

Clinical Profile of Normal Tension Glaucoma: A Hospital-Based Observational Study

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Abstract: ***Background:** Normal tension glaucoma (NTG) is a subtype of primary open-angle glaucoma characterized by progressive glaucomatous optic neuropathy despite intraocular pressure (IOP) remaining within the normal range. Because structural and functional damage occurs without elevated IOP, diagnosis is often delayed. This study evaluated the clinical profile, systemic associations, optic nerve head changes, visual field defects, and retinal nerve fibre layer (RNFL) alterations in patients with NTG. **Materials and Methods:** A hospital-based observational cross-sectional study was conducted over 24 months at the Department of Ophthalmology, Ruxmaniben Deepchand Gardi Medical College, Ujjain. Thirty-eight consecutive patients (76 eyes) with clinically diagnosed NTG underwent comprehensive ophthalmic evaluation including best-corrected visual acuity, Goldmann applanation tonometry with diurnal IOP assessment, gonioscopy, central corneal thickness (CCT) measurement, optic disc examination, Humphrey automated perimetry and optical coherence tomography. Data were analysed using IBM SPSS Statistics version 26.0, with $P < 0.05$ considered statistically significant. **Results:** The mean age was 57.65 ± 9.76 years, with a male predominance (65.8%). More than half of the eyes (56.6%) had CCT below 510 μm , while corrected IOP remained within the normal range in all patients. A cup-to-disc ratio ≥ 0.7 was observed in 76.3% of eyes. Nasalisation of retinal vessels (73.7%) was the commonest optic nerve head finding, and double arcuate scotoma (31.6%) was the predominant visual field defect. Inferior RNFL thinning was the most frequent OCT abnormality (61.8%) and showed significant association with superior arcuate or double arcuate visual field defects ($P=0.027$), whereas temporal RNFL thinning correlated with central or paracentral scotomas ($P=0.015$). **Conclusion:** NTG demonstrates characteristic optic nerve head, visual field, and OCT abnormalities despite normal IOP. Comprehensive evaluation including pachymetry, diurnal IOP assessment, automated perimetry, and OCT facilitates early diagnosis and may improve visual outcomes through timely intervention.*

Keywords: Normal tension glaucoma; Primary open-angle glaucoma; Intraocular pressure; Central corneal thickness; Optical coherence tomography; Retinal nerve fibre layer; Visual field defects; Optic nerve head.

1. Introduction

Glaucoma is a chronic, progressive optic neuropathy characterized by degeneration of retinal ganglion cells, optic nerve head damage, and corresponding visual field defects, representing one of the leading causes of irreversible blindness worldwide.[1] Elevated intraocular pressure (IOP) is the most important modifiable risk factor; however, glaucomatous optic neuropathy may also occur despite IOP remaining within the statistically normal range. This entity, known as normal tension glaucoma (NTG), is considered a subtype of primary open-angle glaucoma (POAG) and poses a considerable diagnostic challenge because patients often remain asymptomatic until advanced stages of disease. [2]

The prevalence of NTG varies considerably among different populations and ethnic groups. Population-based studies have demonstrated that NTG accounts for approximately one-third of POAG cases in Western countries, whereas it constitutes the predominant form of open-angle glaucoma in several Asian populations.[3,4] In India, NTG represents a substantial proportion of glaucoma cases, highlighting the need for increased awareness and systematic evaluation of patients with suspicious optic disc changes despite normal IOP measurements.[5] Since routine glaucoma screening frequently relies on IOP alone, many patients with NTG may remain undiagnosed until irreversible visual loss has occurred. [6]

Unlike high-tension glaucoma, the pathogenesis of NTG is multifactorial and extends beyond mechanical damage due to elevated IOP. Several vascular, systemic, and genetic mechanisms have been implicated, including impaired ocular

perfusion, nocturnal systemic hypotension, vasospasm, endothelial dysfunction, oxidative stress, mitochondrial abnormalities, and increased susceptibility of the optic nerve head to normal IOP levels.[7–9] Systemic conditions such as diabetes mellitus, hypertension, migraine, Raynaud's phenomenon, ischemic heart disease, and obstructive sleep apnoea have also been reported to influence disease development and progression.[10]

Diagnosis of NTG requires meticulous clinical evaluation to exclude secondary causes of optic neuropathy and intermittent ocular hypertension. Office diurnal variation testing is useful for identifying occult IOP fluctuations, while measurement of central corneal thickness (CCT) is essential because thin corneas may lead to underestimation of true IOP.[11,12] Comprehensive assessment further includes gonioscopy, optic nerve head evaluation, automated perimetry, and optical coherence tomography (OCT), which enables quantitative assessment of peripapillary retinal nerve fibre layer (RNFL) thinning. Structural damage detected on OCT often precedes functional visual field loss, facilitating earlier diagnosis and timely intervention. [13,14]

Characteristic optic disc changes in NTG include localized neuroretinal rim thinning, focal notching, disc haemorrhages, peripapillary atrophy, and RNFL defects, while visual field defects are typically deeper, more localized, and closer to fixation than those observed in high-tension glaucoma.[15–17] Correlating OCT-derived RNFL abnormalities with visual field changes provides valuable information regarding disease severity and progression and has become an integral component of contemporary glaucoma evaluation.[18]

Considering the diagnostic challenges and limited regional data, the present study was undertaken to evaluate the demographic profile, systemic associations, central corneal thickness, corrected intraocular pressure, optic nerve head characteristics, visual field patterns, and OCT-derived RNFL changes in patients with normal tension glaucoma attending a tertiary care teaching hospital.

2. Materials and Methods

This hospital-based, observational cross-sectional study was conducted in the Department of Ophthalmology, Ruxmaniben Deepchand Gardi Medical College, Ujjain, over a 24-month period (January 2024–December 2025) after obtaining Institutional Ethics Committee approval and written informed consent. A total of 38 consecutive patients (76 eyes) diagnosed with normal tension glaucoma (NTG) were enrolled. Patients with characteristic glaucomatous optic disc changes, corresponding visual field defects, open angles on gonioscopy, and untreated intraocular pressure (IOP) ≤ 21 mmHg were included. Patients with secondary glaucoma, angle-closure glaucoma, media opacity, previous ocular trauma or surgery, steroid-induced glaucoma, or retinal and neurological disorders affecting the visual field were excluded.

All participants underwent detailed ophthalmic evaluation including best-corrected visual acuity assessment, slit-lamp biomicroscopy, Goldmann applanation tonometry with office diurnal IOP measurement, gonioscopy, central corneal thickness (CCT) measurement using a Topcon SP - 1P Specular Microscopy, dilated optic disc examination with a +90 D lens, automated Humphrey visual field analysis and optical coherence tomography (OCT) for peripapillary retinal nerve fibre layer (RNFL) assessment. Corrected IOP was calculated after adjusting for CCT, and optic nerve head

findings, visual field defects, systemic risk factors, and RNFL thinning were documented.

Data were analysed using IBM SPSS Statistics version 26.0. Continuous variables were expressed as mean $\pm$ standard deviation, while categorical variables were presented as frequency and percentage. Comparisons were performed using the independent-samples t-test, paired t-test, and Chi-square/Fisher's exact test, as appropriate. A P value < 0.05 was considered statistically significant.

3. Results

A total of **38 patients comprising 76 eyes** fulfilled the eligibility criteria and were included in the study. There were **25 males (65.79%)** and **13 females (34.21%)**, giving a male-to-female ratio of **1.92:1**.

Table 1: Age distribution of the study population

Age group (years)	Number of patients	Percentage
31–40	3	7.89%
41–50	6	15.79%
51–60	17	44.74%
61–70	9	23.68%
71–80	3	7.89%
Total	38	100.00%

The mean age of the study population was **57.65 ± 9.76 years**, with an age range of **35–78 years**. The mean age of male patients was **56.90 ± 9.40 years**, while that of female patients was **59.10 ± 10.50 years**. The difference in mean age between males and females was not statistically significant (**independent-samples t-test, $P=0.532$**).

The majority of patients, **17 (44.74%)**, belonged to the age group of 51–60 years, followed by **9 patients (23.68%)** in the 61–70-year age group.

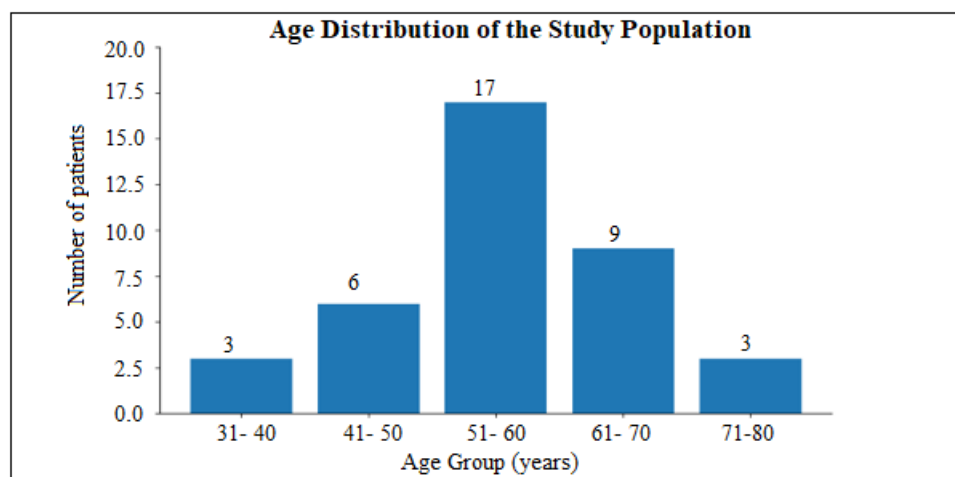


Figure 1: Age distribution of the study population. The majority of patients belonged to the 51–60-year age group.

Presenting visual acuity

Among the 76 eyes, presenting visual acuity was **6/60 in 7 eyes (9.21%)**, **6/36 in 13 eyes (17.11%)**, **6/24 in 14 eyes (18.42%)**, **6/18 in 13 eyes (17.11%)**, **6/12 in 22 eyes (28.95%)**, and **6/9 in 7 eyes (9.21%)**.

Following refraction, best-corrected visual acuity was **6/6 in 37 eyes (48.68%)**, **6/9 in 25 eyes (32.89%)**, **6/12 in 7 eyes (9.21%)**, **6/18 in 4 eyes (5.26%)**, and **6/24 in 3 eyes (3.95%)**. Thus, **62 eyes (81.58%)** achieved a best-corrected visual acuity of 6/9 or better.

Table 2: Diurnal variation of intraocular pressure according to sex

Sex	10–11 AM RE, mmHg	10–11 AM LE, mmHg	3–4 PM RE, mmHg	3–4 PM LE, mmHg
Male	18.30 ± 1.70	16.50 ± 2.00	15.50 ± 1.60	15.20 ± 1.70
Female	17.50 ± 1.90	16.00 ± 2.10	15.10 ± 1.80	14.80 ± 1.90
Total	18.03 ± 1.79	16.33 ± 2.02	15.36 ± 1.66	15.06 ± 1.76
P value, male vs female	0.205	0.483	0.488	0.531

Values are presented as mean ± standard deviation. RE: right eye; LE: left eye.

The mean intraocular pressure was higher during the morning examination than during the afternoon examination. The mean reduction was **2.67 ± 1.26 mmHg in the right eye** and **1.27 ± 1.08 mmHg in the left eye**. The morning-to-afternoon reduction was statistically significant in both eyes (**paired t-test, P<0.001**).

All recorded intraocular pressure measurements remained within the statistically normal range. No significant sex-based difference was observed at either measurement time.

Central corneal thickness

Of the 76 eyes, **8 eyes (10.53%)** had a central corneal thickness greater than 530 µm, **25 eyes (32.89%)** had a thickness between 510 and 530 µm, and **43 eyes (56.58%)** had a thickness below 510 µm. Therefore, more than half of the eyes had relatively thin central corneas.

In male patients, the mean central corneal thickness was **508.60 ± 19.50 µm in the right eye** and **511.40 ± 22.10 µm in the left eye**. In female patients, it was **515.10 ± 25.20 µm in the right eye** and **514.70 ± 24.60 µm in the left eye**.

For the overall study population, mean central corneal thickness was **510.82 ± 21.70 µm in the right eye** and **512.53 ± 22.86 µm in the left eye**. The overall mean central corneal thickness of both eyes was **511.68 ± 22.24 µm**.

There was no statistically significant difference in central corneal thickness between males and females in either the right eye (**P=0.428**) or left eye (**P=0.690**).

Corrected intraocular pressure

After correction for central corneal thickness, corrected intraocular pressure was between **12–13 mmHg in 8 eyes (10.53%)**, **14–15 mmHg in 24 eyes (31.58%)**, **16–17 mmHg in 27 eyes (35.53%)**, **18–19 mmHg in 12 eyes (15.79%)**, and **20–21 mmHg in 5 eyes (6.58%)**.

Table 3: Distribution of mean corrected intraocular pressure

Sex	RE mean, mmHg	RE SD	LE mean, mmHg	LE SD
Male	15.60	2.10	16.10	2.00
Female	16.20	2.40	16.00	2.20
Total	15.81	2.20	16.07	2.04
P value	0.458		0.892	

The mean corrected intraocular pressure was within the normal range in both sexes. No statistically significant difference was observed between males and females in the right or left eye.

Associated systemic factors

A systemic risk factor or comorbidity was present in **25 patients (65.79%)**, whereas **13 patients (34.21%)** had no identifiable systemic association.

Diabetes mellitus was present in **9 patients (23.68%)**, hypertension in **7 patients (18.42%)**, systemic hypotension in **4 patients (10.53%)**, migraine in **2 patients (5.26%)**, ischemic heart disease in **2 patients (5.26%)**, obstructive sleep apnoea in **1 patient (2.63%)**, and a history of acute blood loss in **1 patient (2.63%)**.

Some patients had more than one systemic comorbidity; therefore, the sum of individual systemic conditions exceeds the number of affected patients.

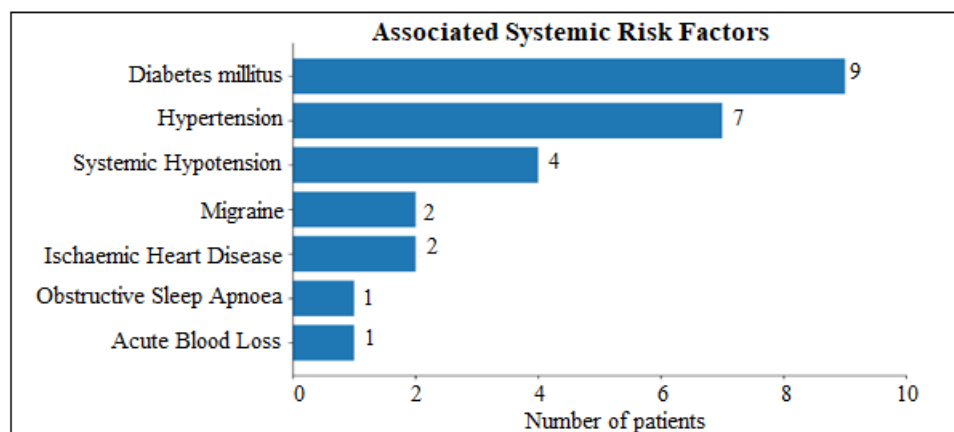


Figure 2: Distribution of associated systemic risk factors. Diabetes mellitus was the most common systemic comorbidity, followed by hypertension.

Cup-to-disc ratio

The cup-to-disc ratio was **0.9 in 11 eyes (14.47%)**, **0.8 in 24 eyes (31.58%)**, **0.7 in 23 eyes (30.26%)**, **0.6 in 16 eyes (21.05%)**, and **0.5 in 2 eyes (2.63%)**.

A cup-to-disc ratio of **0.7 or greater** was observed in **58 eyes (76.32%)**, indicating that most eyes had moderate-to-advanced glaucomatous optic disc cupping.

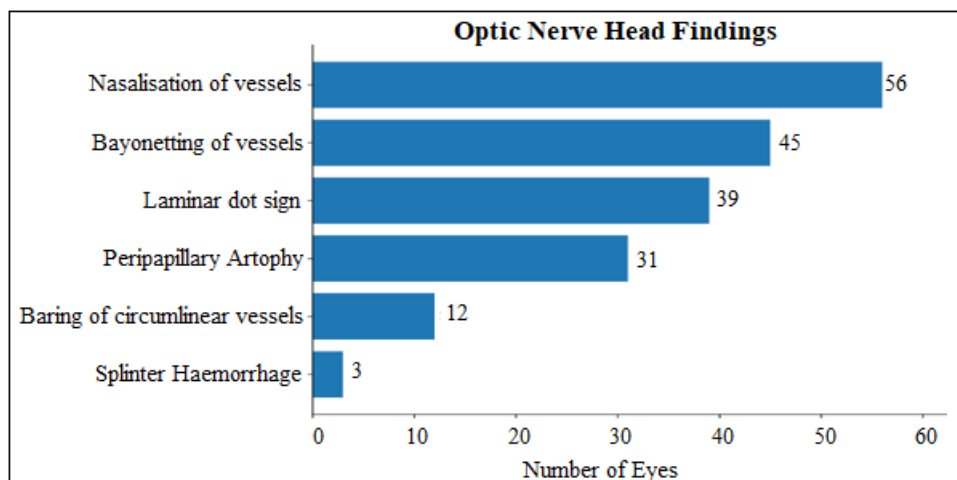
Table 4: Optic nerve head findings in the study population

Optic nerve head finding	Number of eyes	Percentage
Nasalisation of vessels	56	73.68%
Bayonetting of vessels	45	59.21%
Laminar dot sign	39	51.32%
Baring of circumlinear vessels	12	15.79%
Splinter haemorrhage	3	3.95%
Peripapillary atrophy	31	40.79%

Multiple optic nerve head findings could occur in the same eye.

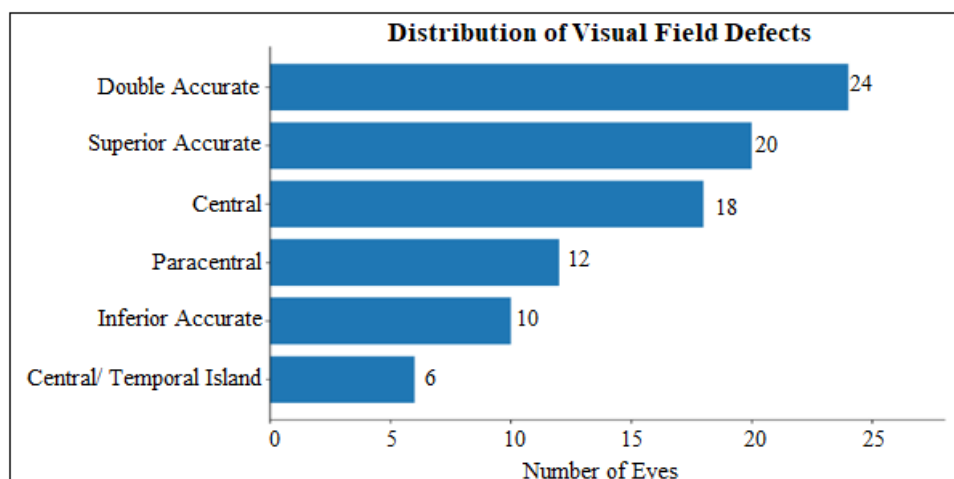
Nasalisation of blood vessels was the most frequent optic nerve head finding, occurring in **56 eyes (73.68%)**, followed by bayonetting in **45 eyes (59.21%)** and laminar dot sign in **39 eyes (51.32%)**.

Peripapillary atrophy was present in **31 eyes (40.79%)**. Splinter haemorrhage was comparatively uncommon and was observed in only **3 eyes (3.95%)**. Localised neuroretinal rim thinning and notching were frequently noted in eyes with advanced cupping.

**Figure 3:** Frequency of optic nerve head findings. Nasalisation of retinal vessels was the predominant optic disc finding, followed by bayonetting and laminar dot sign.**Table 5: Distribution of visual-field defects**

Visual-field defect	Number of eyes	Percentage
Superior arcuate scotoma	20	26.32%
Inferior arcuate scotoma	10	13.16%
Paracentral scotoma	12	15.79%
Double arcuate scotoma	24	31.58%
Central scotoma	18	23.68%
Central and/or temporal island remaining	6	7.89%

Some eyes demonstrated more than one visual-field defect. Double arcuate scotoma was the most frequently observed visual-field defect and was present in **24 eyes (31.58%)**. It was followed by superior arcuate scotoma in **20 eyes (26.32%)** and central scotoma in **18 eyes (23.68%)**. Visual-field defects involving the central 10° of fixation, including central and paracentral scotomas, were observed in **30 eyes (39.47%)**. The defects were generally dense, localised and relatively close to fixation.

**Figure 4:** Distribution of visual field defects. Double arcuate scotoma was the most frequently observed visual field defect.

Retinal nerve fibre layer thickness

Peripapillary retinal nerve fibre layer thinning was observed in the **superior quadrant in 37 eyes (48.68%)**, **inferior quadrant in 47 eyes (61.84%)**, **nasal quadrant in 32 eyes**

(42.11%), and **temporal quadrant in 35 eyes (46.05%)**. The inferior quadrant was the most frequently affected RNFL quadrant.

Table 6: Association of RNFL quadrant thinning with visual-field defects

Visual-field defect	Superior RNFL thinning, n=37	Inferior RNFL thinning, n=47	Nasal RNFL thinning, n=32	Temporal RNFL thinning, n=35
Superior arcuate scotoma	–	20	5	5
Inferior arcuate scotoma	10	–	5	3
Double arcuate scotoma	18	19	8	6
Paracentral scotoma	3	3	6	7
Central scotoma	6	5	8	14
Total	37	47	32	35

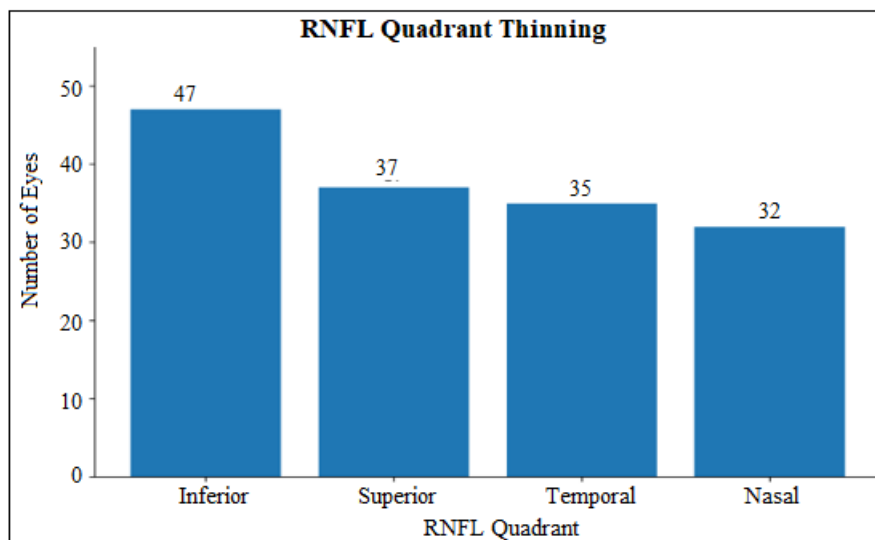
Among the 47 eyes with inferior RNFL thinning, **20 eyes had superior arcuate scotoma**, **19 had double arcuate scotoma**, **3 had paracentral scotoma**, and **5 had central scotoma**.

Among the 37 eyes with superior RNFL thinning, **10 eyes had inferior arcuate scotoma**, **18 had double arcuate scotoma**, **3 had paracentral scotoma**, and **6 had central scotoma**.

Of the 35 eyes with temporal RNFL thinning, central scotoma was the most frequent corresponding field defect, occurring

in **14 eyes**, followed by paracentral scotoma in **7 eyes**. Among the 32 eyes with nasal RNFL thinning, central and double arcuate scotomas were each observed in **8 eyes**.

Inferior RNFL thinning showed a significant association with superior arcuate or double arcuate field defects ($\chi^2=9.18$, $P=0.027$). Temporal RNFL thinning was significantly associated with central or paracentral visual-field involvement ($\chi^2=8.42$, $P=0.015$).

**Figure 5:** Distribution of RNFL quadrant thinning on OCT

Inferior RNFL thinning was the commonest OCT abnormality, indicating predominant inferior quadrant involvement.

The study population was predominantly male, and the largest proportion of patients belonged to the 51–60-year age group. More than half of the examined eyes had a central corneal thickness below 510 μm . Corrected intraocular pressure remained within the normal range in all eyes.

Advanced optic disc cupping was common, with **76.32% of eyes having a cup-to-disc ratio of at least 0.7**. Double arcuate scotoma was the most frequent visual-field defect, while inferior RNFL thinning was the most common OCT finding. Temporal RNFL thinning was predominantly associated with central and paracentral field defects.

4. Discussion

The present study evaluated the demographic profile, clinical characteristics, optic nerve head changes, visual field defects, and retinal nerve fibre layer (RNFL) alterations in patients with normal tension glaucoma (NTG). Similar to previous reports, NTG predominantly affected middle-aged and elderly individuals, with the highest frequency observed in the fifth and sixth decades of life. The mean age of our study population was 57.65 ± 9.76 years, and males constituted nearly two-thirds of the patients. **Shields et al.** described NTG as a disease commonly diagnosed in older adults because of its insidious course and delayed presentation.[2] Likewise, **Vijaya et al.** reported an increasing prevalence of open-angle glaucoma with advancing age in the Chennai Glaucoma Study, highlighting the importance of screening susceptible individuals.[5]

All patients had untreated intraocular pressure within the statistically normal range. Although office diurnal variation demonstrated a significant reduction in IOP during the afternoon, none exhibited ocular hypertension. These findings support the observations of **Shields et al.** and **Drance et al.**, who emphasized that repeated IOP measurements are essential before diagnosing NTG. [2,10] More than half of the eyes in the present study had a central corneal thickness below 510 μm . **Copt et al.** demonstrated that patients with NTG frequently have thinner corneas, resulting in underestimation of true IOP, while **Shih et al.** recommended routine pachymetry for accurate assessment of IOP in glaucoma suspects. [11,12]

Systemic vascular disorders were common in our patients, with diabetes mellitus and hypertension being the predominant comorbidities. Although a direct causal relationship remains uncertain, impaired ocular perfusion and vascular dysregulation have been strongly implicated in NTG. **Flammer et al.** proposed that reduced ocular blood flow and endothelial dysfunction contribute significantly to optic nerve damage,[7] while **Flammer and Mozaffarieh** further emphasized oxidative stress and vascular dysregulation as central mechanisms in disease progression.[8] **Weinreb and Khaw** also suggested that glaucomatous optic neuropathy results from a complex interaction between vascular and biomechanical factors.[9] More recently, **Siesky et al.** highlighted the growing evidence supporting ocular perfusion abnormalities and systemic vascular dysfunction in NTG pathogenesis.[19]

Advanced optic disc cupping was observed in the majority of eyes, with more than three-fourths demonstrating a cup-to-disc ratio ≥ 0.7 . Nasalisation of retinal vessels, bayonetting and laminar dot sign were the predominant optic nerve head findings. Similar observations were reported by **Caprioli et al.**, who found that NTG is characterised by focal neuroretinal rim thinning and localized optic disc damage despite normal IOP.[15] Disc haemorrhages were relatively infrequent in our study but remain an important predictor of disease progression in NTG.

Visual field assessment revealed **double arcuate scotoma** as the commonest defect, followed by superior arcuate and central scotomas. Nearly 40% of eyes demonstrated central or paracentral involvement, reflecting the characteristic tendency of NTG to affect fixation early. Comparable findings were described by **Hitchings et al.** and **Levene**, who reported deeper, localized visual field defects occurring closer to fixation in NTG than in high-tension glaucoma. [16,17] Recent recommendations from the **European Glaucoma Society** also recognise paracentral defects as an important clinical feature of NTG requiring careful surveillance.[20]

Optical coherence tomography demonstrated predominant **inferior RNFL thinning**, followed by superior and temporal quadrant involvement. Inferior RNFL loss showed a significant association with superior arcuate and double arcuate field defects, while temporal RNFL thinning correlated with central and paracentral scotomas. These findings support the structure–function relationship described by **Hood and Kardon**,[13] **Leung et al.**, [14] and **Yum et al.**, [18] who demonstrated that OCT-derived RNFL thinning closely parallels glaucomatous visual field loss. Recent

advances in OCT and OCT angiography have further improved the detection of early structural damage before clinically significant functional deterioration becomes evident.

The present study provides a comprehensive clinical and structural evaluation of NTG in an Indian tertiary care setting. However, the relatively small sample size, single-centre design and cross-sectional methodology limit the generalisability of the findings. Prospective multicentre studies with larger cohorts and incorporation of OCT angiography and ocular perfusion parameters are warranted to improve understanding of disease progression and facilitate earlier diagnosis.

5. Conclusion

Normal tension glaucoma is a clinically significant form of glaucoma that can cause substantial structural and functional optic nerve damage despite intraocular pressure remaining within the normal range. A comprehensive evaluation incorporating diurnal intraocular pressure assessment, central corneal thickness measurement, detailed optic nerve head examination, automated perimetry, and optical coherence tomography is essential for accurate diagnosis. The present study demonstrated that advanced optic disc cupping, characteristic visual field defects, and inferior retinal nerve fibre layer thinning are common features of NTG, with significant structure–function correlation. Early recognition of these findings and identification of associated systemic vascular risk factors may facilitate timely intervention and help preserve visual function in affected patients.

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