INTRODUCTION

Glaucoma is a group of acute and chronic, progressive, multifactorial optic neuropathies in which intraocular pressure (IOP) and other contributing factors are responsible for a characteristic, acquired loss of retinal ganglion cell axons leading to atrophy of the optic nerve with demonstrable visual field defects. Glaucoma is described by the morphological changes in the intra-papillary and para-papillary regions of the optic nerve head and the retinal nerve fiber layer (RNFL)\(^1\)\(^,\)\(^2\).

Retinal Nerve Fiber Layer

The Retinal Nerve Fibre Layer is formed by the expansion of the fibers of optic nerve; it is thickest near the porus opticus gradually diminishing towards the ora serrata\(^3\). In normal eyes the RNFL is most visible in the temporal inferior and temporal superior sectors and least visible in the nasal sectors. This has correlation with the histology of the RNFL which is thicker in inferior and superior peripapillary areas than the temporal and nasal. The NRR is wider and the lamina cribrosa pores and diameter of the retinal arterioles is larger in these areas. The visibility of RNFL decreases with age. To examine the RNFL dilate the pupil and see the fundus with a noncontact lens in red free illumination of the slit lamp. The normal pattern of the fiber bundles can be detected as bright striations in the retinal reflex. In fundus the RNFL is markedly better detectable in the temporal superior sector one can carefully observe the temporal inferior region to find a loss of RNFL. Various studies demonstrate that OCT can measure Peripapillary RNFL thickness. Also observe the vessels as the retinal vessels are normally embedded in the retinal nerve fibers and when there is diffuse RNFL loss the vessels are covered only by the thin inner limiting membrane so are better visible. The RNFL defects could be localized or generalized depending on the stage of the disease and because localized defects are very rare in normal eyes they are highly specific for optic nerve damage. But localized defects are not pathognomic of glaucoma and can

DIAGNOSTIC CAPABILITY OF OCT IN THE EVALUATION OF RNFL THICKNESS IN PRIMARY OPEN ANGLE GLAUCOMA BEFORE AND AFTER TRABECULECTOMY:

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ABSTRACT

Purpose: To study the diagnostic capability of OCT in the evaluation of thickness of RNFL in a population of clinical patients with primary open angle glaucoma undergone trabeculectomy pre-op and 1 week, 1 and 3 month post-operatively in the Sub-Himalayan region.

Methods: Normative data was collected from 27 patients having primary open angle glaucoma. The patient population consists of adults with open anterior chamber angle and with demonstrative RNFL damage. Average and quadrant RNFL thickness measurements were taken. 3D OCT1MAESTRO was used to measure quadrant RNFL thickness within a week before surgery and at 1 week, 1 and 3 month post operatively. Pre and post operative value were analyzed using Repeated Measure ANOVA with Bonferroni correction.

Results: RNFL thickness was observed on an OCT machine in which, Inferior Quadrant of RNFL was observed with Mean value equal to 63.3 ± 8.978 pre-operatively. The Mean values of inferior quadrant observed at 1 week post operatively came to be 69.48 ± 9.002 (p= 0.000). No significant changes were observed in the other quadrants during the period of observation. Though, minor fluctuations can be attributed to lowering of IOP post-Trabeculectomy in POAG.

Conclusions: Short term fluctuations were noted using OCT machine in the RNFL thickness post-operatively, following Trabeculectomy. RNFL thickness showed improvement in 1 week post-operatively only, but reverted back to pre-operative values at 3 month which were analyzed using OCT machine.

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Dr. Yash Pal Sharma et al., Diagnostic Capability of Oct in the Evaluation of RNFL Thickness in Primary Open Angle Glaucoma Before and After Trabeculectomy

occur in other types of optic disc atrophies. In glaucoma, they are more common in normal tension glaucoma followed by POAG and then secondary open angle cases.

Optical Coherence Tomography

Optical coherence tomography (OCT) is a diagnostic imaging technique that provides cross-sectional images of human retinal morphology in vivo. Huang and associate first invented OCT in 1991, the first SD-OCT became commercially available in 2006. Optical coherence tomography (OCT) is the optical analogue to ultra-sonography and measures the echo time delay and magnitude of reflected or backscattered light using the principle of Michelson low-coherence interferometry. Cross-sectional images are obtained by measuring the backscattered light while scanning across multiple sites in a transverse fashion. Echoes from a single point on the retina represent an axial scan (A-scan), and optical cross-sections (B-scans) are obtained by directing the OCT beam in the transverse direction. The data obtained are displayed as false-colour or grey-scale images. The position of the reference mirror is altered in order to obtain reflected light from the retina at several different depths. Spectral domain OCT allows for unprecedented simultaneous ultrahigh speed and ultrahigh resolution ophthalmic imaging without a loss in image quality, and 2D images can be obtained in 1/29th of a second. Spectral domain OCT can image 14,600 to over 29,200 A-lines per second. Spectral domain OCT resolutions of about 2 μm can be achieved with the appropriate light source. Spectral domain OCT can create 3-dimensional (3D) images as well as videos of large areas of the posterior pole (16). Present machine that was used for study was Topcon 3D OCT-1 Maestro that is installed at the Department of Ophthalmology I. G. M. C Shimla.

Various study demonstrate that OCT measure RNFL as thinner in older person with decline of 2μm per decade. The human RNFL losses approximately 5000 axons per year from birth to death. Approximately 2500 per year before 50 years and approximately 7500 per year after 50 years of age. It is not surprising that RNFL thickness decrease with age.

The OCT can also measure optic disc topography. Although there are inherent limitations in the measurement algorithm, the discriminating ability of some parameters for glaucoma has been shown to be nearly as good as the RNFL thickness measurements. OCT may be more advantageous over HRT in having a higher axial resolution and automated outlining of optic disc margin, thus eliminating operator variability. One added advantage of the OCT ONH analysis is that, one can get a cross-sectional view of the ONH rather than the ‘enface’ view provided by the HRT. If cup reversal following IOP reduction is due to the forward movement of the lamina cribrosa, then OCT may be able to demonstrate this phenomenon better.

Trabeculectomy

With its long-established history, remains widely practiced for glaucoma. Studies are robust in supporting its efficacy in lowering IOP. Trabeculectomy is a surgical operation which lowers the intraocular pressure (IOP) inside the eye in patients with glaucoma. This is achieved by making a small hole in the eye wall (sclera), covered by a thin trap-door in the sclera. The fluid inside the eye known as aqueous humour, drains through the trap-door to a small reservoir or bleb just under the eye surface, hidden by the eyelid. The trap-door is sutured (stitched) in a way that prevents aqueous humour from draining too quickly. By draining aqueous humour the Trabeculectomy operation reduces the pressure on the optic nerve and prevents or slows further damage and further loss of vision in glaucoma. Control of the eye pressure with a Trabeculectomy will not restore vision already lost from glaucoma.

The rationale for the current study was, to prospectively study RNFL (by using Topcon 3D OCT-1 Maestro) before and after Trabeculectomy in Primary Open Angle Glaucoma, in patients attending Department of Ophthalmology, I. G. M. C Shimla. The stimulus for this work was only ophthalmological for the exploration of RNFL by using the maximum means at our disposal.

MATERIALS AND METHODS

The rationale for the current study was, to prospectively study of RNFL (by using 3D OCT-1 Maestro) before and after Trabeculectomy in Primary Open Angle Glaucoma, in patients attending Department of Ophthalmology, I. G. M. C Shimla. The stimulus for this work was only ophthalmological for the exploration of RNFL and IOP by using the maximum means at our disposal.

Informed consent was obtained from all recruited individuals. Each subject underwent extensive examination including Best Corrective Visual Acuity (BCVA) by using Snellen’s chart. Slit lamp bio-microscopy was done to assess the ocular adnexa and the anterior segment (AC Depth using Van Herricks Grading) of eye using a slit lamp bio-microscope (Haag Striet-900). Intra ocular pressure is measured by using a Goldman’s applanation tonometer. An open anterior angle chamber using Gonioscopy by Shaffer’s system using Goldmann Single Mirror Gonioscopic Lens. Optic Disc Examination- for glaucomatous changes was performed in dilated pupil with slit lamp (Haag Striet-900) using 90D lens (Magnification= 0.76). Fundus examination was done by using the direct and indirect ophthalmoscope after pupillary dilatation using 5% phelyplehrine and 1% tropicamide drops instilled once or twice as required.

The criteria for inclusion were diagnosis of primary open angle Glaucoma, age taken was older than 40 years and not more than 80 years. No previous Glaucoma surgery, no cataract surgery during follow-up, no retinal or neurological disease and patients having significant cataract affecting OCT were not taken. While the patient was under maximally tolerant medication, the indication for surgery was Optic Nerve Head Parameter and RNFL which was high risk of glaucomatous progression as well as worsening of the visual field. All patients eligible for surgery underwent baseline and postoperative RNFL measurement. All scans pre-operatively were to be acquired within 1 week of the planned surgery.

Optical Coherence Tomography (3D OCT-1MAESTRO) was used for studying RNFL thickness. The RNFL map represents a 6 x 6 mm cube of A-scan data centered over the optic nerve in which a 3.4 mm diameter circle of RNFL data is extracted to create what is referred to as the ISNT map (inferior, superior, nasal and temporal). Each resulting image will consist of RNFL thickness measurements along a 360-degree circle around the optic disc. It is displayed as a false color scale with the
thickness values referenced to a normative database. All OCT scans were acquired by an experienced operator. OCT scans were obtained after pupillary dilatation using 5% phenylephrine and 1% tropicaime drops instilled once or twice as required. All baseline scans was acquired within 1 weeks of the planned surgery. The parameters studied were RNFL Thickness in each quadrant.

**Surgical Technique**

No pupillary dilatation and a bridle suture/corneal Traction Suture were inserted (commonly superior cornea). Site of Trabeculectomy was supero-nasal or supero-temporal. A fornix based flap of conjunctiva and Tenon capsule was fashioned superiorly. Epi-scleral tissue was cleared and major vessels cauterized.

An incision was made through about 50% of sclera thickness to create a trap-door lamellar sclera flap. This flap was triangular according to preference. The superficial triangular flap was dissected forwards until clear cornea is reached. A paracentesis was made in temporal peripheral clear cornea and air injected. The anterior chamber was entered along most of the width of the trapdoor base. Sclerotomy incision was 1mm clear of either side of sclera flap. After the initial linear incision into anterior chamber sclerotomy is fashioned with sclera punch.

A fistula 0.5mm to 1mm in height and 1.5 to 2mm in width created. Peripheral iridectomy was created. Superficial scleral flap was sutured to its underlying bed tightly with Apex suture, using nylon 10-0 suture. Balanced salt sol was repeated to produce a bleb. Steroid and antibiotic was injected through the paracentesis to deepen the anterior chamber sclerotomy is fashined with sclera punch.

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Postoperative analysis of IOP and RNFL were done at 1 week, 1 and 3 month respectively. All data was collected on data forms.

**Statistical analysis**

Data collected during the study was tabulated and analyzed by using Repeated Measure ANOVA with Bonferroni correction. The probability value (‘p’-value) was calculated and a value of <0.05 was implied to be statistically significant.

**RESULT**

**Inferior Quadrant Thickness (μm)**

Inferior Quadrant of RNFL readings were observed on an OCT machine in this the pre-op Mean value came to be equal to 63.3 ± 8.978. The Mean values of inferior quadrant observed at 1 week post operatively came to be 69.48 ± 9.002 (p= 0.000). The consecutive period of observation was at 1 month in which the Mean value of Inferior Quadrant came to be 68.93 ± 11.19 (p = 0.096). The final readings of the Inferior Quadrant were observed to be equal to 66.67 ± 9.919 (p=0.144).

<table>
<thead>
<tr>
<th>Inferior Quadrant</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>IQ : Pre Op</td>
<td>63.3</td>
<td>±8.978</td>
<td></td>
</tr>
<tr>
<td>IQ : 1 Week - Post Op</td>
<td>69.48</td>
<td>±9.002</td>
<td>0.000</td>
</tr>
<tr>
<td>IQ : 1 Month - Post Op</td>
<td>68.93</td>
<td>±11.19</td>
<td>0.096</td>
</tr>
</tbody>
</table>

Mean values of Superior Quadrant. In the pre-operative period the Mean value for study group came to be equal to 67.52 ± 12.801. The Superior Quadrant was then observed post operatively at 1 week and the Mean values came to be 67.85 ± 13.640 (p=1.000). At 1 month post operatively the Mean value came to be 69.37 ± 12.122(p =0.880). At 3 month Post operatively the Mean value were observed to be 69.81 ± 13.270 (p=1.000).

**Superior Quadrant Thickness (Mm)**

<table>
<thead>
<tr>
<th>Mean</th>
<th>Standard Deviation</th>
<th>p-VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Operative</td>
<td>67.52</td>
<td>± 12.801</td>
</tr>
<tr>
<td>Post-OP 1 week</td>
<td>67.85</td>
<td>± 13.640</td>
</tr>
<tr>
<td>Post-OP 1 Month</td>
<td>69.37</td>
<td>± 12.122</td>
</tr>
<tr>
<td>Post-OP 3 Month</td>
<td>69.81</td>
<td>± 13.270</td>
</tr>
</tbody>
</table>

The Mean value at pre-operative period was equal to 62.63 ± 8.317. 1 Week post-operatively the Mean value was observed to be equal to 63.22 ± 9.112 (p=1.000). The Nasal Quadrant then was observed at 1 month post-operatively the Mean values were 64.22 ± 9.316 (p =1.000). The follow-up was then done at
3rd month; the Mean values came to be equal to 65.33 ± 8.256 (p = 0.846).

**Nasal Quadrant Thickness (μm)**

![Nasal Quadrant Thickness](image)

The Mean value at pre-operative period was equal to 50.81 ± 9.915. 1 Week post-operatively the Mean value was observed to be equal to 50.52 ± 9.345 (p = 1.000). The Temporal Quadrant then was observed at 1 month post-operatively the Mean values were 51.48 ± 9.267 (p = 1.000). The follow-up was then done at 3rd month; the Mean values came to be equal to 51.85 ± 10.117 (p = 1.000).

**Temporal Quadrant Thickness (μm)**

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Operative</td>
<td>50.81</td>
<td>± 9.915</td>
<td></td>
</tr>
<tr>
<td>Post-Op 1 Week</td>
<td>50.52</td>
<td>± 9.345</td>
<td>1.000</td>
</tr>
<tr>
<td>Post-Op 1 Month</td>
<td>51.48</td>
<td>± 9.267</td>
<td>1.000</td>
</tr>
<tr>
<td>Post-Op 3 Month</td>
<td>51.85</td>
<td>± 10.117</td>
<td>1.000</td>
</tr>
</tbody>
</table>

In our study the Mean value of Nasal quadrant Mean value at pre-operative period was equal to 50.81 ± 9.915 and post-operatively at 1 Week the Mean value was 64.22 ± 8.978, at 1 month the Mean value was 63.3 ± 8.978 and at 3rd month the Mean value was 63.33 ± 8.256 (p = 0.884). The results showed improvement of (RNFL) Nasal Quadrant thickness at 3rd month as compared to pre-operative value. Similar study done by Sarkar, et al. (2014) shows that the RNFL thickness changes among the patients of pre-operative and post-operative glaucoma (52.56 ± 17.40 and 58.48 ± 20.20, respectively) cases were statistically significant. There was an increased RNFL thickness (superior quadrant: 4.45 ± 7.61 μm, nasal quadrant 6.57 ± 11.19 μm, inferior quadrant 7.57 ± 12.16 μm, and temporal quadrant 3.27 ± 12.32 μm) in all quadrants, but more changes were found in nasal quadrant. The improvement was confined to the nasal quadrant and the adjacent RNFL thickness because this area might be least affected by the disease.

**DISCUSSION**

Glaucomatous optic neuropathy is characterized by optic disc cupping and progressive thinning of the retinal nerve fiber layer (RNFL). It is well known that patients with glaucoma could suffer approximately 40% loss of retinal ganglion cell axons before a visual field defect is evident. Therefore, if one can elucidate early RNFL thinning, then glaucoma may be detected at a much earlier stage. The Retinal Nerve Fiber Analyzer or OCT is a computerized scanning device designed for the objective and quantitative in vivo relative measurement of RNFL thickness. A possible explanation suggested for the immediate increase in RNFL thickness postoperatively is the reversal or rebound of the physical compressive effect on the RNFL by the elevated pre intervention IOP, leading to a recovery of normal shape and size by the retinal ganglion cell axons. Another explanation that has been postulated may be retinal swelling from acute postoperative reduction in IOP.

In the present study all the four quadrants were analyzed, differences between normal and Glaucomatous eye has been well documented. The changes in four quadrants Inferior, Superior, Nasal and Temporal were analyzed. Inferior Quadrant of RNFL pre-op Mean value was 63.3 ± 8.978, 1 week post-operatively was 69.48 ± 9.002 (p = 0.006), 1 month the Mean value of Inferior Quadrant was 68.93 ± 11.19 (p = 0.096) and at 3rd month reading of Inferior Quadrant was 66.67 ± 9.199 (p = 0.144). Hence Inferior Quadrant thickness showed significant improvement in the first week post-operatively, but were tending to pre-operative values in the 1 month and 3rd month of follow-up. Similar results were observed by N Raghu et al (2012) in their study the RNFL parameters, average and inferior and temporal quadrant RNFL thickness measurements increased significantly at 1 week after surgery, but reverted to baseline levels at the subsequent follow-up visits. Aydin et al (2003) in his study found a significant increase in the peripapillary NFL thickness, as determined by OCT, after glaucoma filtration surgery.

In our study the Mean value of Superior Quadrant pre-operatively was 67.52 ± 12.801, post-operatively at 1 week the Mean values was 67.85 ± 13.640 (p = 1.000), 1 month the Mean value was 69.37 ± 12.122 (p = 0.880) and at 3 month the Mean value was 69.81 ± 13.270 (p = 1.000). There was only numerical improvement in RNFL superior quadrant thickness but the thickness was not statistically significant.
thickening was significant for the overall measurement and in all quadrants except the inferior quadrant. Segmental analysis should be performed cautiously because the reproducibility decreased for quadrant measurements in glaucoma subjects, especially in the temporal and nasal quadrants. He found a significant increase in the NFL thickness was found for the overall measurement and in all quadrants except the inferior quadrant. Figus et al (2011) in his study observes that Mean RNFL thickness showed statistically significant changes and said thickness increased by 0.05mm out of 0.19±0.034mm baseline at 3 months (P<0.05), and 0.03mm at 6 months (P<0.05). The mean value of RNFL in normal elderly patients is 0.23±0.07mm; On the basis of his results he raised the hypothesis that the increase of RNFL thickness may reflect the recovery of the compressed RNFL, which would regain its original shape thanks to IOP reduction. As compression on the axons is relieved by IOP reduction, the axons may recover their normal shape and size, with resultant increase in RNFL thickness.

Other studies that showed similar results were Bowd et al, Chang et al, Figus et al, Hong Lee et al, Leung et al, Lin et al, Soliman et al, Xu et al, Yung et al.

CONCLUSION

OCT is a computerized scanning device used in in-vivo analysis of RNFL thickness for early and later stage detection of POAG. This early stage mitigation of POAG can lead to better results in Glaucoma Filtration surgery. The minor changes observed in present study could be improved by early stage analysis of Glaucomatous eye using OCT which has shown better results. The OCT can also measure optic disc topography. Some studies have shown OCT may be more advantageous over HRT in having a higher axial resolution and automated outlining of optic disc margin, thus eliminating operator variability.

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References