Association of Central Macular Thickness with Severity of Diabetic Retinopathy: An Optical Cohorence Based-Cross Sectional Study

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Abstract

Background: Diabetic retinopathy (DR) is a leading cause of preventable blindness, with macular involvement being the primary determinant of visual impairment. Optical coherence tomography (OCT) provides an objective, non-invasive method for evaluating central macular thickness (CMT) and detecting early macular changes.

Aim: To assess changes in central macular thickness in diabetics with different stages of diabetic retinopathy using optical coherence tomography.

Materials and Methods: This cross-sectional observational study was conducted over a period of 18 months. A total of 114 patients were evaluated. Comprehensive ophthalmic examination, best-corrected visual acuity (BCVA), fundus evaluation, and OCT-based CMT measurement were performed. Diabetic retinopathy was staged as mild, moderate, severe non-proliferative diabetic retinopathy (NPDR) and proliferative diabetic retinopathy (PDR). Statistical analysis included one-way ANOVA and chi-square tests.

Results: The mean CMT showed a progressive increase with severity of diabetic retinopathy: mild NPDR (240.2 ± 20.2 µm), moderate NPDR (277.2 ± 8.8 µm), severe NPDR (308.7 ± 5.9 µm), and PDR (308.8 ± 19.4 µm), which was statistically significant ($p < 0.001$). Diabetic macular edema was significantly associated with advanced stages of DR ($p < 0.001$). Higher CMT values were observed with increasing age, poor glycemic control, and male gender.

Conclusion: Central macular thickness increases significantly with advancing stages of diabetic retinopathy. OCT-measured CMT is a reliable and objective parameter for early detection and assessment of macular involvement, facilitating timely intervention and prevention of vision loss.

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Introduction

Diabetes Mellitus is a Chronic metabolic condition, which is then characterized by the sustained elevation of the blood sugar level because of the defects in the insulin secretion, insulin action, or both.[1]

It is also now considered one of the most widespread non-communicable diseases in the world, with millions of people affected and has become a significant health issue of the population, with severe long-term effects on the eyes, kidneys, heart, nerves and blood vessels. These complications rank among the leading causes of morbidity, poor quality of life, and high cost of healthcare. [2]

It is a well known fact that common and severe ocular complications of diabetes, diabetic retinopathy is a major cause of avoidable adult blindness. It is a progressive disease that is caused by the destruction of the retinal microvasculature due to long- term hyperglycemia. [3]

Depending on the severity, the disease Diabetic retinopathy is then further divided into two phases non-proliferative and proliferative phases, with the initial ones characterized by microaneurysms, hemorrhages, and exudates, whereas the other ones are characterized by abnormal new blood vessels formation, which may result in different forms such as vitreous hemorrhage and retinal detachment. The risk and severity of diabetic retinopathy have a close relationship with the duration of the diabetes, the poor glycemic control, the hypertension, and other systemic factors. [4]

Diabetic macular edema(DME) is one of the major causes of visual impairment in diabetic retinopathy, and it is caused by hyper vascular permeability and loss of the blood-retinal barrier. [5] The retina thickens and distressed foveal architecture, which are caused by fluid retention in the macula and therefore central vision is generally affected at any stage of diabetic retinopathy and might even precede the appearance of clinically evident edema. These structural changes, which happen early on, usually come before the onset of visual symptoms and hence early detection is critical in averting long-term visual impairment. [6] The optical coherence tomography (OCT) has turned out to be a critical instrument in the assessment of diabetic retinal disease. It is an imaging procedure that is non-invasive and offers retina images with high clarity in cross-sectional mode and enables measurement of the retinal layers and macular thickness to be done accurately. [7] "OCT does not involve dye injection like fluorescein angiography and can be safely repeated in the follow-up. It allows early detection of subtle changes in the macula that mightnot be apparent to the clinical examination, thus leading to timely intervention. [8] Central macular thickness measured by OCT offers an objective and reproducible measurement of diabetic retinopathy macular involvement. The visual acuity can be influenced by even slight changes in central macular thickness. [9] Macular thickness assessment can be conducted simultaneously as the disease advances, to assess the response to the treatment, and the management decisions. It is also a valuable indicator to help establish patients who are more likely to have visual impairment. [10]

Despite the widespread use of OCT in assessing diabetic retinal changes, the association between CMT and the severity of diabetic retinopathy remains unclear.Slight thickening of the macula may occur before diabetic macular edema is clinically visible,making it a possible early marker of retinal changes. Early assessment of these changes across different stages of diabetic retinopathy may improve understanding of disease progression, facilitate early identification of eyes at risk of visual loss and facilitate early treatment. Therefore, our study was carried out to analyze and compare central macular thickness among patients with different stages of diabetic retinopathy using spectral-domain OCT and to determine its association with the severity of diabetic retinopathy.

Materials and Methods

Study Design and Setting

A cross-sectional observational study was conducted for a total number of 114 patients diagnosed with diabetes mellitus and diabetic retinopathy over a period of eighteen months in a tertiary care hospital.

Inclusion Criteria

- Patients with diabetes mellitus and diabetic retinopathy
- Patients who provided informed consent

Exclusion Criteria

- Non-diabetic patients
- History of ocular trauma
- Previous retinal pathology or retinal surgery
- Coexisting hypertension

Ethical Considerations

Ethical approval was obtained from the Institutional Ethics Committee prior to commencement of the study(IEC approval no.SU/R/2024/1833). Written informed consent was obtained from all participants. The study adhered to the Declaration of Helsinki.

Statistical Analysis

The data were created in Microsoft Excel and analyzed with the help of the correct statistical software. Nominal variables were presented in form of frequencies and percentages. Continuous variables were given in terms of mean standard deviation. The tests were done statistically as needed and the p-value less than 0.05 was taken to be statistically significant.

Data Collection

After obtaining data informed consent,detailed were collected using a pre-designed proforma.

Clinical evaluation

A detailed and structured clinical history was obtained from each patient after securing informed written consent.Demographic details including age,gender,residence and occupation were recorded for all patients.Each patient was subjected to detailed history and a clear medical history in terms of type of diabetes mellitus,duration of diabetes,blood sugar levels and current treatment followed by external ocular examination,resolution of vision for near and distance by using snellen's chart, anterior segment examination was done by slit lamp (SN 1509220260, Appasamy Associates, Chennai, India),intraocular pressure measurement was done by Goldmann's applanation tonometer.Posterior segment examination was done by direct ophthalmoscopy(heines direct ophthalmoscope) and indirect ophthalmoscopy(by volk 90D lens and appasamy indirect ophthalmoscope using volk 20D lens) and measurement of CMT was done by OCT examination(APPA OCT 2019 AMBATUR CHENNAI).

Results

A total of 114 patients with diabetic retinopathy were enrolled in the study. Of these, all were evaluated for staging of diabetic retinopathy and macular thickness analysis using optical coherence tomography.

Table 1 summarizes the demographic profile of the study participants. The majority of patients belonged to the 51–60 years age group (36.8%), followed by 41–50 years (32.5%). Patients aged 61–70 years constituted 21.9%, while the least number of patients were observed in the 31–40 years age

group (8.8%). With respect to gender distribution, males accounted for 54.4% of cases and females for 45.6%, indicating a slight male predominance in the study population.

Table 1: Demographic Profile of Study Participants (n = 114)

Variable	Category	Number	Percentage (%)
Age (years)	31–40	10	8.8
	41–50	37	32.5
	51–60	42	36.8
	61–70	25	21.9
Gender	Male	62	54.4
	Female	52	45.6

The distribution of eyes according to the stage of diabetic retinopathy is shown in Table 2. Mild non-proliferative diabetic retinopathy (NPDR) was the most frequently observed stage, accounting for 39.5% of eyes, followed by proliferative diabetic retinopathy (PDR) in 29.8%. Moderate NPDR was seen in 17.5% of eyes, while severe NPDR constituted the least proportion 13.2%. This distribution indicates a predominance of early-stage disease, although a substantial number of eyes had advanced diabetic retinopathy.

Table 2: Distribution of Eyes According to Stage of Diabetic Retinopathy (n = 114 patients)

Stage of Diabetic Retinopathy	Number of patients	Percentage (%)
Mild NPDR	45	39.5
Moderate NPDR	20	17.5
Severe NPDR	15	13.2
PDR	34	29.8
Total	114	100

Table 3 depicts the variation in mean central macular thickness (CMT) across different stages of diabetic retinopathy. The mean CMT was lowest in mild NPDR (240.2 ± 20.2 µm) and showed a progressive increase with disease severity. Eyes with moderate NPDR had a mean CMT of 277.2 ± 8.8 µm, while those with severe NPDR demonstrated a further increase to 308.7 ± 5.9 µm. The highest mean CMT was observed in PDR (308.8 ± 19.4 µm). This increasing trend was found to be highly statistically significant ($p < 0.001$) on one-way ANOVA, indicating a strong association between macular thickness and severity of diabetic retinopathy.

Table 3: Mean Central Macular Thickness (CMT) in Different Stages of Diabetic Retinopathy

Stage of DR	Mean CMT (µm) ± SD	Statistical Test	p-value
Mild NPDR	240.2 ± 20.2	One-way ANOVA	< 0.001 (Highly Significant)
Moderate NPDR	277.2 ± 8.8		
Severe NPDR	308.7 ± 5.9		
PDR	308.8 ± 19.4		

The association between diabetic macular edema (DME) and severity of diabetic retinopathy is illustrated in Table 4. DME was absent in all eyes with mild and moderate NPDR. In contrast, 92.3% of eyes with severe NPDR and 76.7% of eyes with PDR showed the presence of DME. The association between DME and severity of diabetic retinopathy was found to be highly statistically significant ($\chi^2 = 77.56$, $p < 0.001$), demonstrating that DME predominantly occurs in advanced stages of the disease.

Table 4: Association of Diabetic Macular Edema (DME) with Severity of Diabetic Retinopathy

Stage of DR	DME Absent	DME Present	Chi-square (χ^2)
Mild NPDR	45	0	χ^2=77.56 p-value: < 0.001
Moderate NPDR	18	0	
Severe NPDR	1	12	
PDR	7	23	

Table 5 shows the relationship between central macular thickness and selected clinical variables including age, gender, and best-corrected visual acuity (BCVA). Mean CMT increased progressively with advancing age, from 246.3 µm in the 31–40 years group to 293.1 µm in the 61–70 years group, indicating greater macular involvement in older patients. With respect to gender, males had a significantly higher mean CMT (276.2 ± 35.3 µm) compared to females (261.8 ± 40.3 µm), and this difference was statistically significant ($p = 0.048$).

Table 5: Association of Central Macular Thickness with Age, Gender, and Visual Acuity

Variable	Category	Mean CMT (µm) ± SD	p-value
Age (years)	31–40	246.3	
	41–50	260.1	
	51–60	269.7	
	61–70	293.1	
Gender	Male	276.2 ± 35.3	0.048
	Female	261.8 ± 40.3	
BCVA (Snellen)	6/6 – 6/9	287.8 ± 31.2	0.373
	6/12 – 6/18	286.8 ± 16.2	
	6/24 – 6/36	299.8 ± 28.9	

When CMT was analyzed in relation to BCVA, eyes with poorer visual acuity showed relatively higher mean CMT values; however, the association between BCVA and mean CMT was not statistically significant (p = 0.373). This suggests that although increased macular thickness tends to be associated with reduced vision, visual acuity is influenced by multiple retinal factors beyond central macular thickness alone.

Discussion

Diabetic retinopathy (DR) is a chronic, progressive microvascular complication of diabetes mellitus and remains a major cause of visual impairment among adults worldwide. With the rising prevalence of diabetes, especially in developing countries, the burden of diabetic eye disease continues to increase. Among the various manifestations of diabetic retinopathy, macular involvement plays a critical role in determining visual prognosis. Optical coherence tomography (OCT) has emerged as a highly sensitive, non-invasive, and reproducible imaging modality that enables objective evaluation of macular structure and quantitative assessment of central macular thickness (CMT). [1]

The present study was undertaken to evaluate changes in central macular thickness across different stages of diabetic retinopathy using OCT and to assess its association with age, gender, glycemic status, diabetic macular edema (DME), and best-corrected visual acuity (BCVA).

In the present study, the age of patients ranged from 31 to 70 years, with the majority belonging to the 51–60 years age group. This age distribution is comparable to that reported by McKay *et al.* [2], Hautala *et al.* [3], and Tyagi and Chander [1], who observed a higher prevalence of diabetic retinopathy in the fifth and sixth decades of life. Increasing age and longer duration of diabetes contribute to cumulative microvascular damage, resulting in progressive retinal ischemia and macular involvement.

A slight male predominance was observed, similar to findings reported by Goebel *et al.* [4] and Tyagi and Chander[1]. This may be attributed to a higher prevalence of diabetes among males, greater exposure to lifestyle-related risk factors, and differences in healthcare-seeking behavior. However, gender-related differences in diabetic retinopathy remain inconsistent across studies.

With regard to disease severity, mild non-proliferative diabetic retinopathy was the most common stage observed, followed by proliferative diabetic retinopathy. This distribution is comparable to findings reported by Tyagi and Chander[1] and Lattanzio *et al.* [5]. The relatively high proportion of proliferative disease in the present study highlights delayed presentation or inadequate glycemic control in a subset of patients, emphasizing the need for regular screening and early intervention.

A significant finding of the present study was the progressive increase in central macular thickness with advancing stages of diabetic retinopathy. Mean CMT increased significantly from mild NPDR to moderate NPDR and further in severe NPDR and PDR. These findings are in strong agreement with those reported by Lattanzio *et al.* [5], Sánchez-Tocino *et al.* [6], and Pradhan *et al.* [17], all of whom demonstrated maximum macular thickness in advanced stages of the disease. This increase reflects breakdown of the blood–retinal barrier, increased vascular permeability, and accumulation of intraretinal fluid.

Diabetic macular edema was absent in mild and moderate NPDR but was predominantly observed in severe NPDR and PDR. This strong association between DME and disease severity is consistent with observations reported by Yang *et al.* [7], Goebel *et al.* [4], and Virgili *et al.* [8], further emphasizing the role of OCT in early detection of macular edema.

Poor glycemic control was common among study participants, and previous studies by Jamaiyar *et al.* [9] and Fu *et al.*[10] have established a strong relationship between chronic hyperglycemia and macular thickening. Persistent hyperglycemia leads to oxidative stress, endothelial dysfunction, and increased vascular permeability, contributing to retinal thickening and edema.

Although mean CMT showed a tendency to increase with worsening BCVA, the association was not statistically significant, similar to findings reported by Browning *et al.* [11] and Bong *et al.* [12]. This suggests that visual acuity is influenced by multiple retinal factors beyond macular thickness alone.

Mean CMT increased progressively with advancing age and was significantly higher in males compared to females. Eyes with higher CMT values were predominantly associated with severe NPDR and PDR. These observations are comparable with those reported by Tyagi and Chander[1], Pokhrel *et al.* [16], and Pradhan *et al.* [17].

Overall, the present study demonstrates that central macular thickness increases progressively with advancing stages of diabetic retinopathy and is strongly associated with diabetic macular edema, age, gender, and glycemic status. These findings reinforce the role of OCT as a sensitive, objective, and reproducible tool for early detection, monitoring, and management of macular involvement in diabetic retinopathy. [13]

Conclusion

The present study demonstrates that central macular thickness increases progressively with advancing stages of diabetic retinopathy. Optical coherence tomography provides an objective and reliable method for detecting macular involvement and quantifying central macular thickness

across different stages of the disease. Increased central macular thickness was strongly associated with advanced stages of diabetic retinopathy and the presence of diabetic macular edema, and showed significant associations with age, gender, and glycemic status. Although a trend toward increased macular thickness was observed with worsening visual acuity, this relationship was not statistically significant, indicating that visual function is influenced by multiple retinal factors beyond macular thickness alone. Routine OCT evaluation in diabetic patients can facilitate early detection of macular changes, enable timely intervention, and help prevent vision-threatening complications associated with diabetic retinopathy.

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