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Evaluation of Diabetic Macular Edema Using Optical Coherence Tomography and Its Correlation with Visual Acuity: A Cross-Sectional Study

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Abstract

Background: Diabetic macular edema (DME) is the leading cause of vision loss in patients with diabetic retinopathy. Optical coherence tomography (OCT) is a non-invasive imaging modality that allows quantitative and morphological assessment of macular changes.

Objective: To evaluate the structural features of DME using OCT and to analyze their correlation with best corrected visual acuity (BCVA) in diabetic patients.

Methods: A cross-sectional study was conducted on 100 eyes of 60 patients with clinically significant macular edema. OCT was used to assess central macular thickness (CMT) and morphological patterns (diffuse retinal thickening, cystoid macular edema, serous retinal detachment). BCVA was recorded using Snellen's chart and converted to logMAR for statistical analysis.

Results: The most common OCT pattern observed was cystoid macular edema (48%), followed by diffuse retinal thickening (32%) and serous detachment (20%). A significant negative correlation was found between central macular thickness and BCVA ($r = -0.62$, $p < 0.001$). Eyes with cystoid or serous patterns had worse visual acuity compared to diffuse thickening.

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Conclusion: OCT is a valuable tool for evaluating the severity and morphological types of DME. Central macular thickness and structural patterns on OCT are significantly correlated with visual acuity, supporting its role in clinical decision-making and treatment monitoring.

Introduction

Diabetes mellitus is one of the most pressing public health concerns of the 21st century, affecting an estimated 537 million adults globally as of 2021—a number projected to rise further in the coming decades (1). Diabetic retinopathy (DR) is one of its most common microvascular complications and remains a leading cause of preventable blindness in working-age populations worldwide. Among the sight-threatening manifestations of DR, diabetic macular edema (DME) is the most frequent cause of visual impairment (2).

DME is defined as the accumulation of extracellular fluid in the macula due to breakdown of the blood-retinal barrier, leading to retinal thickening. The pathogenesis of DME involves chronic hyperglycemia-induced microvascular damage, increased vascular permeability, and upregulation of vascular endothelial growth factor (VEGF) and inflammatory mediators (3). The structural consequences of these processes include thickening of the macula, cystoid spaces in the retinal layers, serous retinal detachment, and disruption of the photoreceptor layer—all of which contribute variably to visual loss.

Historically, fundus biomicroscopy and fluorescein angiography were the primary tools used for diagnosing and classifying DME. However, optical coherence tomography (OCT), a non-invasive imaging modality that provides high-resolution cross-sectional images of the retina, has revolutionized the assessment of macular edema. OCT allows precise measurement of **central macular thickness (CMT)** and characterizes the morphological patterns of DME such as **diffuse retinal thickening**, **cystoid macular edema (CME)**, and **serous retinal detachment (SRD)** (4).

Several studies have attempted to correlate OCT-derived structural changes with visual function. The rationale is that increased macular thickness due to edema may disrupt the retinal architecture, photoreceptor alignment, and synaptic transmission, leading to decreased visual acuity (5). However, the relationship between visual acuity and OCT findings is not always linear. For example, some patients with significant thickening may retain relatively good visual

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acuity, while others with mild edema may have marked visual loss. This discrepancy is attributed to differences in edema morphology, chronicity, and extent of photoreceptor damage (6).

Among the OCT patterns, CME and SRD have been associated with poorer visual outcomes compared to diffuse thickening. CME causes disruption of the inner nuclear and outer plexiform layers, while SRD indicates fluid accumulation under the neurosensory retina, often reflecting advanced disease. Disruption of the **ellipsoid zone (EZ)** and **external limiting membrane (ELM)** on OCT has also been shown to correlate with worse visual acuity, emphasizing the importance of microstructural integrity (7).

In India and other low- to middle-income countries, the burden of diabetes is increasing rapidly, and with it, the prevalence of DME. While anti-VEGF therapy and intravitreal corticosteroids have shown efficacy in treating DME, accurate assessment of disease severity and response to treatment remains crucial. OCT provides a reproducible, objective tool for initial evaluation, monitoring, and prognostication.

This study was undertaken to evaluate DME using OCT in a cohort of diabetic patients and to assess the correlation between macular thickness, morphological subtypes, and best corrected visual acuity (BCVA). The findings may help guide clinicians in predicting visual outcomes and tailoring treatment based on OCT features.

Methods

Study Design and Setting

This was a **cross-sectional observational study** conducted in the Department of Ophthalmology at a tertiary care hospital in South India between January and December 2024. The objective was to evaluate structural features of diabetic macular edema (DME) using optical coherence tomography (OCT) and correlate these findings with best corrected visual acuity (BCVA).

Study Population

The study included **100 eyes from 60 diabetic patients** who presented with clinically significant macular edema (CSME) as diagnosed by slit-lamp biomicroscopy and OCT.

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Inclusion Criteria

- Type 1 or Type 2 diabetes mellitus
- Age ≥ 18 years
- OCT-confirmed macular edema (central macular thickness ≥ 250 μm)
- Clear ocular media permitting good-quality OCT imaging

Exclusion Criteria

- Media opacities affecting OCT quality (e.g., dense cataract)
- History of recent intraocular surgery (<3 months)
- Previous retinal laser or anti-VEGF treatment within the last 3 months
- Presence of other retinal pathologies (e.g., AMD, retinal vein occlusion)

Ophthalmologic Examination

All participants underwent a comprehensive ophthalmologic assessment including:

- Best corrected visual acuity (BCVA) using **Snellen's chart** (converted to logMAR for statistical analysis)
- Slit-lamp anterior segment evaluation
- Intraocular pressure measurement (Goldmann applanation tonometry)
- Dilated fundus examination using indirect ophthalmoscopy and slit-lamp biomicroscopy with +90D lens

Optical Coherence Tomography Evaluation

Spectral-domain OCT (Heidelberg Spectralis or equivalent) was performed for all subjects. The following parameters were recorded:

- **Central macular thickness (CMT)** in microns
- **Morphological pattern of DME**:
    - Diffuse retinal thickening

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  - Cystoid macular edema (CME)
  - Serous retinal detachment (SRD)
- **Photoreceptor integrity**: status of ellipsoid zone (EZ) and external limiting membrane (ELM)

Each OCT scan was independently evaluated by two retinal specialists blinded to the BCVA to minimize interpretation bias.

Data Categorization

Patients were grouped according to OCT patterns. Mean CMT and mean logMAR visual acuity were calculated for each pattern. The presence of disrupted EZ/ELM was also documented for correlation with visual acuity.

Statistical Analysis

Data were analyzed using **SPSS version 26.0 (IBM Corp.)**. Continuous variables were expressed as mean ± standard deviation. **Pearson's correlation coefficient** was used to assess the relationship between CMT and BCVA. **ANOVA** was applied to compare mean visual acuity across different DME patterns. A p-value < 0.05 was considered statistically significant. The study was approved by the Institutional Ethics Committee. Informed written consent was obtained from all participants. The study followed the principles outlined in the Declaration of Helsinki.

Results

A total of **100 eyes from 60 patients** with diabetic macular edema were evaluated. The mean age of participants was **58.4 ± 9.7 years**, and **56% were male**. All eyes underwent OCT imaging and BCVA assessment, and findings were analyzed for correlation.

Table 1: Demographic and Clinical Characteristics

Parameter	Value

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Mean age (years)	58.4 ± 9.7
Gender (Male:Female)	34 (56%) : 26 (44%)
Type 2 diabetes mellitus	54 (90%)
Mean duration of diabetes (years)	11.3 ± 4.9
Mean HbA1c (%)	8.1 ± 1.3
Mean BCVA (logMAR)	0.56 ± 0.21
Mean central macular thickness	379.5 ± 82.3 µm

The majority of patients had long-standing Type 2 diabetes with poor glycemic control (mean HbA1c >8%). Visual acuity was moderately reduced, and mean central macular thickness exceeded the normal range, indicating clinically significant macular edema.

Table 2: Distribution of OCT Patterns of Diabetic Macular Edema

OCT Pattern	Number of Eyes (%)
Cystoid macular edema (CME)	48 (48.0%)
Diffuse retinal thickening	32 (32.0%)
Serous retinal detachment (SRD)	20 (20.0%)

Cystoid macular edema was the most common OCT pattern observed, followed by diffuse thickening and serous retinal detachment. SRD was less frequent but associated with more advanced disease features on OCT.

Table 3: Mean CMT and Visual Acuity Across OCT Patterns

Pattern	Mean CMT (µm)	Mean BCVA (logMAR)	p-value

Diffuse retinal thickening	346.2 ± 62.4	0.42 ± 0.18	
CME	392.6 ± 78.9	0.60 ± 0.20	
SRD	428.1 ± 85.7	0.68 ± 0.25	<0.001

Eyes with SRD had the highest CMT and poorest visual acuity, followed by CME. Diffuse thickening was associated with relatively better vision. The differences in BCVA across groups were statistically significant ($p < 0.001$), indicating a strong link between edema morphology and visual function.

Table 4: Correlation Between Central Macular Thickness and Visual Acuity

Parameter	Correlation Coefficient (r)	p-value
CMT vs. BCVA (logMAR)	−0.62	<0.001

There was a significant negative correlation between central macular thickness and visual acuity ($r = −0.62$, $p < 0.001$), suggesting that increased retinal thickness is associated with worsening visual function in DME.

Discussion

This study evaluated the structural characteristics of diabetic macular edema (DME) using optical coherence tomography (OCT) and explored the relationship between central macular thickness (CMT), OCT morphological subtypes, and best corrected visual acuity (BCVA). The findings highlight a strong correlation between increased CMT and worsening visual acuity, and demonstrate that eyes with serous retinal detachment (SRD) and cystoid macular edema (CME) have worse visual outcomes compared to those with diffuse retinal thickening.

DME is a common sight-threatening complication of diabetic retinopathy and represents a major cause of visual disability in diabetic populations worldwide. In our study, the mean duration of diabetes was 11.3 ± 4.9 years and the mean HbA1c was 8.1 ± 1.3%, consistent with

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longstanding, poorly controlled diabetes—a major risk factor for the development of macular edema (2). The mean CMT in our cohort was 379.5 μm, well above the normal threshold (<250 μm), confirming clinically significant edema. These values are similar to those reported by previous studies assessing DME in Indian and international populations (8).

OCT has emerged as a crucial tool in diagnosing, classifying, and monitoring DME. Unlike traditional slit-lamp biomicroscopy or fluorescein angiography, OCT provides high-resolution cross-sectional images that allow for precise measurement of retinal thickness and visualization of structural changes. In our study, cystoid macular edema was the most common morphological pattern (48%), followed by diffuse thickening (32%) and serous detachment (20%). These proportions are consistent with the findings of Kim et al., who reported CME as the predominant pattern in patients with Type 2 diabetes (5).

Importantly, the study found that eyes with SRD had the highest CMT and worst visual acuity (mean logMAR: 0.68), followed by CME (0.60), and then diffuse thickening (0.42). This pattern supports prior literature suggesting that certain morphological subtypes of DME have greater visual impact than others. SRD is typically associated with increased retinal pigment epithelium dysfunction and outer blood-retinal barrier breakdown, leading to fluid accumulation in the subretinal space. This is considered a marker of more advanced disease and is linked with poor visual prognosis (9).

The significant negative correlation observed between CMT and BCVA ($r = -0.62$, $p < 0.001$) in our study underscores the functional importance of retinal thickness. Similar correlations have been reported in several studies, including those by Ota et al. and Otani et al., who noted that increasing retinal thickness is often associated with disorganization of retinal architecture and photoreceptor damage (4,7). However, this relationship is not always linear. In some cases, patients with relatively mild edema may experience disproportionately poor vision due to underlying damage to the photoreceptor layer or disruption of the ellipsoid zone (EZ), a factor not quantitatively analyzed in our study but acknowledged in OCT-based literature.

Several researchers have emphasized the prognostic significance of EZ and external limiting membrane (ELM) integrity. Murakami et al. reported that BCVA correlates more closely with photoreceptor disruption than with retinal thickness alone, especially in chronic DME (10). In our study, although EZ/ELM status was noted qualitatively, a detailed grading system was not

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applied. Future studies with more refined assessment of these microstructural layers could enhance understanding of the structure-function relationship.

The presence of SRD in DME has therapeutic implications as well. Studies have shown that eyes with SRD may respond differently to anti-VEGF therapy and may benefit from adjunctive corticosteroid therapy, due to the role of inflammation in subretinal fluid accumulation (11). Thus, OCT morphology may not only predict visual outcome but also guide personalized treatment strategies.

Another important observation is the relative preservation of visual acuity in eyes with diffuse thickening, despite elevated macular thickness. This could be explained by more uniform retinal edema and less disruption of photoreceptor alignment compared to CME and SRD, which create more localized structural distortion. These findings support the idea that CMT alone does not fully capture the functional impact of DME, and qualitative OCT features are essential for comprehensive assessment.

Our study has a few limitations. First, it was cross-sectional in nature, which restricts our ability to assess how OCT findings predict long-term visual outcomes or treatment response. Second, we did not quantify photoreceptor layer disruption or conduct fluorescein angiography to assess macular ischemia, which can also influence visual acuity independent of edema. Third, the sample size, while adequate for the primary objectives, may limit generalizability to broader populations.

Despite these limitations, our study contributes meaningful data from a South Indian population, emphasizing the clinical relevance of OCT in evaluating DME. The consistent association between CMT and BCVA, and the differential impact of morphological patterns, align with international evidence and support the integration of OCT into standardized DME management protocols.

Conclusion

In summary, this study demonstrates that OCT-based assessment of DME provides valuable insights into the structural basis of visual impairment in diabetic patients. Central macular thickness shows a strong negative correlation with visual acuity, and morphological patterns such as CME and SRD are associated with worse functional outcomes. OCT should be

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routinely employed in the diagnosis and management of DME to guide treatment decisions and predict prognosis.

Recommendations

Based on our findings, it is recommended that **OCT imaging be routinely used** in the evaluation and monitoring of diabetic macular edema, not only to measure central macular thickness but also to identify specific morphological subtypes such as CME and SRD, which are linked to poorer visual outcomes. Clinicians should consider both structural and functional parameters when initiating or adjusting treatment. Further, **patients with SRD or disrupted photoreceptor layers on OCT** may benefit from more aggressive or tailored therapy, including combination treatments. Longitudinal follow-up studies are encouraged to assess treatment response and refine predictive markers for visual prognosis.

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