

Assessment of Macular Thickness Changes in Diabetic Patients: A Cross-sectional Study

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Background:

The macula is essential for central vision, and its thickness can be affected by diabetes mellitus, leading to complications such as macular edema and progressive vision loss.

Objective:

To evaluate changes in macular thickness among diabetic patients compared with age-matched non-diabetic controls.

Methodology:

This cross-sectional study included 89 participants (178 eyes), comprising 45 diabetic and 44 non-diabetic individuals aged 40–70 years. Participants with cataract, glaucoma, or prior ocular surgery were excluded. All underwent detailed ophthalmic examination and macular thickness measurement using optical coherence tomography (OCT).

Results:

Diabetic patients showed significantly higher central and perifoveal macular thickness than non-diabetic controls in most quadrants ($p < 0.05$). Mean central macular thickness was $264.57 \pm 66.61 \mu\text{m}$ in the right eye and $243.90 \pm 44.88 \mu\text{m}$ in the left eye among diabetics. Macular thickness positively correlated with HbA1c, duration of diabetes, and blood pressure.

Conclusion:

Diabetic patients exhibited increased macular thickness compared with non-diabetic controls, indicating early subclinical retinal changes even before the development of clinical diabetic retinopathy. OCT can serve as a useful screening tool for early retinal structural alterations in diabetes.

Keywords: Diabetes Mellitus; Optical Coherence Tomography; Macular Thickness; Retinopathy

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Introduction

Chronic hyperglycemia is associated with progressive organ damage, dysfunction, and failure [1]. Among patients with diabetic retinopathy, diabetic maculopathy is one of the most common complications [2]. Diabetic retinopathy is characterized by macular edema, retinal ischemia, and increased retinal vascular

permeability, resulting in central vision loss due to microvascular dysfunction [3]. Optical coherence tomography (OCT), with a longitudinal resolution of approximately 10 microns, is a reliable diagnostic tool for assessing disease severity and monitoring progression [4,5].

Multiple factors are associated with retinal changes in individuals with type 2 diabetes mellitus (T2DM), including the duration of diabetes, obesity, intraocular pressure (IOP), glycated hemoglobin (HbA1c), hypertension, and microalbuminuria [6,7]. A Chinese study also demonstrated that alcohol consumption is



associated with thinning of the retinal nerve fiber layer (RNFL) and macula [8]. Furthermore, a UK Biobank-based study reported that age-related macular degeneration (AMD) risk alleles (e.g., *rs3138141* near *RDH5* and *rs10922109* in *CFH*) are linked to variations in outer retinal layer thickness, suggesting a genetic contribution to retinal structure even in the absence of clinical disease [9].

A case report described a patient with liver cirrhosis who experienced unexpected visual decline due to reticular pseudodrusen deposits, which improved following vitamin A supplementation [10]. A prospective randomized controlled trial reported improvement in RNFL thickness following intravitreal Avastin injections, both with and without posterior sub-Tenon triamcinolone; however, the difference between the two groups was not statistically significant at follow-up [11]. Similarly, a quasi-experimental study revealed that mean RNFL thickness increased postoperatively in the superior and nasal quadrants but decreased in the inferior and temporal quadrants after peeling of the epiretinal membrane (ERM); these changes persisted for up to six months [12].

Traditionally, diabetic retinopathy has been considered a microvascular retinal disorder leading to gradual central vision loss due to macular edema, maculopathy, and neuronal cell death. To better understand early structural retinal changes before clinical maculopathy develops, this study included diabetic patients with clinically normal maculae. The aim was to determine changes in macular thickness among diabetic patients with and without comorbidities.

Methodology

Study Design and Setting

This cross-sectional study was conducted at the Eye Outpatient Department (OPD) of Shalamar Hospital, Lahore, from July 1 to December 15, 2023.

Sample Size Calculation

The sample size was calculated using G*Power version 3.1.9.7 (Heinrich Heine University, Düsseldorf, Germany) for the comparison of two independent means (two-tailed t-test). The parameters included a 95% confidence level ($\alpha = 0.05$), 80% power ($1-\beta = 0.80$), an expected mean difference of 30 μm in central macular thickness between diabetic and non-diabetic eyes, and a standard deviation of 45 μm based on previous OCT-based studies [13-15]. The calculated minimum required sample size was 40 eyes per group. To account for potential data loss and poor-quality OCT scans, the sample size was increased by 10%, resulting in a final total of 89 participants (178 eyes).

Sampling and Study Population

Participants were selected using purposive sampling. A total of 89 subjects were enrolled, comprising 45 diabetic and 44 non-diabetic individuals aged 40 to 70 years.

Eligibility Criteria

Inclusion criteria:

- ❖ Patients diagnosed with diabetes mellitus for five years or more (diabetic group)
- ❖ Non-diabetic individuals within the same age range serving as controls

Exclusion criteria:

- ❖ Presence or history of cataract or cataract surgery
- ❖ Diagnosis of glaucoma or any other ocular pathology
- ❖ History of previous ocular laser treatment

Data Collection Tools and Procedure

The following instruments were used for examination and data collection: pen torch, autorefractometer, LogMAR visual acuity chart, slit-lamp biomicroscope, and optical coherence tomography (OCT).

Eligible participants were enrolled after obtaining written informed consent. Each subject underwent a comprehensive ocular examination, including anterior segment evaluation, fundus

examination with a slit-lamp biomicroscope, and OCT scanning to assess macular thickness.

Outcome Measures

The primary outcome included:

- ❖ Difference in central macular thickness (CMT) between diabetic and non-diabetic groups.

Secondary outcomes included:

- ❖ Evaluation of perifoveal macular thickness changes
- ❖ Assessment of associations between macular thickness and clinical variables such as age, gender, and duration of diabetes

Ethical Considerations

The study was conducted in accordance with the Declaration of Helsinki. Ethical approval was obtained from the Institutional Review Board (IRB) of Shalamar Medical and Dental College, Lahore. Written informed consent was obtained from all participants prior to enrollment, and data confidentiality was maintained throughout the study.

Data Analysis

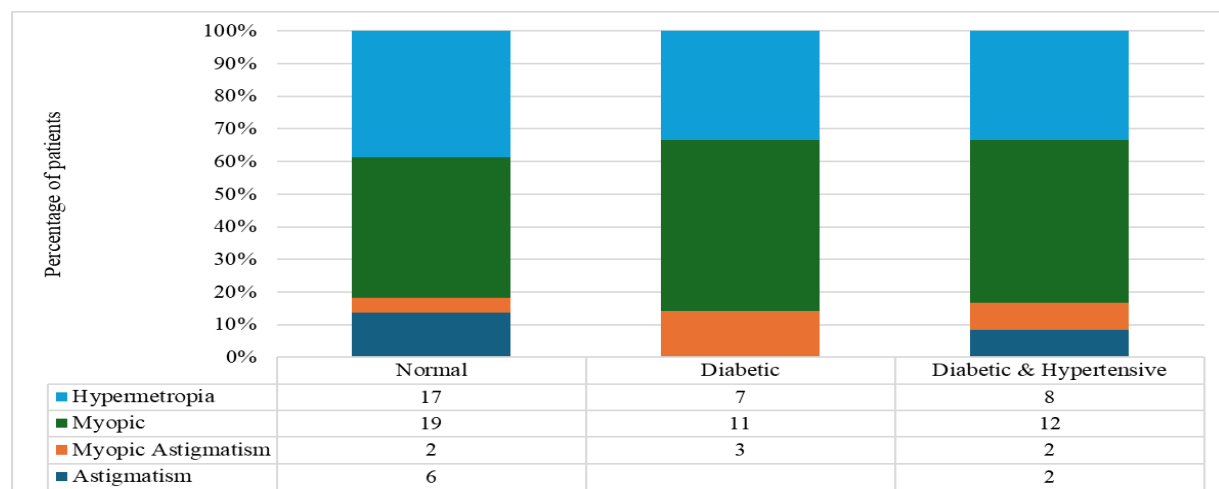
Data were analyzed using SPSS version 25 (IBM Corp., Armonk, NY, USA). Quantitative variables were presented as mean $\pm$ standard deviation (SD), while categorical variables were summarized as frequencies and percentages. The independent samples t-test was applied to compare mean macular thickness values between groups. The Pearson correlation coefficient was used to assess the strength and direction of linear relationships between continuous variables. The Chi-square test was applied to evaluate associations between categorical variables. A p-value ≤ 0.05 was considered statistically significant.

Results

A total of 89 patients were included in the study, comprising 42 males (47.2%) and 47 females (52.8%). The mean age of male participants was 57.36 ± 7.01 years, while that of females was 57.40 ± 8.23 years, showing no statistically significant difference between the two groups ($p = 0.977$).

Regarding refractive status, 8 patients (9.0%) had astigmatism, 32 (36.0%) had hypermetropia, 42 (47.2%) were myopic, and 7 (7.9%) presented with myopic astigmatism (Figure 1).

Figure 1: Comparison of diabetic status and types of refractive errors among study participants.



Macular Thickness Measurements (Right Eye)

In the right eye, the mean central macular thickness (CMT) was $238.90 \pm 62.03 \mu\text{m}$. The mean inner superior quadrant thickness was $285.03 \pm 56.48 \mu\text{m}$, and the outer superior quadrant was $262.40 \pm 51.16 \mu\text{m}$. The inner inferior quadrant measured $282.82 \pm 57.52 \mu\text{m}$, and the outer inferior quadrant $247.31 \pm 56.80 \mu\text{m}$. The inner nasal quadrant had a thickness of $311.96 \pm 81.90 \mu\text{m}$, while the outer nasal quadrant measured $269.82 \pm 52.41 \mu\text{m}$. The inner temporal and outer temporal quadrants had mean values of $276.43 \pm 49.68 \mu\text{m}$ and $245.25 \pm 44.35 \mu\text{m}$, respectively.

The differences in mean thickness between diabetic and non-diabetic groups were statistically significant for the central macula ($p = 0.017$), inner superior ($p < 0.001$), outer superior ($p < 0.001$), inner inferior ($p < 0.001$), outer inferior ($p < 0.001$), outer nasal ($p < 0.001$), inner temporal ($p < 0.001$), and outer temporal ($p < 0.001$) quadrants. However, the difference in the inner nasal quadrant was not statistically significant ($p = 0.069$).

Macular Thickness Measurements (Left Eye)

In the left eye, the mean central macular thickness was $235.03 \pm 58.19 \mu\text{m}$. The mean inner and outer superior quadrants measured $278.39 \pm 53.64 \mu\text{m}$ and $258.58 \pm 44.27 \mu\text{m}$, respectively. The inner inferior quadrant had a thickness of $277.52 \pm 52.20 \mu\text{m}$, and the outer inferior quadrant $249.16 \pm 47.54 \mu\text{m}$. The inner nasal quadrant measured $278.49 \pm 55.37 \mu\text{m}$, while the outer nasal quadrant measured $264.29 \pm 53.08 \mu\text{m}$. The inner temporal and outer temporal quadrants measured $275.99 \pm 50.69 \mu\text{m}$ and $252.42 \pm 46.83 \mu\text{m}$, respectively.

Statistically significant differences were found between diabetic and non-diabetic groups for the inner superior ($p < 0.001$), outer superior ($p < 0.001$), inner inferior ($p < 0.001$), outer inferior ($p < 0.001$), inner nasal ($p = 0.002$), outer nasal ($p = 0.046$), inner temporal ($p < 0.001$), and outer temporal ($p < 0.001$) quadrants. However, central macular thickness did not differ significantly ($p = 0.237$).

Table 1: Comparison of Macular Thickness (μm) in Both Eyes According to Diabetic Status

Macular Thickness (μm)	Right Eye (OD)			Left Eye (OS)		
	Normal	Diabetic	Diabetic & Hypertensive	Normal	Diabetic	Diabetic & Hypertensive
Central	221.00 ± 10.92	264.57 ± 66.61	249.25 ± 96.50	224.45 ± 9.87	243.90 ± 44.88	246.67 ± 102.93
Superior (Inner)	253.32 ± 15.69	318.71 ± 52.61	313.71 ± 74.31	247.05 ± 11.26	308.67 ± 44.40	309.38 ± 73.06
Superior (Outer)	240.41 ± 10.61	287.00 ± 68.65	281.21 ± 62.13	237.86 ± 12.59	277.95 ± 46.63	279.63 ± 60.71
Inferior (Inner)	255.52 ± 14.80	309.81 ± 41.60	309.25 ± 89.01	250.75 ± 9.18	296.48 ± 26.82	310.00 ± 82.72
Inferior (Outer)	219.07 ± 16.41	273.67 ± 29.38	276.04 ± 89.82	219.61 ± 13.46	273.57 ± 35.65	281.96 ± 62.20
Nasal (Inner)	258.52 ± 12.53	430.62 ± 56.27	306.08 ± 86.85	257.66 ± 7.64	300.24 ± 59.33	297.67 ± 83.16
Nasal (Outer)	243.66 ± 19.22	286.76 ± 24.59	302.96 ± 81.80	250.27 ± 47.83	278.29 ± 49.00	277.75 ± 60.59
Temporal (Inner)	250.18 ± 11.27	310.19 ± 53.45	295.00 ± 63.27	249.09 ± 9.09	293.33 ± 25.52	310.13 ± 78.98
Temporal (Outer)	219.52 ± 13.20	274.38 ± 38.68	269.29 ± 56.86	218.23 ± 10.78	283.57 ± 32.80	285.46 ± 55.09



Correlation Analysis

Among patients with proliferative diabetic retinopathy (PDR), there was a weak inverse correlation between macular thickness and variables such as age, body mass index (BMI), HbA1c, blood pressure, and duration of diabetes.

In contrast, among pre-proliferative diabetic retinopathy (pre-PDR) patients, a strong direct correlation was observed between age and macular thickness in most quadrants, except for the inner inferior quadrant (OS), which showed an inverse relationship ($r = -0.897$).

BMI, HbA1c, blood pressure, and duration of diabetes were generally weakly and inversely related to macular thickness, except for blood pressure, which showed a direct correlation with the outer nasal quadrant (OS) ($r = 0.965$) and outer superior quadrant (OS) ($r = 0.836$).

Discussion

This study demonstrated that diabetic patients had greater central and perifoveal macular thickness than non-diabetic individuals, even in the absence of clinically detectable macular

edema. This suggests that diabetes causes early subclinical retinal changes that may precede the onset of diabetic retinopathy. We found that the duration of diabetes, HbA1c > 7%, and systemic parameters such as total cholesterol, triglycerides, and blood pressure were positively correlated with macular thickness, in agreement with previous research [4]. These results highlight the multifactorial nature of retinal structural changes in diabetes, where both metabolic and hemodynamic factors may contribute to macular edema pathogenesis. Optical coherence tomography (OCT) proved to be an effective tool for detecting subtle retinal changes before the appearance of clinical diabetic retinopathy. However, previous literature remains inconclusive some studies reported increased macular thickness [2], whereas others noted no difference or even thinning [5]. These discrepancies may be due to differences in ethnicity, imaging protocols, age distribution, and disease duration across studies.

To better contextualize our findings, Table 2 compares the results of the present study with previously published research on macular thickness measurements in diabetic patients using OCT-based techniques.

Table 2. Comparison of Present Study Findings with Published Literature

Study (Year)	Study Population / Method	Main Findings	Comparison with Present Study
Ezhilvendhan et al. (2021) [13]	Type 2 diabetic patients vs controls using SD-OCT	Increased central macular thickness in diabetics; nasal quadrant most affected	Similar trend our study also found higher macular thickness in diabetics, especially in nasal and superior quadrants.
Islam et al. (2016) [15]	Diabetic patients with macular edema assessed by OCT	Foveal thickness correlated with visual acuity; mean thickness 395 μm in edema group	Our mean values ($\approx 238\text{--}235 \mu\text{m}$) were lower, indicating early pre-edema structural change.
Wong et al. (2024) [16]	Compared OCT and OCTA acquisition modes in diabetics	No significant macular thickness difference across most ETDRS subfields	Our results differ significant quadrant-wise thickening seen in diabetics, suggesting true retinal alteration beyond measurement variability.
Kagmeni et al. (2020) [17]	Diabetics in Cameroon (OCT-based study)	Detected subclinical macular changes in 78.2% of diabetic eyes	Our cohort showed greater mean thickness, possibly due

			to comorbid hypertension and longer diabetes duration.
Murthy et al. (2023) [18]	Diabetic and non-diabetic cataract patients pre- & post-surgery (SD-OCT)	Progressive postoperative macular thickening in diabetics	Our study found baseline thickening even before surgery, reflecting chronic microvascular compromise.
Present Study (2025)	89 patients (diabetic vs non-diabetic) assessed via SD-OCT	Diabetic patients had significantly higher macular thickness across most quadrants; correlated with HbA1c and BP	Confirms early subclinical retinal changes in diabetics even without clinical retinopathy.

The collective evidence summarized in Table 2 reinforces the observation that diabetes leads to measurable retinal thickening even before clinical retinopathy develops. While previous studies varied in methodology and patient characteristics, most support the presence of early subclinical macular changes in diabetic individuals. Our findings further highlight the role of systemic factors particularly glycemic control and hypertension in influencing retinal morphology, underscoring the importance of early OCT-based screening and risk-factor management.

The main strength of this study lies in its inclusion of both diabetic and non-diabetic participants with comparable age distribution, allowing for direct comparison of macular morphology. The use of OCT provided objective and reproducible measurements of retinal thickness.

However, the study has several limitations. Being cross-sectional, it cannot establish causality between diabetes duration and retinal changes. The relatively small sample size and single-center design may limit generalizability. In addition, the study did not control lipid-lowering or antihypertensive medications, which might influence macular structure.

Future research should employ longitudinal designs to monitor macular thickness changes over time in diabetic patients. Including biochemical markers of oxidative stress and vascular dysfunction may also help clarify the mechanisms linking hyperglycemia to retinal changes. Larger multicenter studies are recommended to validate these findings and establish normative OCT data for the local population.

Conclusion

Macular thickness was significantly higher among diabetic patients compared with non-diabetic individuals, indicating early structural retinal changes even before the appearance of clinical diabetic retinopathy. Hypertension showed an inverse relationship with macular thickness, suggesting a complex vascular interplay. These findings support the use of OCT as a sensitive, non-invasive screening tool for early detection of diabetic retinal changes. Early identification and management of systemic risk factors could help prevent progression to vision-threatening stages of diabetic eye disease.

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