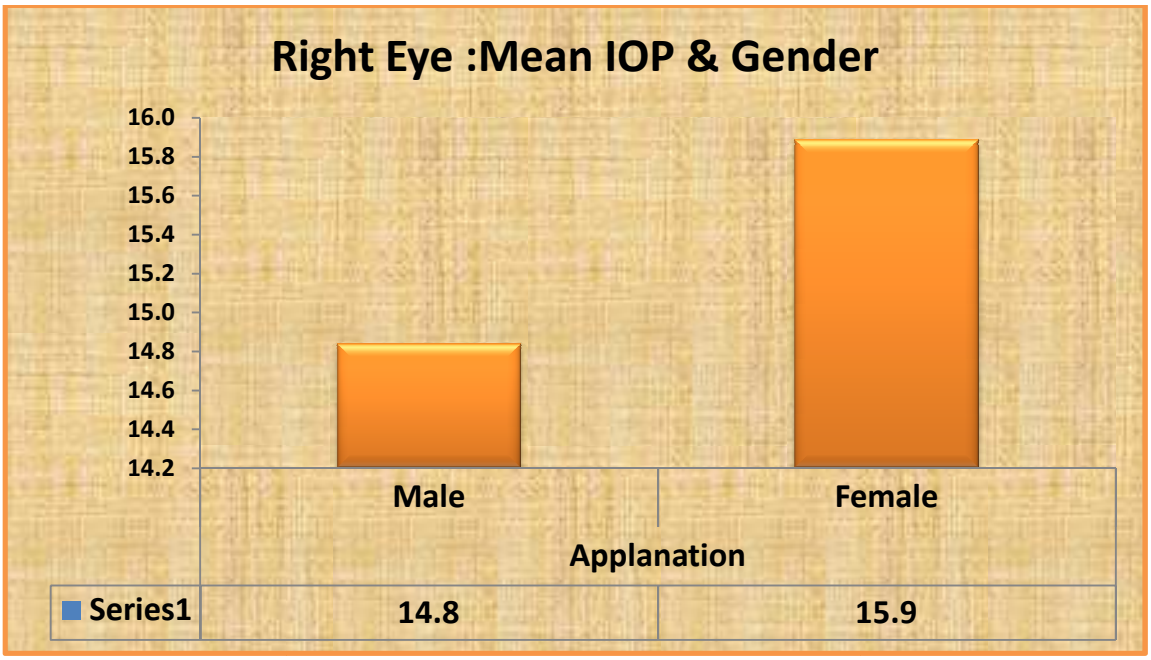
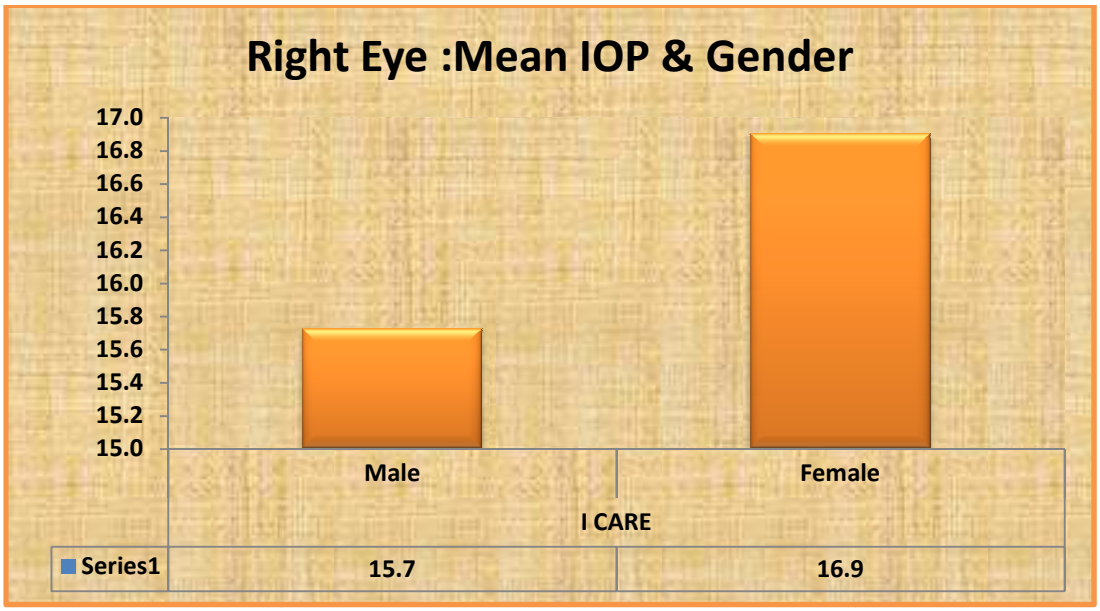


**Table No. 13 ICARE**

| NUMBER OF CASES | | | Mean IOP | SD | Minimum IOP | Maximum IOP | p value |
|---|---|---|---|---|---|---|---|
| ICARE | Male | 40 | 15.7 | 2.8 | 7.0 | 21.0 | 0.04 |
| | Female | 62 | 16.9 | 2.8 | 10.0 | 22.0 | |
| | Total | 102 | 16.4 | 2.8 | 7.0 | 22.0 | |

For right eye the mean IOP of ICARE was compared between male and female groups to find out whether any statistical difference exists. It was found that there was a significant statistical difference between those groups, as p value was 0.04.

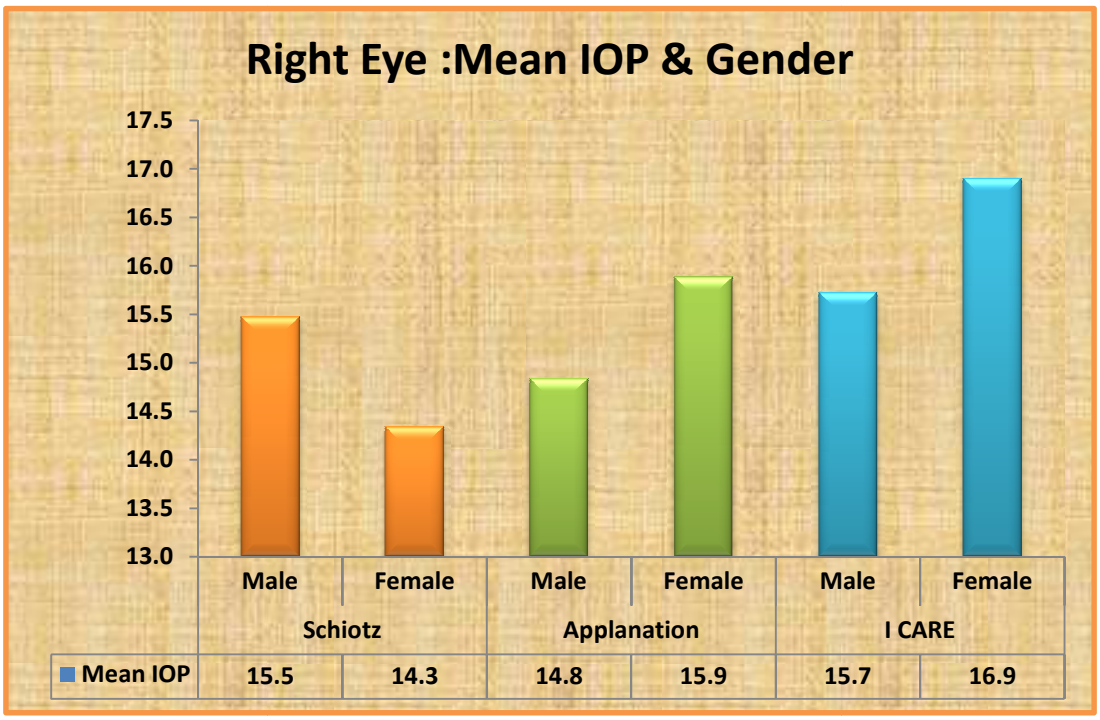
**Chart No. 13 ICARE**



## Table No. 14 Mean IOP & Gender - Right Eye

| NUMBER OF CASES | | | Mean IOP | SD | Minimum IOP | Maximum IOP | p value |
|---|---|---|---|---|---|---|---|
| Schiotz | Male | 40 | 15.5 | 3.4 | 8.5 | 22.4 | 0.089 |
| | Female | 62 | 14.3 | 3.2 | 8.5 | 22.4 | |
| | Total | 102 | 14.8 | 3.3 | 8.5 | 22.4 | |
| Applanation | Male | 40 | 14.8 | 3.1 | 9.0 | 22.7 | 0.123 |
| | Female | 62 | 15.9 | 3.4 | 8.1 | 22.2 | |
| | Total | 102 | 15.5 | 3.3 | 8.1 | 22.7 | |
| I CARE | Male | 40 | 15.7 | 2.8 | 7.0 | 21.0 | 0.04 |
| | Female | 62 | 16.9 | 2.8 | 10.0 | 22.0 | |
| | Total | 102 | 16.4 | 2.8 | 7.0 | 22.0 | |

## Chart No. 14 Mean IOP & Gender - Right Eye



# Mean IOP & Gender – Left Eye:

**Table No. 15 Schiotz Tonometer**

| NUMBER OF CASES | | | Mean IOP | SD | Minimum IOP | Maximum IOP | p value |
|---|---|---|---|---|---|---|---|
| Schiotz | Male | 40 | 15.5 | 3.7 | 9.4 | 22.4 | 0.104 |
| | Female | 62 | 14.4 | 3.0 | 9.4 | 20.6 | |
| | Total | 102 | 14.8 | 3.3 | 9.4 | 22.4 | |

For left eye the mean IOP of Schiotz was compared between male and female groups to find out whether any statistical difference exists. It was found that statistically significant difference was absent between those groups, as p value was 0. 104.

**Chart No. 15 Schiotz Tonometer**

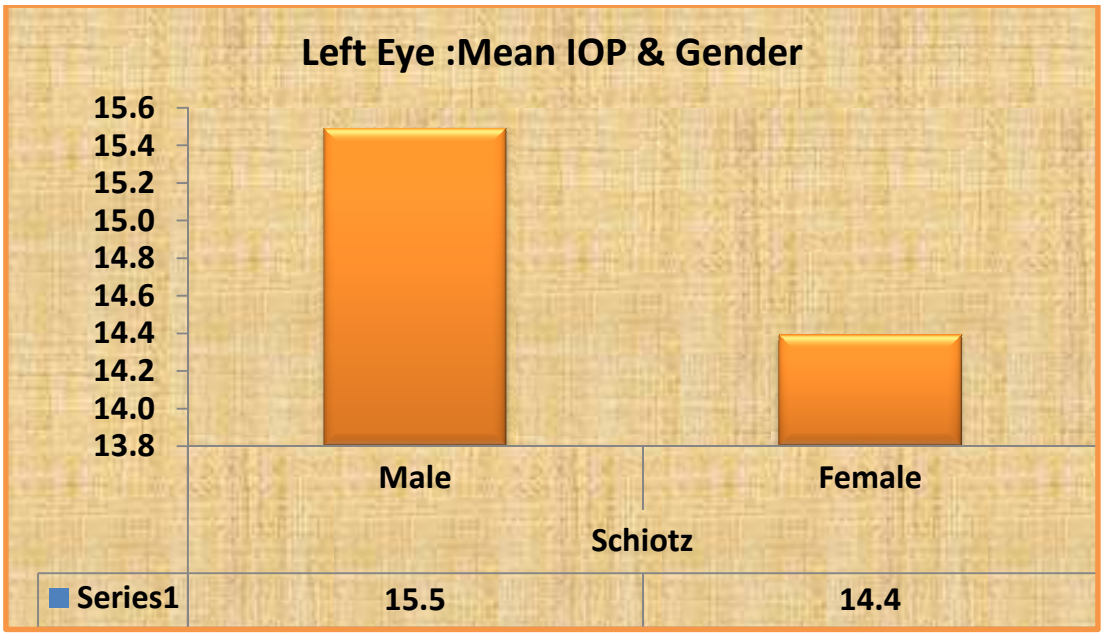


**Table No. 16 GAT**

| NUMBER OF CASES | | | Mean IOP | SD | Minimum IOP | Maximum IOP | P Value |
|---|---|---|---|---|---|---|---|
| GAT | Male | 40 | 15.0 | 3.3 | 8.8 | 21.8 | 0.146 |
| | Female | 62 | 16.0 | 3.7 | 7.1 | 23.9 | |
| | Total | 102 | 15.6 | 3.6 | 7.1 | 23.9 | |

For left eye the mean IOP of GAT was compared between male and female groups to find out whether any statistical difference exists between those groups. It was found that there was no statistically significant difference between those two groups exists, as p value was 0. 146.

**Chart No. 16 GAT**

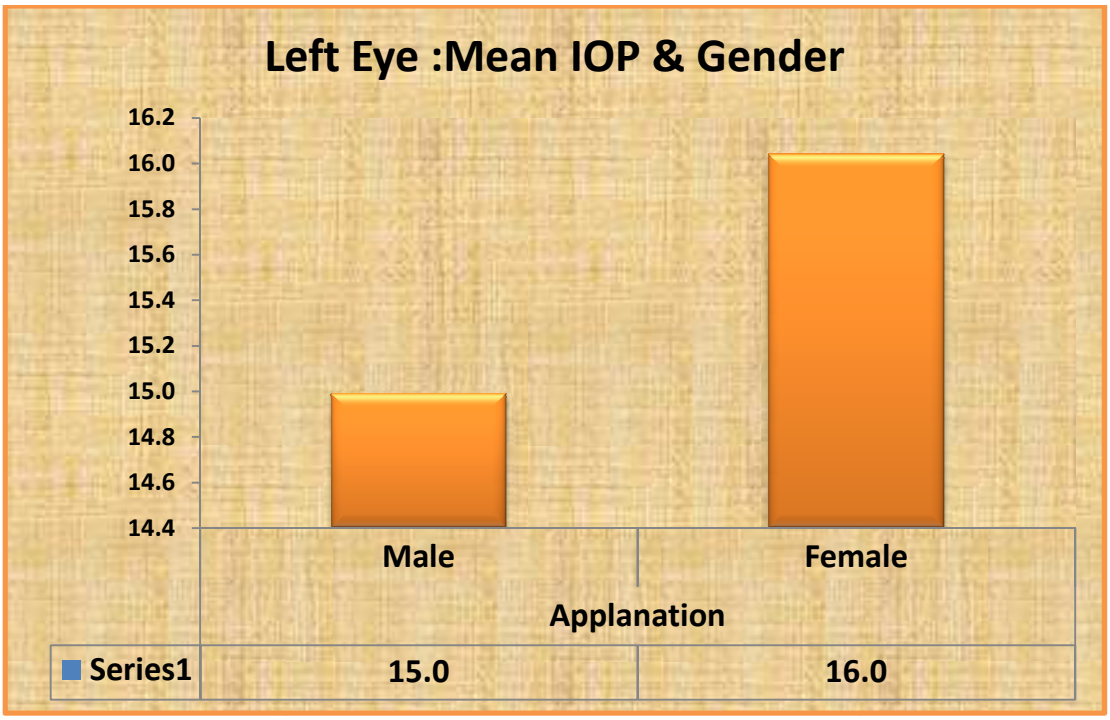


**Table No. 17 ICARE**

| NUMBER OF CASES | | | Mean IOP | SD | Minimum IOP | Maximum IOP | p value |
|---|---|---|---|---|---|---|---|
| ICARE | Male | 40 | 16.7 | 3.0 | 10.0 | 23.0 | 0.348 |
| | Female | 62 | 17.3 | 3.0 | 10.0 | 24.0 | |
| | Total | 102 | 17.0 | 3.0 | 10.0 | 24.0 | |

For left eye the mean IOP of ICARE was compared between male and female groups to find out whether any statistical difference exists. It was found that statistically significant difference was absent between those two groups, as p value was 0. 348.

**Chart No. 17 ICARE**

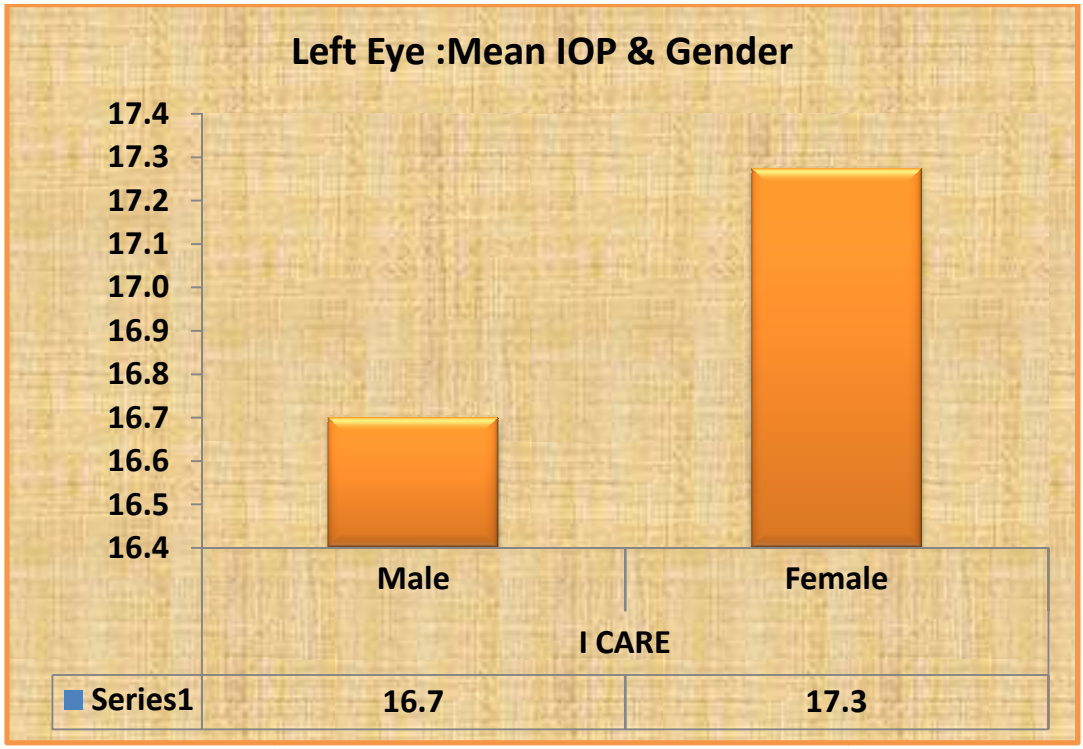
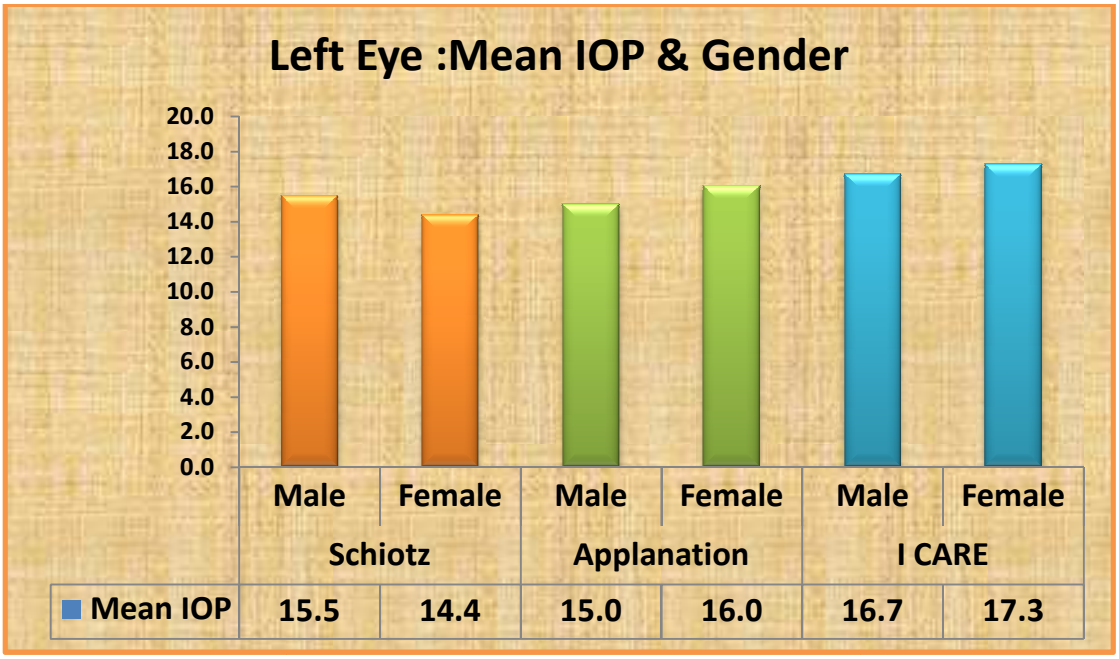


**Table No. 18 Left Eye – Mean IOP & Gender**

| NUMBER OF CASES | | | Mean | SD | Minimum | Maximum | p value |
|---|---|---|---|---|---|---|---|
| Schiotz | Male | 40 | 15.5 | 3.7 | 9.4 | 22.4 | 0.104 |
| | Female | 62 | 14.4 | 3.0 | 9.4 | 20.6 | |
| | Total | 102 | 14.8 | 3.3 | 9.4 | 22.4 | |
| GAT | Male | 40 | 15.0 | 3.3 | 8.8 | 21.8 | 0.146 |
| | Female | 62 | 16.0 | 3.7 | 7.1 | 23.9 | |
| | Total | 102 | 15.6 | 3.6 | 7.1 | 23.9 | |
| I CARE | Male | 40 | 16.7 | 3.0 | 10.0 | 23.0 | 0.348 |
| | Female | 62 | 17.3 | 3.0 | 10.0 | 24.0 | |
| | Total | 102 | 17.0 | 3.0 | 10.0 | 24.0 | |

**Chart No. 18 Left Eye – Mean IOP & Gender**

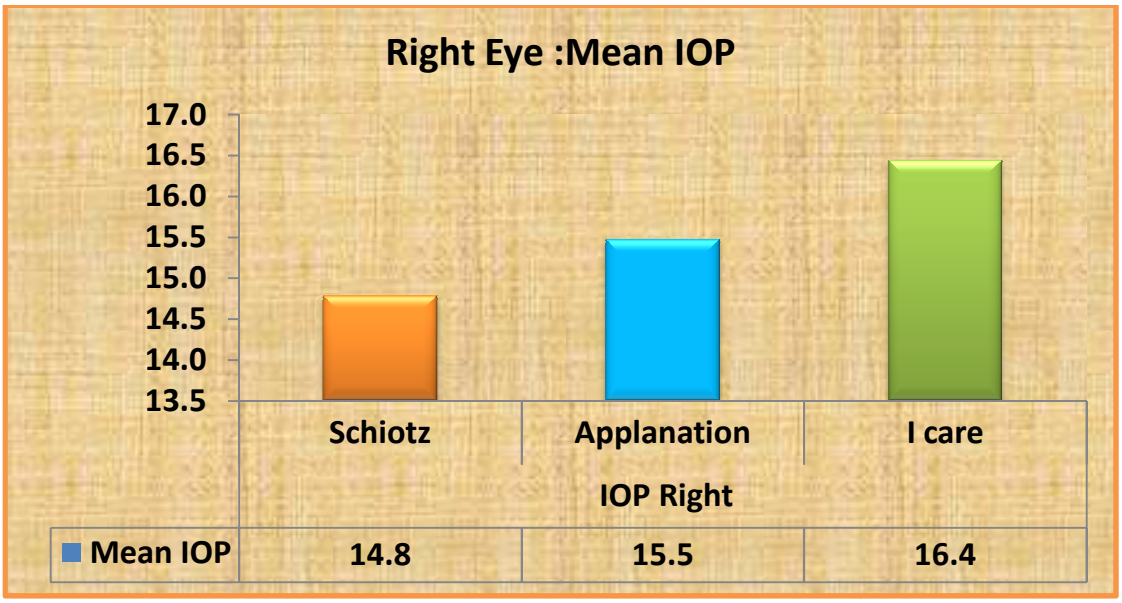


# Mean IOP & Laterality

## Table No. 19 Right Eye

| NUMBER OF CASES | | | Mean IOP | SD | Minimum IOP | Maximum IOP |
|---|---|---|---|---|---|---|
| IOP in tonometers | Schiotz | 102 | 14.8 | 3.3 | 8.5 | 22.4 |
| | Applanation | 102 | 15.5 | 3.3 | 8.1 | 22.7 |
| | I care | 102 | 16.4 | 2.8 | 7.0 | 22.0 |
| | Total | 306 | 15.6 | 3.2 | 7.0 | 22.7 |

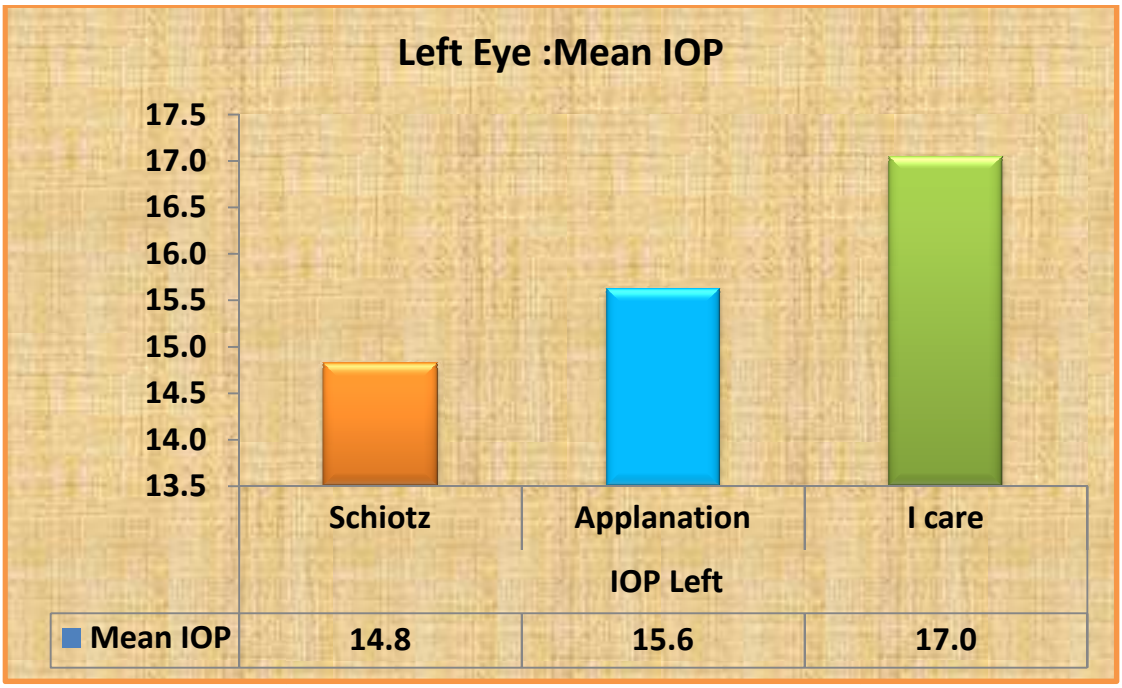
## Chart No. 19 Right Eye



## Table No. 20 Left Eye

| NUMBER OF CASES | | | Mean IOP | SD | Minimum IOP | Maximum IOP |
|---|---|---|---|---|---|---|
| IOP in tonometers | Schiotz | 102 | 14.8 | 3.3 | 9.4 | 22.4 |
| | Applanation | 102 | 15.6 | 3.6 | 7.1 | 23.9 |
| | I care | 102 | 17.0 | 3.0 | 10.0 | 24.0 |
| | Total | 306 | 15.8 | 3.4 | 7.1 | 24.0 |

## Chart No. 20 Left Eye



The mean IOP between right and left eyes, given each of the three tonometers were compared to find whether there is any difference exists between those three groups. It was found that the mean IOP values by schiotz alone were same in both the eyes and those by Icare and GAT were found to be high in left eye.

# Correlation study – Right Eye

Correlation study is a measure of the strength and direction of association that exists between two variables.

**Table 21 Schiotztonometer vs. GAT**

| Tonometers | | GAT |
|---|---|---|
| Schiotz | Correlation | 0.218* |
| | Significance | 0.027 |
| | Total number of cases | 102 |

Here schiotz and applanation tonometers are studied, which showed a weak agreement with a positive correlation. It was stastically significant.

**Chart No 21 Schiotz tonometer vs. GAT**

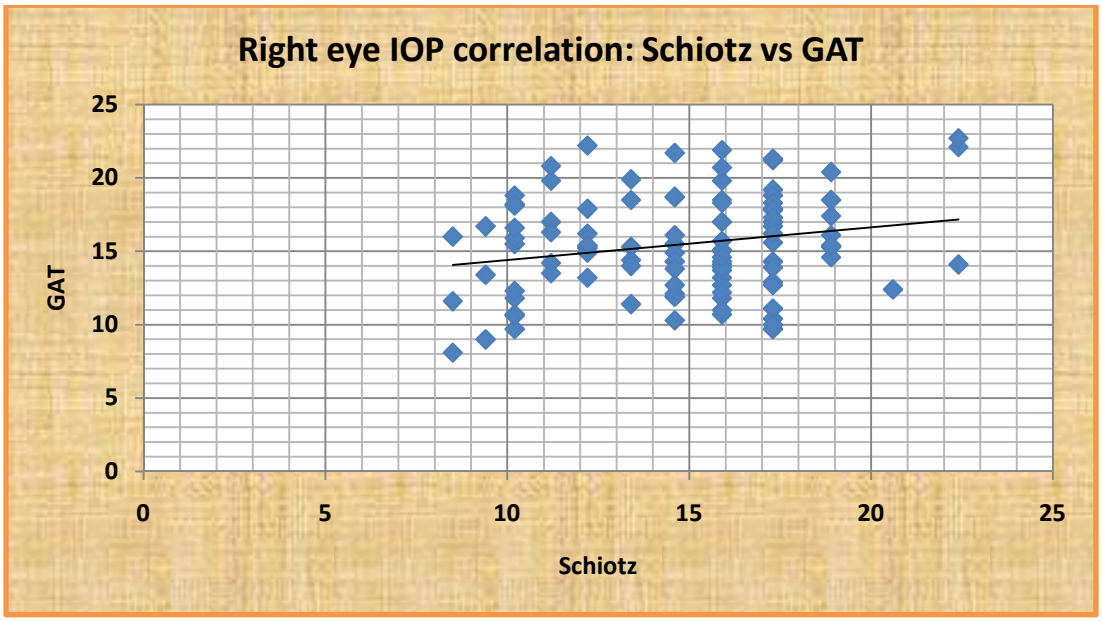


**Table No. 22 Schiotz vs. Icare tonometer**

| Tonometers | | I care |
|---|---|---|
| Schiotz | Correlation | 0.122 |
| | Significance | 0.223 |
| | Total number of cases | 102 |

Here schiotz and Icare tonometers are studied, which showed a very weak agreement with a positive correlation. It was not statistically significant.

**Chart No. 22 Schiotz vs. Icare tonometer**

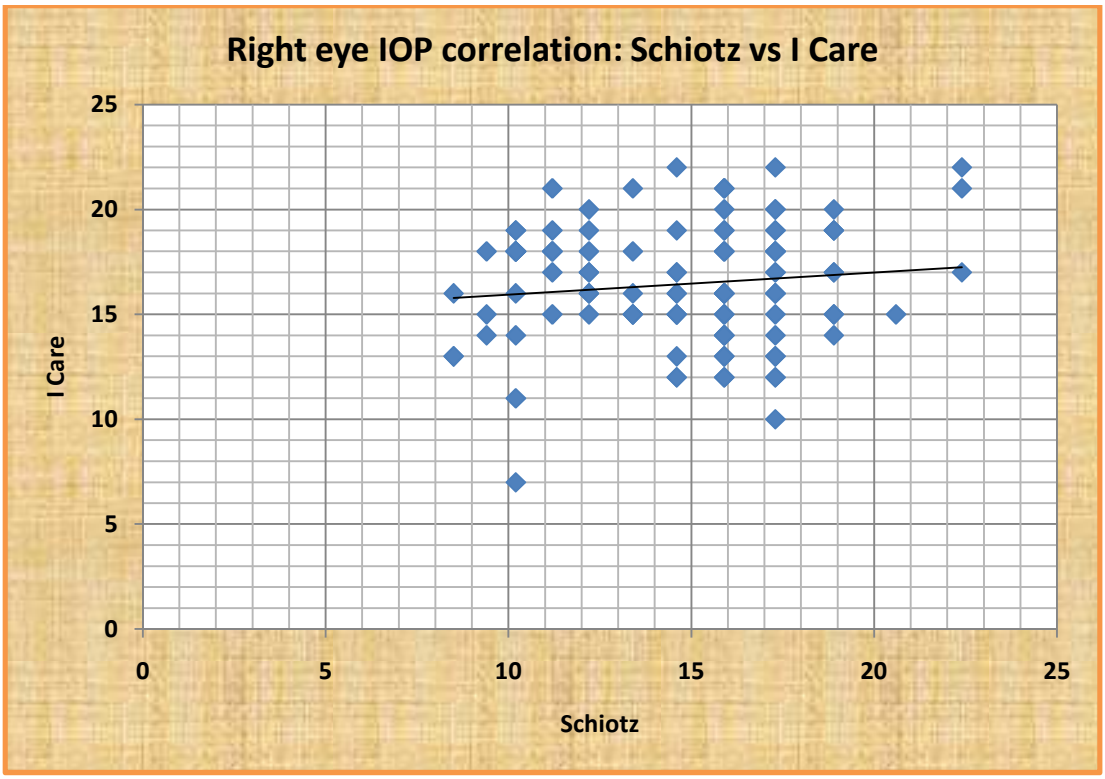
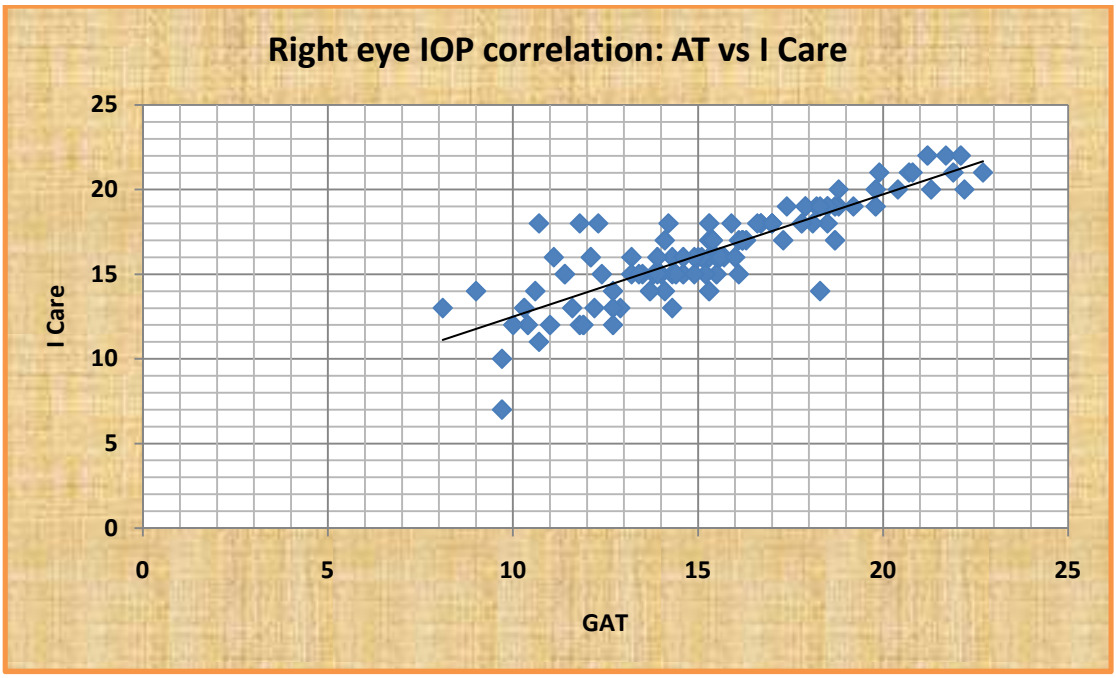


**Table No.23 GAT vs. Icare tonometer**

| Tonometers | | I care |
|---|---|---|
| GAT | Correlation | 0.851** |
| | Significance | 0.000 |
| | Total number of cases | 102 |

Here GAT and Icare tonometers are studied, which showed a very strong agreement with a positive correlation. It was statistically very significant.

**Chart No.23 GAT vs. Icare tonometer**



# Left Eye – Correlations:

**Table No. 24 Schiotz tonometer vs.GAT**

| Tonometers | | GAT |
|---|---|---|
| Schiotz | Correlation | 0.175 |
| | Significance | 0.078 |
| | Total number of cases | 102 |

Here schiotz tonometer and GAT are studied, which showed a very weak agreement with a positive correlation. It was statistically insignificant.

**Chart No. 24 Schiotz tonometer vs.GAT**

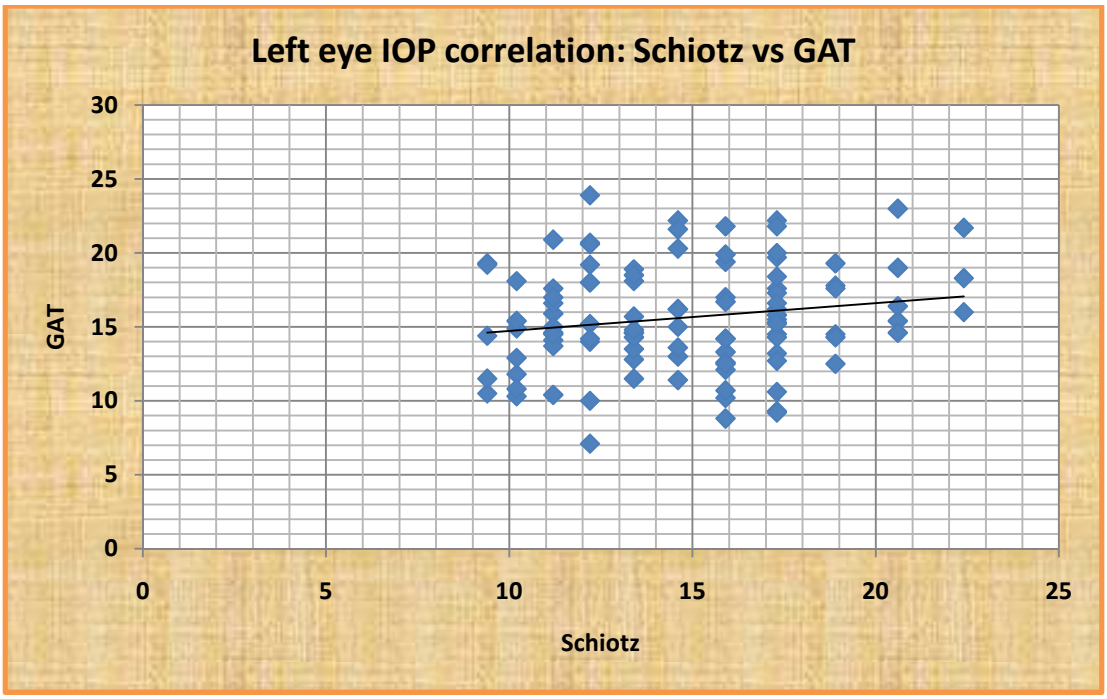


**Table No. 25 Schiotz vs. ICARE tonometer**

| Tonometers | | I care |
|---|---|---|
| Schiotz | Correlation | 0.103 |
| | Significance | 0.303 |
| | Total number of cases | 102 |

Here schiotz and ICARE tonometers are studied, which showed a very weak agreement with a positive correlation. It was statistically insignificant.

**Chart No. 25 Schiotz vs. ICARE tonometer**

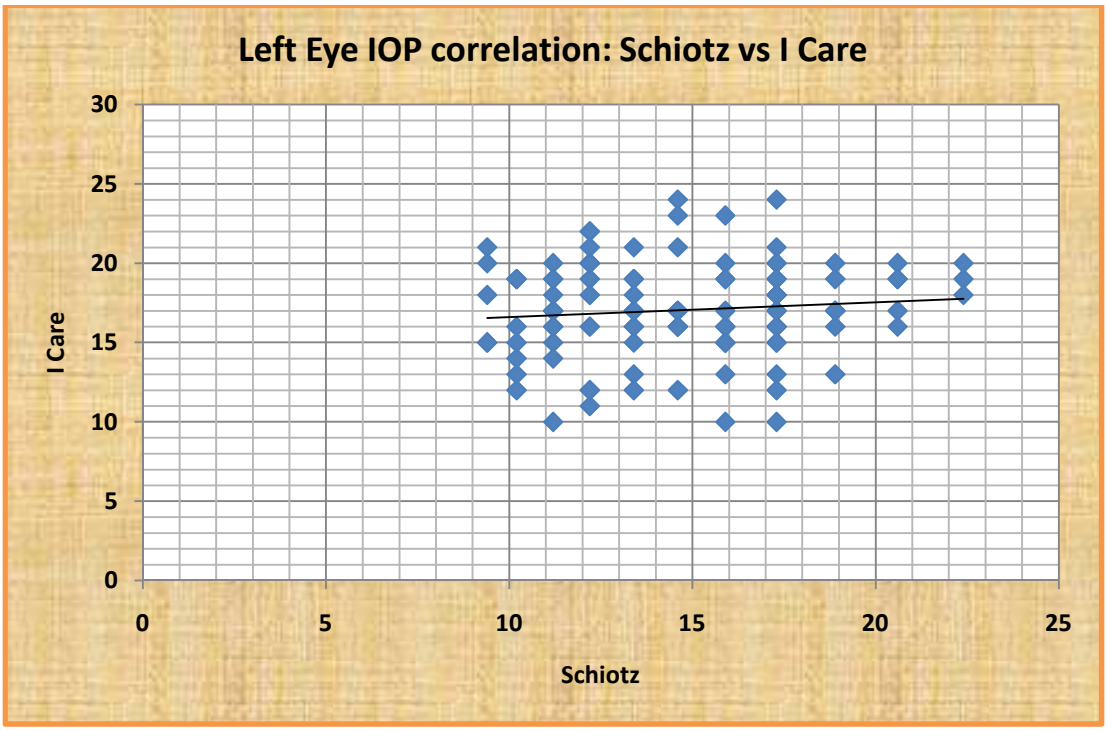


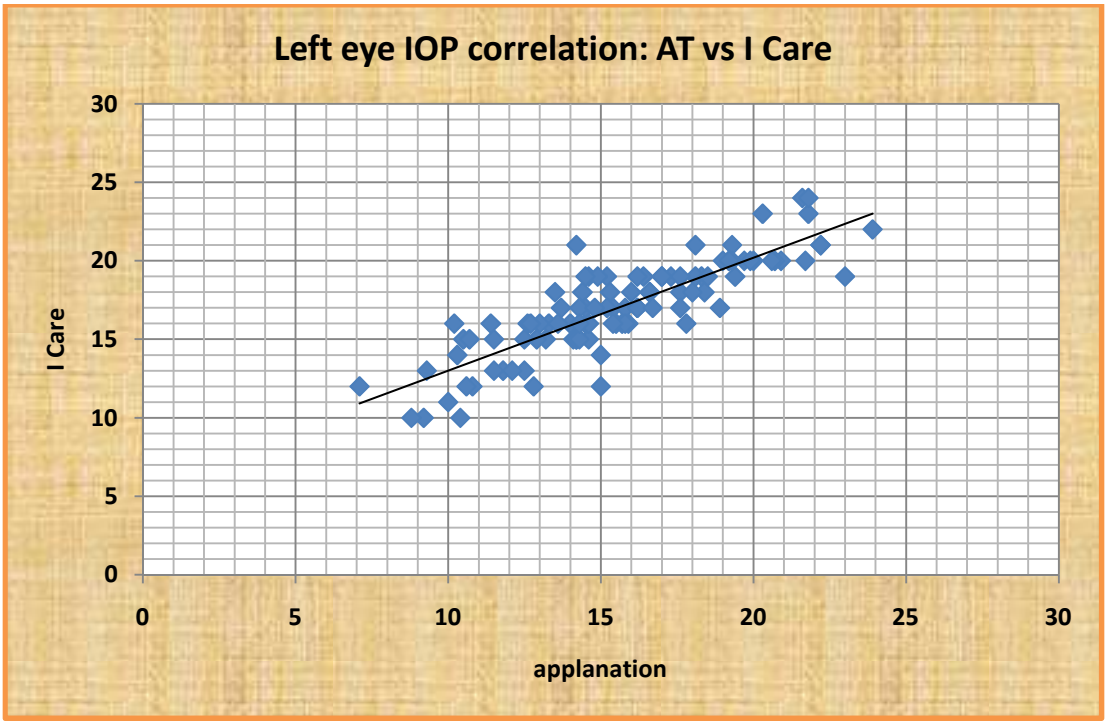
**Table No. 26 GAT vs. ICARE tonometer**

| Tonometers | | Icare |
|---|---|---|
| GAT | Correlation | 0.853** |
| | Significance | 0.000 |
| | Total number of cases | 102 |

** - Correlation is significant at the 0.01 level.

Here GAT and Icare tonometers are studied, which showed a very strong agreement with a positive correlation. It was statistically very significant.

**Chart No. 26 GAT vs. ICARE tonometer**

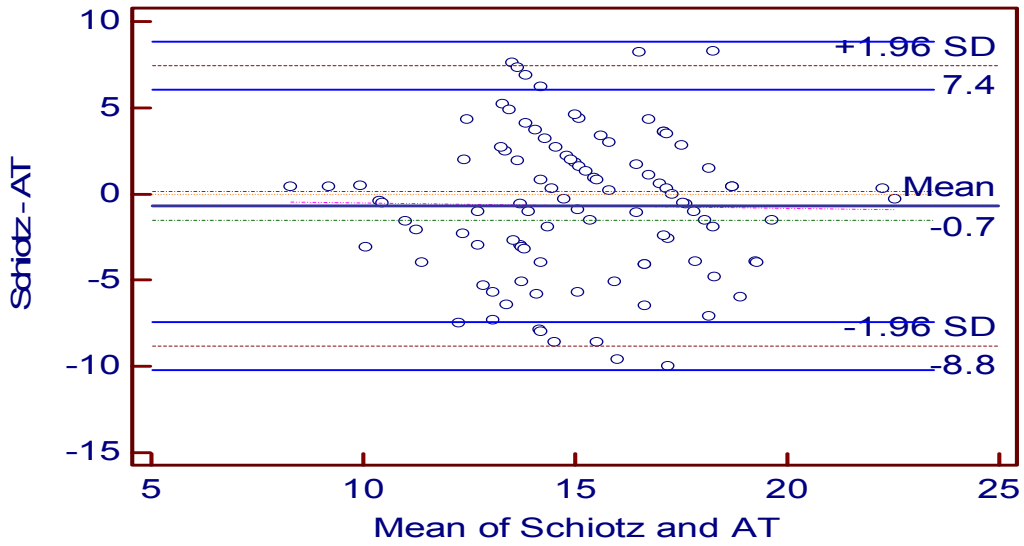


A **Bland–Altman plot** is a type of plotting data used for analysing the agreement between two different tests.

Here, 'agreement' of a new method of investigation is compared with the gold standard technique.

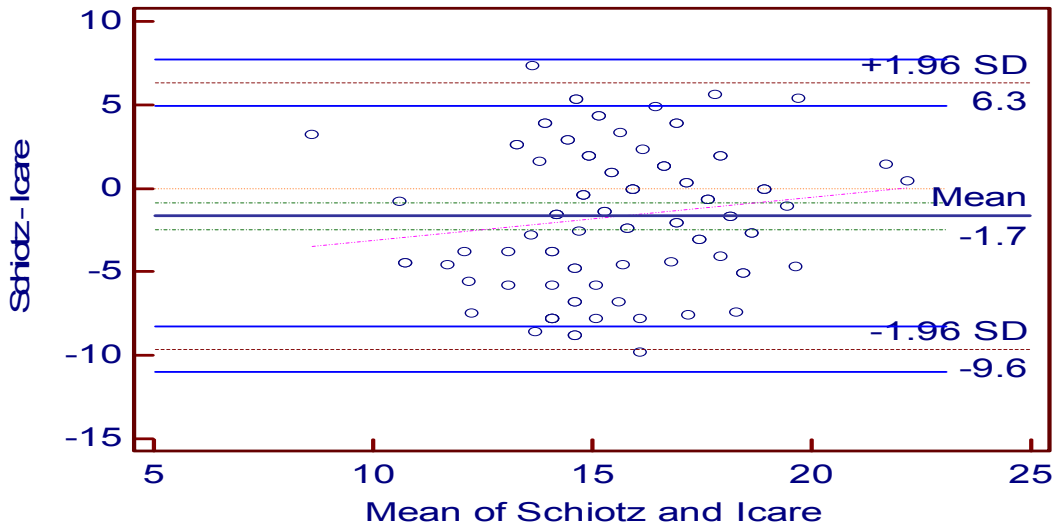
## Bland-Altman Plot - in Right Eye

**Chart No27 Schiotz vs. GAT**



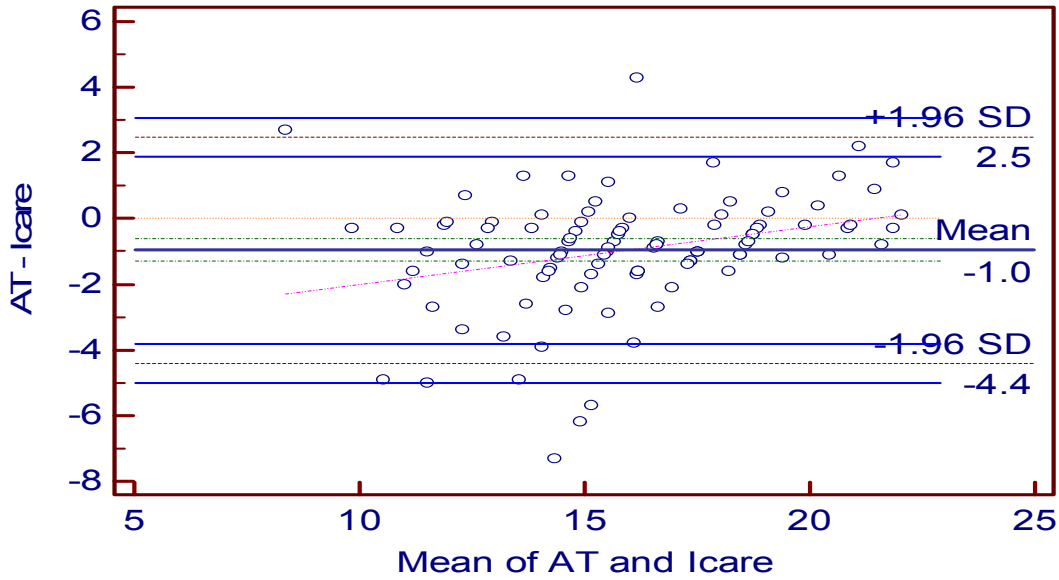

Here the measurements plotted are not clustered around the mean 0 line, so the values between the schiotz tonometer and GAT are not so coherent.

**Chart No. 28 Schiotz vs. Icare**




Here the measurements plotted are not clustered around the mean 0 line, so the values between the schiotz and ICARE tonometers are not so coherent.

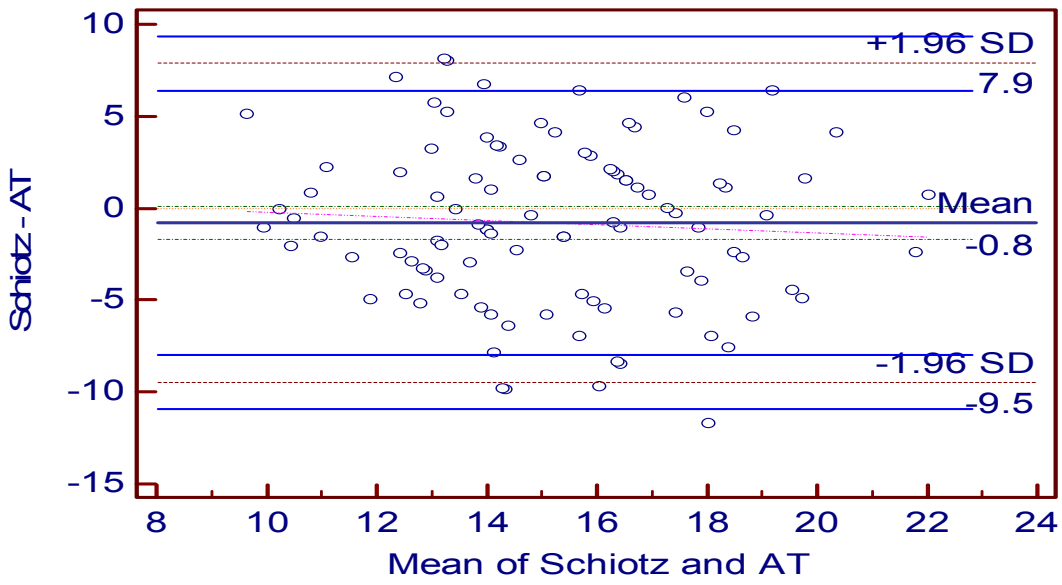
**Chart No. 29 GAT vs. Icare**



Here the measurements plotted are very well clustered around the mean 0 line, so the values between the GAT and Icare tonometers are coherent. Hence the two are in good agreement.

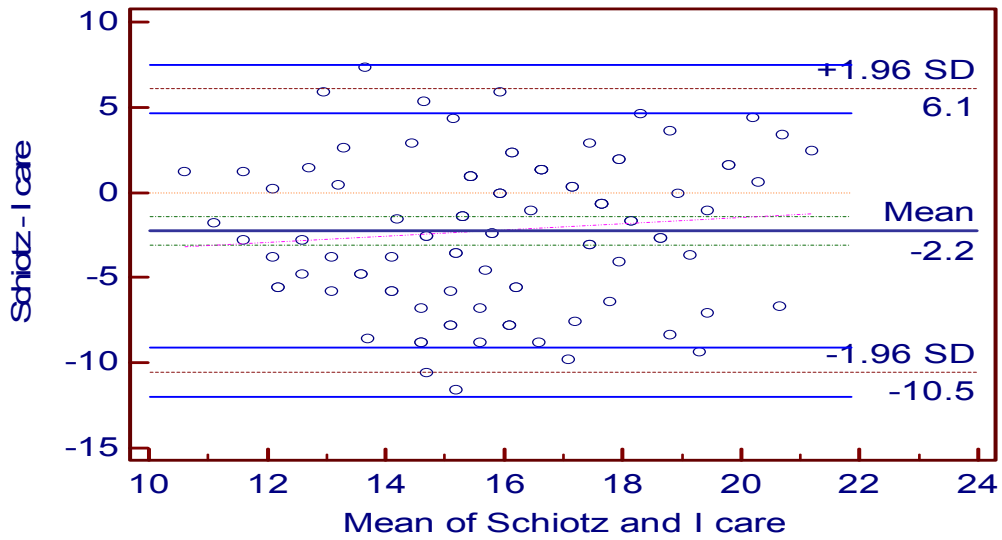
## Bland-Altman Plot - in Left Eye:

**Chart No. 30 Schiotz vs. GAT**



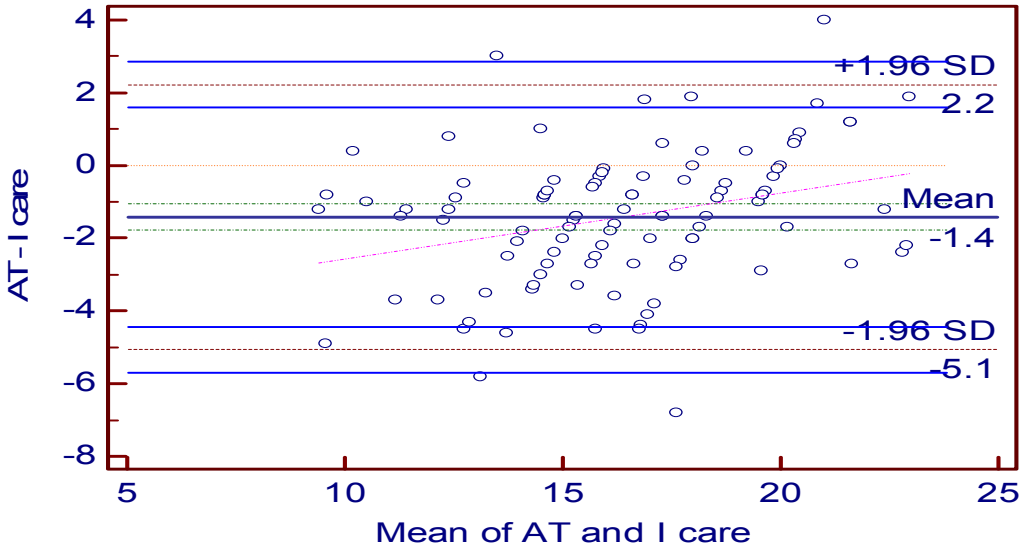

Here the measurements plotted are not clustered around the mean 0 line, so the values between the GAT and schiotz tonometers are not so coherent. Hence the two are not in good agreement.

**Chart No. 31 Schiotz vs. Icare:**




Here the measurements plotted are not clustered around the mean 0 line, so the values between the ICARE and schiotz tonometers are not so coherent. Hence the two are not in good agreement**.**

**Chart No. 32 GAT vs. Icare:**



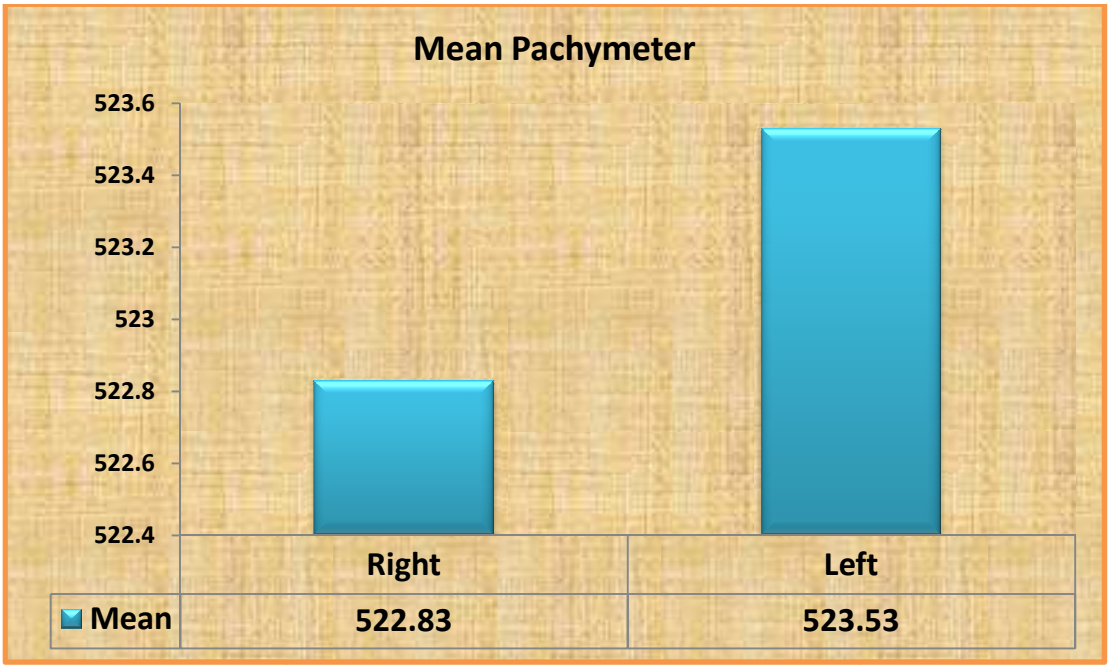

Here the measurements plotted are clustered around the mean 0 line, so the values between the GAT and ICARE tonometers are very well coherent. Hence the two are in good agreement.

## Table No. 27 Pachymetry

| Pachymeter ( in micron) | | | | |
|---|---|---|---|---|
| Eye | Mean | SD | 2 SD of mean | Range |
| Right | 522.83 | 31.205 | 516.7-528.96 | 469-603 |
| Left | 523.53 | 32.924 | 517.06-530 | 453-615 |

In our study Pachymeter was used to find the corneal thickness of all the cases. And the mean CCT of male cases was 522.83 microns and that of female cases was 523.53microns.

## Chart No. 33 Pachymetry



# DISCUSSION

Even though there are many parameters for glaucoma screening and diagnosis, IOP assessment is of paramount importance in diagnosing and follow up of glaucoma cases.

Throughout the world many instruments and techniques are followed to measure IOP. Also newer technologies are discovered for IOP measurement with least possible error. But these instruments before they can be allowed to replace the existing or to be considered as equal with the current gold standard it has to be evaluated in different clinical settings and in different population groups.

The same holds good for a gold standard instrument; that is it has to be constantly evaluated against the new technology, so that its errors and biases can be eliminated.

Such analysis and improvements in both technique and instrumentation can finally help in quick, accurate and patient friendly diagnostic modalities for IOP assessment.

All these measures help in increasing the diagnostic rate of glaucoma among the patients attending ophthalmology clinics.

This is a pivotal achievement as the crux of the problem in glaucoma detection is poor diagnosis either due to faulty techniques/wrong instrument for a given case/ overloaded outpatient departments etc.

The same has been the basis for this study to compare old and new technology with the gold standard technology for better glaucoma assessment in our outpatient department.

In our study, even though schiotz is an age old technique it was used since it very portable, cheap & quick technique. It is used in many parts of the world even today including our outpatient department for the same above reasons.

Icare is a recently used technology for IOP assessment with not much of population based study in this part of the world. Hence it was used to compare with the gold standard to find its reliability against the gold standard. Also it was a portable and quick technology, so it was used to find whether it can be a source of replacement for accurate yet time consuming and cumbersome gold standard applanation technique.

Goldmann's applanation was used in this study to compare it against the other two as it was "The gold standard technique". Being a time consuming / cumbersome / not so patient comfortable technique for IOP assessment, it has stood the test of time in giving accurate and reliable IOP values in various groups of patients in different demographic profiles.

In our study a total of 102 patients were evaluated with three tonometers namely schiotz, GAT and ICARE.

Demographic profile of the study showed that females (61%) were more than the males (39%) in this study.

The minimum and maximum age of patients among those participated in this study was 35 & 80 years respectively.

In our study there was no linear correlation between **age** and IOP in both eyes. Higher IOP was found in both <50 and > 50years age group depending on the instrument used. But all the comparative studies were statistically insignificant.

This was not the case in a study by **Qureshi IA (1995),** which says that IOP increases with age by a factor of 0.28 mm hg every 10 years[56].

With respect to **gender** based difference in IOP prevalence there was no sex predilection for higher IOP. Higher IOP was noted in males in both eyes in schiotz tonometer compared to females in both the eyes. But in GAT and Icare tonometers females had higher IOP in both the eyes compared to males. These results were also statistically insignificant except for the right eye Icare IOP values which alone was slightly significant. But considering the scale by which it was significant, it was not an important difference to consider.

**Bonomi L et al, (1998)** showed that with age IOP also increased & that it was more pronounced in males than in females[57].

Based on **laterality** of IOP measurements, the mean IOP recorded by schiotz was the same. Difference between right and left eye

measurements was absent. But with GAT and Icare measurements there was a tendency to record higher IOP in left eye than right eye.

This significant difference in IOP between left and right eye could be explained based on a study by **Pekmezci M et al.** According to him the first measured eye had higher IOP than the other eye[58].

Also the examiner being a right handed person the likelihood of using patients left eye for examination first was more; which could explain this left eye high values.

But there are studies suggesting right eye with higher IOP than left eye like the one done by **Şenol Dane et al**. According to him males right eye had higher IOP and this difference was absent in females[59].

Few other studies state otherwise that the difference in IOP between right and left eye was absent. Such a study was done by **Sit AJ et al**, which states that right and left eye had the same IOP[60].

In order to assess the consistency of different tonometers in giving reliable results, intra class coefficient study was done for both the eyes. Intra class coefficient study is the assessment of consistency or reproducibility of (IOP) measurements made by different instruments measuring the same quantity.

Next the intra class coefficient study showed that there was very strong correlation between Icare and GAT than between schiotz vs. Icare

(or) schiotz vs. GAT. This was given by the correlation values of >0.8 in both eyes, which suggest a very strong correlation.

The same results were confirmed in a study by **Pakrou N et al**, which states that there is good correlation between the ICARE and GAT methods of IOP measurement[61].

In order to find the 'agreement' of a new investigation with the gold standard technique a **Bland–Altman plot** analysis is made. This is a type of data plotting used for analysing the agreement between two different investigations under study.

This showed that there was good agreement between ICARE and GAT tonometers than between other tonometers.

The same good agreement was shown in a study by **Jose M. Martinez-de-la-Casa et al, (2005)**[62].

# SUMMARY

The study aimed at comparing IOP measurement by schiotz, Goldmann's applanation and ICARE tonometer and was conducted in Coimbatore medical college hospital which included 102 patients.

These patients were subjected to IOP measurement by three tonometers namely schiotz, Goldmann's applanation and Icare tonometry.

The results concluded that most of the patients in our study were females. And the average age group was 62 year for males and 58 year for females. A statistical difference in IOP between right and left eye was absent. Also there was no significant change in IOP with respect to age in both sexes.

The correlation studies showed that the correlation between schiotz and other two tonometers namely Icare and GAT were weak. But that of GAT and Icare was very strong which was also statistically very significant in both the eyes.

Also the agreement between IOP values of GAT and Icare was very good than the agreement between schiotz and other tonometers.

# CONCLUSION

1. Accurate IOP assessment is of pivotal importance in glaucoma diagnosis.
2. Schiotz tonometry though cheap, portable, light weight and quick method of IOP assessment it is not accurate and reliable method of assessment.
3. GAT is the gold standard technique of IOP assessment in glaucoma patients, giving reliable and accurate readings. But it is time consuming, not portable and cumbersome to use.
4. ICARE tonometer is easy to use, comfortable to patients, quick, lightweight and portable. Yet it gives reliable and accurate IOP readings comparable with GAT.
5. Thus ICARE tonometer can be used as an effective screening tool.

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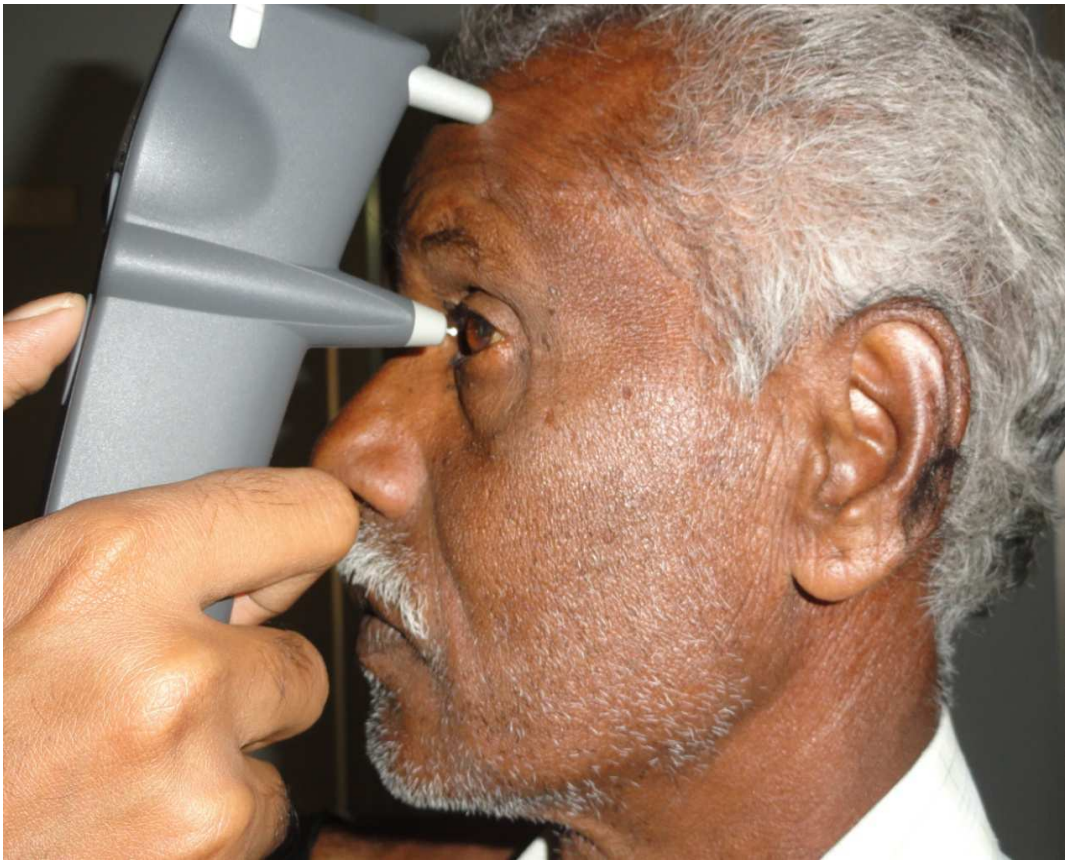
## IOP MEASUREMENT BY SCHIOTZ TONOMETER

## IOP MEASUREMENT BY GOLDMANN'S APPLANATION TONOMETER

# IOP MEASUREMENT BY ICARE



# PROFORMA

Serial number :

Name of the patient :

Age: Sex: IP.NO:

Brief history:

| S.NO: | Investigation | Right eye | Left eye |
|---|---|---|---|
| 1. | Visual acuity: | | |
| 2. | Fields: | | |
| 3. | Anterior segment examination: with<br>a) TORCH LIGHT : | | |
| | b) SLIT LAMP: | | |
| 4. | Schiotz tonometry: | | |
| 5. | Applanation tonometry: | | |
| 6. | Icare tonometry: | | |
| 7. | Pachymetry: | | |
| 8. | Corrected IOP: | | |
| 9. | Fundus examination: | | |

# CONSENT FORM

Here by I volunteer and consent to participate in this study called **"A COMPARATIVE STUDY OF INTRAOCULAR PRESSURE MEASURMENT BY SCHIOTZ, GOLDMANN'S APPLANATION & ICARE TONOMETERS".** I was fully explained about the nature of this study by the doctor; knowing which I Mr / Ms ……fully consent to volunteer in this study.

Date :

Place : Signature of the Volunteer

Signature of Witness

# MASTER CHART

| S.No | TONOMETERS | AGE | SEX | SCHIOTZ | | APPLANATION | | PACHYMETER | | CORRECTED IOP | | ICARE | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Name of the Patient | | | RIGHT | LEFT | RIGHT | LEFT | RIGHT | LEFT | RIGHT | LEFT | RIGHT | LEFT |
| 1 | Alamaleu | 64 | F | 14.6 | 17.3 | 16 | 18 | 532 | 523 | 15.5 | 17.6 | 15 | 18 |
| 2 | Karuppa gounder | 65 | M | 15.9 | 17.3 | 16 | 12 | 495 | 507 | 18.5 | 13.2 | 19 | 15 |
| 3 | Ruckmani | 56 | F | 13.4 | 13.4 | 12 | 14 | 492 | 513 | 15.3 | 15.7 | 16 | 16 |
| 4 | Shanmuga sundaram | 76 | M | 17.3 | 15.9 | 16 | 14 | 544 | 537 | 10.4 | 13.3 | 12 | 16 |
| 5 | Natchammal | 70 | F | 18.9 | 11.2 | 20 | 16 | 548 | 551 | 18.5 | 14.6 | 19 | 16 |
| 6 | Palanathal | 62 | F | 13.4 | 10.2 | 18 | 12 | 529 | 498 | 18.5 | 11.8 | 18 | 13 |
| 7 | Saroja | 47 | F | 17.3 | 17.3 | 20 | 20 | 541 | 536 | 19.2 | 19.7 | 19 | 20 |
| 8 | Sarojini | 50 | F | 14.6 | 13.4 | 18 | 18 | 528 | 504 | 18.7 | 18.9 | 17 | 17 |
| 9 | Rangal | 60 | F | 11.2 | 12.2 | 16 | 16 | 507 | 536 | 17 | 15.2 | 18 | 19 |
| 10 | Ramathal | 55 | F | 12.2 | 11.2 | 14 | 14 | 544 | 528 | 13.2 | 14.1 | 16 | 15 |
| 11 | Hamsalakshmi | 55 | F | 15.9 | 15.9 | 14 | 14 | 511 | 532 | 14.1 | 14.2 | 14 | 15 |
| 12 | Santhalakshmi | 60 | F | 18.9 | 9.4 | 18 | 16 | 537 | 552 | 17.4 | 14.4 | 19 | 18 |
| 13 | Chandra | 60 | F | 18.9 | 12.2 | 14 | 12 | 505 | 499 | 16.1 | 14 | 15 | 16 |
| 14 | Rangan | 66 | F | 10.2 | 11.2 | 16 | 16 | 485 | 505 | 18.8 | 17.6 | 19 | 17 |
| 15 | Subbathal | 62 | F | 18.9 | 17.3 | 12 | 12 | 491 | 498 | 15.3 | 14.5 | 17 | 16 |
| 16 | Raju | 51 | M | 12.2 | 9.4 | 16 | 12 | 521 | 547 | 16.2 | 10.5 | 17 | 15 |
| 17 | Mani | 35 | F | 14.6 | 11.2 | 20 | 14 | 539 | 546 | 18.7 | 13.7 | 19 | 17 |

| S.No | TONOMETERS | AGE | SEX | SCHIOTZ | | APPLANATION | | PACHYMETER | | CORRECTED IOP | | ICARE | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Name of the Patient | | | RIGHT | LEFT | RIGHT | LEFT | RIGHT | LEFT | RIGHT | LEFT | RIGHT | LEFT |
| 18 | Janbee | 55 | F | 11.2 | 15.9 | 14 | 14 | 525 | 568 | 14.2 | 10.2 | 18 | 16 |
| 19 | Bagyam | 65 | F | 13.4 | 14.6 | 18 | 22 | 494 | 513 | 19.9 | 22.2 | 21 | 21 |
| 20 | Subbamal | 60 | F | 17.3 | 17.3 | 18 | 22 | 506 | 517 | 18.8 | 22.2 | 20 | 21 |
| 21 | Nallichettiar | 78 | M | 18.9 | 18.9 | 14 | 14 | 514 | 528 | 14.6 | 14.5 | 15 | 17 |
| 22 | Nagammal | 65 | F | 10.2 | 11.2 | 16 | 20 | 502 | 488 | 18.1 | 20.9 | 18 | 20 |
| 23 | Jayapal | 63 | M | 15.9 | 13.4 | 18 | 18 | 557 | 565 | 15.7 | 14.6 | 16 | 19 |
| 24 | Subbanna gounder | 72 | M | 9.4 | 10.2 | 12 | 14 | 553 | 563 | 9 | 10.3 | 14 | 14 |
| 25 | Ramaswamy | 65 | M | 15.9 | 15.9 | 18 | 20 | 548 | 521 | 19.8 | 21.8 | 20 | 23 |
| 26 | Kaliyammal | 60 | F | 14.6 | 14.6 | 18 | 18 | 478 | 485 | 21.7 | 21.6 | 22 | 24 |
| 27 | Karupathal | 65 | F | 15.9 | 20.6 | 10 | 14 | 491 | 512 | 13.2 | 15.4 | 15 | 17 |
| 28 | Palaniswamy | 75 | M | 18.9 | 20.6 | 14 | 16 | 511 | 516 | 15.3 | 16.4 | 14 | 19 |
| 29 | Meenakshiammal | 67 | F | 17.3 | 18.9 | 12 | 16 | 522 | 497 | 11.1 | 17.8 | 16 | 16 |
| 30 | Manthiriammal | 47 | F | 17.3 | 17.3 | 22 | 22 | 539 | 518 | 21.2 | 21.8 | 22 | 24 |
| 31 | Thulasiammal | 50 | F | 12.2 | 13.4 | 18 | 18 | 529 | 523 | 17.9 | 18.1 | 19 | 21 |
| 32 | Ayyammal | 70 | F | 9.4 | 9.4 | 16 | 16 | 513 | 487 | 16.7 | 19.3 | 18 | 21 |
| 33 | Alammal | 60 | F | 11.2 | 12.2 | 16 | 16 | 479 | 487 | 19.8 | 19.2 | 19 | 20 |
| 34 | Sarojini | 45 | F | 10.2 | 15.9 | 14 | 10 | 483 | 505 | 18.2 | 12.6 | 19 | 16 |
| 35 | Thirumathal | 65 | F | 15.9 | 14.6 | 12 | 12 | 548 | 542 | 10.7 | 11.4 | 18 | 16 |

| S.No | TONOMETERS | AGE | SEX | SCHIOTZ | | APPLANATION | | PACHYMETER | | CORRECTED IOP | | ICARE | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Name of the Patient | | | RIGHT | LEFT | RIGHT | LEFT | RIGHT | LEFT | RIGHT | LEFT | RIGHT | LEFT |
| 36 | Kannammmal | 50 | F | 12.2 | 13.4 | 16 | 16 | 537 | 544 | 15.2 | 14.6 | 15 | 15 |
| 37 | Dhandapani | 57 | M | 14.6 | 13.4 | 12 | 10 | 527 | 534 | 12.1 | 11.5 | 16 | 13 |
| 38 | Pattiyappan | 54 | M | 18.9 | 12.2 | 16 | 16 | 477 | 468 | 20.4 | 20.7 | 20 | 20 |
| 39 | Selvaraj | 58 | M | 15.9 | 14.6 | 18 | 18 | 492 | 504 | 20.7 | 20.3 | 21 | 23 |
| 40 | Shanmugam | 53 | M | 15.9 | 10.2 | 14 | 12 | 522 | 547 | 14.3 | 10.8 | 13 | 12 |
| 41 | Armugam | 55 | M | 10.2 | 13.4 | 18 | 16 | 557 | 568 | 15.5 | 12.8 | 16 | 12 |
| 42 | Palanathal | 45 | F | 18.9 | 18.9 | 16 | 14 | 541 | 523 | 15.4 | 14.3 | 17 | 17 |
| 43 | Karuppaswamy | 55 | M | 17.3 | 17.3 | 14 | 14 | 481 | 499 | 18.3 | 15.5 | 14 | 16 |
| 44 | Mylathal | 57 | F | 15.9 | 11.2 | 12 | 16 | 548 | 547 | 11.8 | 15.9 | 12 | 16 |
| 45 | Palanthal | 62 | F | 14.6 | 15.9 | 18 | 20 | 572 | 553 | 16.1 | 19.4 | 17 | 19 |
| 46 | Mylathal | 61 | F | 18.9 | 20.6 | 14 | 14 | 481 | 474 | 18.5 | 19 | 19 | 20 |
| 47 | Palaniswamy | 60 | M | 14.6 | 17.3 | 10 | 14 | 541 | 520 | 10.3 | 15.8 | 13 | 17 |
| 48 | Duraiswamy | 56 | M | 20.6 | 20.6 | 14 | 16 | 567 | 548 | 12.4 | 14.6 | 15 | 16 |
| 49 | Kalimuthu | 60 | M | 17.3 | 11.2 | 14 | 16 | 540 | 536 | 14.3 | 16.6 | 15 | 18 |
| 50 | Palaniswamy | 65 | M | 17.3 | 10.2 | 16 | 14 | 534 | 532 | 16.7 | 14.9 | 18 | 19 |
| 51 | Mandaral | 60 | M | 10.2 | 17.3 | 12 | 14 | 489 | 457 | 15.9 | 20 | 18 | 20 |
| 52 | Koppammmal | 70 | M | 17.3 | 18.9 | 10 | 10 | 503 | 509 | 12.9 | 12.5 | 13 | 13 |
| 53 | Thannasi | 65 | M | 10.2 | 17.3 | 16 | 16 | 603 | 613 | 9.7 | 9.3 | 7 | 13 |

| S.No | TONOMETERS | AGE | SEX | SCHIOTZ | | APPLANATION | | PACHYMETER | | CORRECTED IOP | | ICARE | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Name of the Patient | | | RIGHT | LEFT | RIGHT | LEFT | RIGHT | LEFT | RIGHT | LEFT | RIGHT | LEFT |
| 54 | Soornapal | 70 | F | 22.4 | 18.9 | 18 | 14 | 486 | 469 | 22.1 | 19.3 | 22 | 20 |
| 55 | Veelal | 67 | F | 17.3 | 17.3 | 16 | 16 | 530 | 526 | 17 | 17.3 | 18 | 19 |
| 56 | Koppathal | 42 | F | 15.9 | 14.6 | 14 | 14 | 531 | 548 | 15 | 13 | 16 | 16 |
| 57 | Pappal | 70 | F | 12.2 | 12.2 | 18 | 18 | 485 | 508 | 22.2 | 20.6 | 20 | 20 |
| 58 | Kamalam | 52 | F | 10.2 | 11.2 | 14 | 14 | 508 | 503 | 16.6 | 17 | 18 | 19 |
| 59 | Veeraswamy | 68 | M | 15.9 | 17.3 | 12 | 14 | 534 | 519 | 12.7 | 15.8 | 14 | 16 |
| 60 | Varman | 58 | M | 17.3 | 22.4 | 14 | 18 | 564 | 541 | 12.7 | 18.3 | 13 | 19 |
| 61 | Nagarathinam | 65 | F | 17.3 | 11.2 | 16 | 16 | 551 | 559 | 15.6 | 15 | 16 | 14 |
| 62 | Bagyalakshmi | 52 | F | 13.4 | 13.4 | 16 | 16 | 567 | 581 | 14.4 | 13.5 | 15 | 18 |
| 63 | Shabura | 42 | F | 17.3 | 17.3 | 20 | 20 | 574 | 567 | 17.9 | 18.4 | 19 | 18 |
| 64 | Sulaha | 50 | F | 15.9 | 15.9 | 18 | 18 | 490 | 517 | 21.9 | 19.9 | 21 | 20 |
| 65 | Kalyani | 62 | F | 10.2 | 10.2 | 14 | 16 | 556 | 544 | 11.8 | 15.4 | 18 | 16 |
| 66 | Sundaram | 65 | F | 11.2 | 12.2 | 14 | 16 | 513 | 502 | 16.3 | 18 | 17 | 18 |
| 67 | Puspham | 52 | F | 12.2 | 12.2 | 18 | 18 | 584 | 600 | 15.3 | 14.2 | 18 | 21 |
| 68 | Rajan | 51 | M | 13.4 | 12.2 | 16 | 12 | 567 | 582 | 14 | 10 | 15 | 11 |
| 69 | Ramathal | 55 | F | 14.6 | 14.6 | 10 | 12 | 474 | 485 | 14.9 | 16.2 | 15 | 17 |
| 70 | Chandran | 55 | M | 11.2 | 10.2 | 12 | 12 | 523 | 532 | 13.5 | 12.9 | 15 | 15 |
| 71 | Rajammal | 67 | F | 8.5 | 9.4 | 12 | 12 | 551 | 552 | 11.6 | 11.5 | 13 | 15 |

| S.No | TONOMETERS | AGE | SEX | SCHIOTZ | | APPLANATION | | PACHYMETER | | CORRECTED IOP | | ICARE | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Name of the Patient | | | RIGHT | LEFT | RIGHT | LEFT | RIGHT | LEFT | RIGHT | LEFT | RIGHT | LEFT |
| 72 | Rajamani | 58 | F | 14.6 | 14.6 | 10 | 10 | 483 | 473 | 14.3 | 15 | 16 | 12 |
| 73 | Rangammal | 55 | F | 15.9 | 15.9 | 10 | 10 | 472 | 485 | 15.1 | 14.2 | 16 | 15 |
| 74 | Pitchammal | 63 | F | 8.5 | 12.2 | 12 | 12 | 600 | 615 | 8.1 | 7.1 | 13 | 12 |
| 75 | Avinasiappan | 56 | M | 17.3 | 17.3 | 14 | 12 | 547 | 535 | 13.9 | 12.7 | 16 | 16 |
| 76 | Amasiakkal | 60 | F | 15.9 | 15.9 | 10 | 10 | 514 | 515 | 12.2 | 12.1 | 13 | 13 |
| 77 | Sitalakshmi | 62 | F | 17.3 | 17.3 | 8 | 8 | 521 | 507 | 9.7 | 10.6 | 10 | 12 |
| 78 | Karuppuswamy | 70 | M | 15.9 | 14.6 | 18 | 16 | 541 | 541 | 18.3 | 16.2 | 19 | 17 |
| 79 | Annamalai | 67 | M | 8.5 | 10.2 | 12 | 12 | 488 | 457 | 16 | 18.1 | 16 | 19 |
| 80 | Umamaheswari | 42 | F | 10.2 | 11.2 | 12 | 12 | 565 | 567 | 10.6 | 10.4 | 14 | 10 |
| 81 | Marathal | 62 | F | 11.2 | 12.2 | 16 | 20 | 477 | 490 | 20.8 | 23.9 | 21 | 22 |
| 82 | Chinnal | 60 | F | 9.4 | 9.4 | 12 | 18 | 525 | 527 | 13.4 | 19.2 | 15 | 20 |
| 83 | Suryakandi | 65 | F | 10.2 | 13.4 | 12 | 18 | 564 | 538 | 10.7 | 18.5 | 11 | 19 |
| 84 | Palanal | 50 | F | 14.6 | 15.9 | 10 | 10 | 518 | 534 | 11.9 | 10.7 | 12 | 15 |
| 85 | Rangammal | 39 | F | 17.3 | 17.3 | 8 | 8 | 516 | 527 | 10 | 9.2 | 12 | 10 |
| 86 | Meibunbeevi | 70 | F | 14.6 | 14.6 | 14 | 14 | 548 | 551 | 13.8 | 13.6 | 15 | 16 |
| 87 | Jaibal | 63 | M | 22.4 | 22.4 | 18 | 18 | 478 | 492 | 22.7 | 21.7 | 21 | 20 |
| 88 | Ramathal | 50 | F | 12.2 | 17.3 | 10 | 10 | 474 | 469 | 14.9 | 15.3 | 16 | 18 |
| 89 | Chakkaraiammal | 60 | F | 15.9 | 17.3 | 14 | 14 | 550 | 540 | 13.7 | 14.3 | 14 | 15 |

| S.No | TONOMETERS | AGE | SEX | SCHIOTZ | | APPLANATION | | PACHYMETER | | CORRECTED IOP | | ICARE | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Name of the Patient | | | RIGHT | LEFT | RIGHT | LEFT | RIGHT | LEFT | RIGHT | LEFT | RIGHT | LEFT |
| 90 | Kuppamal | 60 | F | 15.9 | 17.3 | 14 | 12 | 502 | 485 | 17 | 16.2 | 18 | 19 |
| 91 | Mahali | 65 | F | 17.3 | 20.6 | 16 | 18 | 469 | 473 | 21.3 | 23 | 20 | 19 |
| 92 | Palani | 65 | M | 17.3 | 18.9 | 14 | 14 | 491 | 494 | 17.8 | 17.6 | 18 | 19 |
| 93 | Rayappan | 75 | M | 15.9 | 15.9 | 8 | 6 | 502 | 453 | 11 | 12.5 | 12 | 15 |
| 94 | Veluswamy | 80 | M | 17.3 | 17.3 | 12 | 16 | 485 | 536 | 16.2 | 16.6 | 17 | 18 |
| 95 | Devaraj | 65 | M | 15.9 | 15.9 | 12 | 14 | 518 | 502 | 13.9 | 17 | 15 | 19 |
| 96 | Joseph | 63 | M | 14.6 | 15.9 | 12 | 8 | 534 | 534 | 12.7 | 8.8 | 12 | 10 |
| 97 | Periyaswamy | 49 | M | 15.9 | 17.3 | 16 | 18 | 548 | 556 | 14.6 | 15.2 | 16 | 17 |
| 98 | Ramaswamy | 55 | M | 22.4 | 22.4 | 14 | 14 | 521 | 498 | 14.1 | 16 | 17 | 18 |
| 99 | Paran | 53 | M | 17.3 | 15.9 | 18 | 18 | 537 | 545 | 17.3 | 16.7 | 17 | 17 |
| 100 | Muthuraj | 46 | M | 10.2 | 11.2 | 16 | 18 | 578 | 581 | 12.3 | 14.5 | 18 | 19 |
| 101 | Krishnaswamy | 67 | M | 13.4 | 13.4 | 12 | 14 | 536 | 525 | 11.4 | 14.3 | 15 | 16 |
| 102 | Kittan | 71 | M | 12.2 | 13.4 | 12 | 12 | 486 | 497 | 15.4 | 14.8 | 17 | 17 |