OCT ASSESSMENT OF MACULAR THICKNESS IN NON-PROLIFERATIVE DIABETIC RETINOPATHY IN RELATION TO GLYCOSYLATED HEMOGLOBIN

By

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ABSTRACT

Background: Diabetic retinopathy (DR), also known as diabetic eye disease, is a retinal damage that occurs due to diabetes. Blindness can be the end result of diabetic retinopathy.

Objective: To evaluate the relation of macular thickness to glycosylated hemoglobin in patients with non-proliferative diabetic retinopathy.

Patients and Methods: This study included 100 eyes of 100 patients with a diagnosis of type 2 DM. This was designed as an observational, cross-sectional and non-cohort study during the period from 6/2019 to 3/2020. One hundred eyes were divided into two equal groups: one group included diabetic patients with no diabetic retinopathy and the other group included diabetic patients with non-proliferative diabetic retinopathy. Patients were recruited from Retinal clinic in Al-Azhar University Hospital and asked to participate in this study.

Results: The results showed that non-proliferative diabetic retinopathy (NPDR) group and group of no DR were comparable as regard age, sex and best corrected visual acuity (BCVA). There was a statistically insignificant difference between group of no DR and NPDR group, but group of no DR had shorter duration of DM, lower HbA1c level, lower macular thickness in all of the 9 standard early treatment diabetic retinopathy study (ETDRS) subfields, lower total macular volume (TMV) than NPDR Group. The results showed that central subfield macular thickness (CST) is positively and significantly related to glycosylated hemoglobin (HbA1c) level in each group of no DR and NPDR, and that severity of DR stage was significantly increased with increased HbA1c levels. The results also showed that there's significant positive association between severity of DR stage and macular thickness in all of the nine standard ETDRS subfields. There was a positive significant relation between duration of DM and HbA1c level in type 2 diabetic patients, while there was no significant relation between duration of DM and macular thickness. The results also showed significant inverse relation between insulin use and HbA1c level, and significant inverse relation between insulin use and prevalence of DR in type 2 diabetic patients.

Conclusion: Increased incidence of DR, increased macular thickness and increased incidence of diabetic macular edema were associated with increased level of glycosylated hemoglobin in type II diabetic patients.

Keywords: Macular Thickness, Non-Proliferative Diabetic Retinopathy, Glycosylated Hemoglobin.

INTRODUCTION

Diabetic retinopathy (DR), also known as diabetic eye disease, is a retinal damage that occurs due to diabetes. Blindness can be the end result of diabetic retinopathy *(Hooper et al., 2012)*. Is a progressive disease predominantly affects the integrity of the microscopic vessels found in the retina. DR can be broadly divided into two clinical stages: non-proliferative diabetic retinopathy (NPDR) and proliferative diabetic retinopathy (PDR) *(Sohn et al., 2016)*.

In NPDR, hyperglycemia results in damage of capillaries walls causing microaneurysms that eventually rupture to form dot and blot hemorrhages. The weakened vessels also become leaky causing macular edema. Resolution of fluid can leave behind yellow sediment of lipid byproducts called hard exudates. As NPDR progresses, obstruction of affected vessesls may cause infarction of the nerve fiber layer resulting in fluffy white patches called cotton wool spots (CWS) *(Wani et al., 2010)*.

While the effects of neovascularization in PDR can be devastating, the most common cause of vision loss in diabetics is macular edema. Macular edema can occur in NPDR, but it is more common in more severe cases of DR due to the leakiness of the new blood vessels *(Pierro et al., 2010)*.

It has been estimated that without treatment for PDR, 50% of all patients will become blind within 5 years following diagnosis. Optical coherence tomography (OCT) gave us the possibility to measure the macular thickness objectively and also the ability to follow the progression of DR quantitatively *(Hee et al., 2010)*.

Long term control of hyperglycemia can be monitored by periodic measurements of glycosylated hemoglobin (HbA1c). Diabetes control and complications trials showed that intensive glycemic control had been proved to be effective in decreasing development and progression of diabetic retinopathy incidence rate in type 1 and type 2 diabetes mellitus *(Moon et al., 2011)*.

The aim of the present work was to evaluate the relation of macular thickness to glycosylated hemoglobin in patients with non-proliferative diabetic retinopathy.

PATIENTS AND METHODS

This study included 100 eyes of 100 diabetic patients. This study was designed as an observational, cross-sectional and non-cohort study during the period from 6/2019 to 3/2020. Patients were recruited from Retinal clinic in Al-Azhar University Hospital and asked to participate in this study.

Patients were divided into 2 equal groups: Group A: Diabetic patients without diabetic retinopathy, and **Group B:** Diabetic patients with non-proliferative diabetic retinopathy.

Inclusion criteria:

1. Type II diabetic patients without DR.

2. Type II diabetic patients with non-proliferative DR.

Exclusion criteria:

1. Patients with a history of Type I DM.

2. Proliferative DR.

3. Ocular diseases (i.e. Pre-existing glaucoma, high myopia, optic nerve pathology, vitreous hemorrhage, dense cataract).

4. Systemic disease (i.e. hypertension)

5. Systemic medication (i.e. Chloroquine, Tamoxifen, Canthaxanthine) to exclude its effect on macular thickness.

6. Previous ocular surgery (retinal surgery, previous laser treatment).

All subjects participating in the study were asked to sign consent before inclusion. Then they were subjected to:

1. Full Medical history.

2. Careful ocular examination on the day of OCT assessment.

The non-proliferative diabetic retinopathy (NPDR) was diagnosed according to the simplified Early Treatment Diabetic Retinopathy study (ETDRS) severity scale. Mild NPDR was characterized by the presence of a few microaneurysms, moderate NPDR which was characterized by the presence of multiple microaneurysms, dot-and-blot hemorrhages, venous beading, and/or cotton wool spots, severe NPDR which was characterized by the presence of cotton wool spots, venous beading, and severe intraretinal microvascular abnormalities (IRMA). It was diagnosed using the "4-2-1 rule." A diagnosis was made if the patient has any of the following: diffuse intraretinal hemorrhages and microaneurysms in 4 quadrants, venous beading in ≥2 quadrants, or IRMA in ≥1 quadrant.

3. Investigations:

● Hemoglobin A1c: Blood sample was taken on the day of OCT assessment to measure HbA1c level.

● OCT macular thickness was performed by a single examiner.

Optical Coherence Tomography (OCT):

The same examiner performed all OCT measurements. Optical Coherence Tomography (OCT) measurement for macular thickness was performed using the same device using Topcon SD-OCT (3D OCT-2000, version 8.30; Topcon Corporation, Tokyo, Japan). This OCT system has a resolution of 6 μm. As a light source, it uses super luminescent diodes with a wavelength of 840 nm. And a high speed of 27,000 A-scans per second.

Macular Thickness Measurements:

After pharmacological pupillary dilation using tropicamide eye drop 1.0% by putting 1 drop every 5 minutes 3 times, the Patients were asked to fixate on an internal fixation target during the scanning process and if fixation was not central, the external fixation target was used to move the scanning area centrally over the macula.

The 3D macula protocol was used for macular thickness measurements. All scans were taken as close to the fovea as possible, such that the thinnest point of the macula was imaged, so as to avoid errors in the thickness measurements due to slight differences in positioning. OCT scans were segmented automatically by the segmentation algorithms incorporated in the Topcon 3D OCT-2000 software,

which demarcates the internal limiting membrane (ILM) and the retinal pigment epithelium (RPE) and the retinal thickness map was generated. For each eye, the automatically-registered ETDRS grid over the topographic map was recorded. If the ETDRS grid was not properly placed over the fovea, the grid was manually moved to the correct position. The retinal thickness map was scanned by moving the computer cursor in the macular area and the point with the highest retinal thickness was recorded as maximum retinal thickness (MRT). Scans with a quality factor <40 were excluded.

The 3D macula protocol used for macular thickness measurements consisted of a raster-scan composed of 512×128 axial scans covering an area of 6×6 mm in the macular region. It reconstructed a color topographic image displayed with numeric averages of thickness measurements for each of the 9 map regions within a 6×6 mm area centered on the fovea, as defined by the ETDRS. According to ETDRS map, macula was divided into 9 regions with 3 concentric rings measuring 1 mm (innermost ring), 3 mm (inner ring) and 6 mm in diameter (outer ring) centered on the fovea. The innermost 1 mm ring is the fovea while the 3 mm inner ring and 6 mm outer ring are further divided into four equal regions. It identified the layers of the retina and determined macular thickness by measuring the distance between the inner limiting membrane (ILM) and the inner boundary of retinal pigment epithelium.

Statistical Analysis:

Data were collected, revised, coded and entered to the Statistical Package for the Social Sciences (IBM SPSS) version 23. The quantitative data were presented as mean, standard deviations and ranges when their distribution found parametric. Also qualitative variables were presented as number and percentages. So, the p-value was considered significant when $P < 0.05$. The comparisons between groups with qualitative data were done by using Chi-square test. The comparison between two groups with quantitative data and parametric distribution were done by using Independent t-test. Spearman correlation coefficients were used to assess the correlation between two quantitative parameters in the same group.

RESULTS

This work included one hundred eyes from 100 patients with a diagnosis of type II DM, the ranged age 30-60 years with mean 54.27±8.74 years, while 56 were males and 44 were females, mean duration of DM was 17.67±6.73 years, mean HbA1c level was 8.15±1.42 % and mean corrected visual acuity was 0.83±0.10, 53% of patients were on oral hypoglycemic agents, 27% on insulin and 20% on combination of both insulin and oral hypoglycemic agents, 50% of patients were without diabetic retinopathy and 50% with non-proliferative diabetic retinopathy of diabetic retinopathy **(Table 1)**.

Table (1): Distribution of optical coherence tomography (OCT) cases according to their demographic data regarding gender and age (n=100)

	Total (n=100)
Demographic data	
Age (years)	
Range	30-60
Mean(M)±SD	54.27±8.74
Gender	
Male	56 (56%)
Female	44 (44%)
Duration of DM (years)	17.67±6.73
HbA1c level %	8.15±1.42
Corrected visual acuity	0.83±0.10
CST (µm)	237.66±35.73
Total macular volume (mm^3)	7.33±0.68
Sugar control	
Oral hypoglycemic agents	53 (53%)
Insulin	27 (27%)
Combination	20 (20%)
Diabetic retinopathy grading	
No diabetic retinopathy	50 (50%)
Non-proliferative diabetic retinopathy	50 (50%)

There was no statistically significant difference between the no DR and NPDR groups according to gender. This table shows statistically significant difference between the two groups regarding duration of DM and HbA1c level% **(Table 2)**.

Table (1): Comparison between group of no DR and NPDR group according to gender, age, duration of DM, Hba1c level % and corrected visual acuity

Parameters	Groups	No DR (n=50)	NPDR (n=50)	p-value
Gender	Male	30 (60.0%)	26 (52.0%)	>0.05
	Female	20 (40.0%)	24 (48.0%)	
Age (years)		54.59±10.91	56.11±10.37	>0.05
Duration of DM (years)		15.20±4.19	19.29±3.80	<0.001
HbA1c level %		7.58±1.74	8.72±1.92	<0.003
Corrected visual acuity		0.84±0.12	0.82±0.08	>0.05

There wasa statistically significant difference between the two groups regarding TMV, average MT and macular thickness of all of the standard 9 ETDRS subfields. This table shows statistically significant difference between the two groups according to HbA1c level % **(Table 3)**.

Table (3): **Comparison between group of no DR and NPDR group as regard total macular volume (TMV), average MT, central subfield macular thickness (CST), superior inner MT, superior outer MT, temporal inner MT, temporal outer MT, inferior inner MT, inferior outer MT, nasal inner MT, nasal outer MT and HbA1c level %**

Variables \ Groups	NO DR group (n=50)		NPDR group (n=50)		p-value
	Mean	**±SD**	**Mean**	**±SD**	
TMV (mm³)	7.12	0.58	7.53	0.77	<0.004
Average MT (µm)	245	31.67	286	52.87	<0.001
CST (µm)	218.72	35.78	256.59	35.68	<0.001
Superior inner MT (µm)	264.26	47.57	321.32	57.84	<0.001
Superior outer MT (µm)	222.22	35.56	261.26	41.80	<0.001
Temporal inner MT (µm)	249.25	37.39	309.31	46.40	<0.001
Temporal outer MT (µm)	205.21	43.09	261.26	54.86	<0.001
Inferior inner MT (µm)	285.29	51.35	318.32	57.30	<0.001
inferior outer MT (µm)	245.25	39.24	254.25	40.68	>0.05
Nasal inner MT (µm)	271.27	40.69	322.32	48.35	<0.001
nasal outer MT (µm)	252.25	52.97	272.27	57.18	>0.05
HbA1c level % ≤8	41 (82%)		15 (30%)		<0.001
HbA1c level % >8	9 (18%)		35 (70%)		

The following figures showed different examples of OCT measurement of macular thickness from both groups of no DR and NPDR:
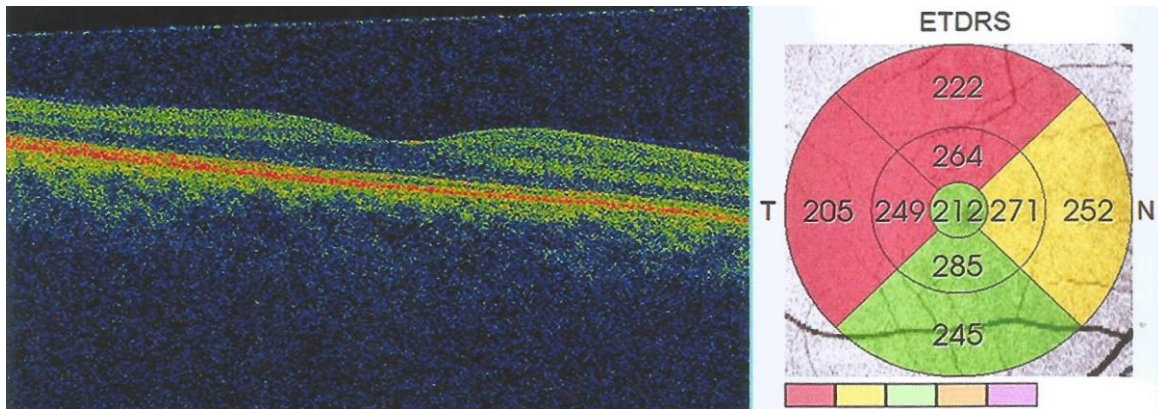
Figure (1): OCT of a case of no DR showing that CST was 185 µm, the measured HbA1c was 6.8% in the same patient
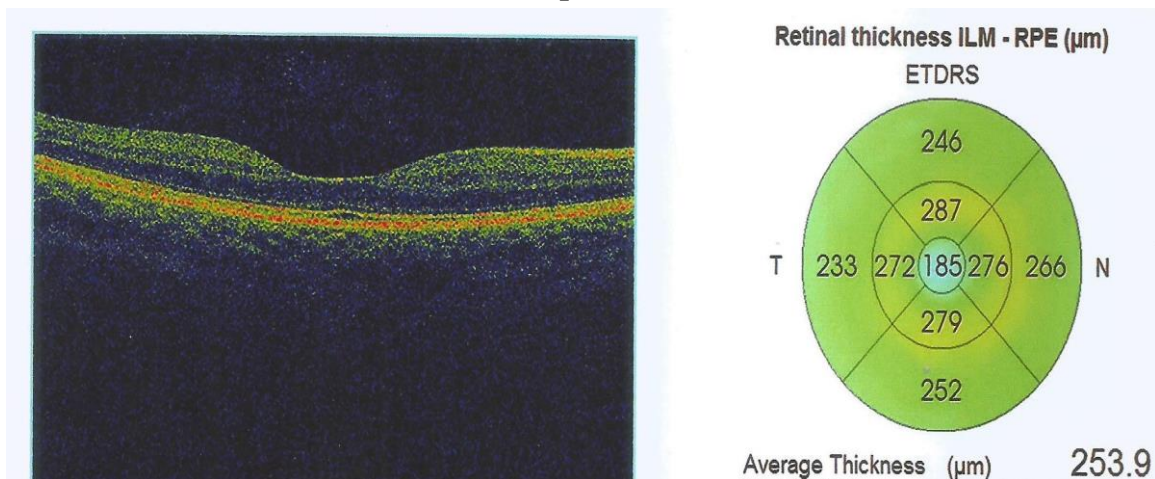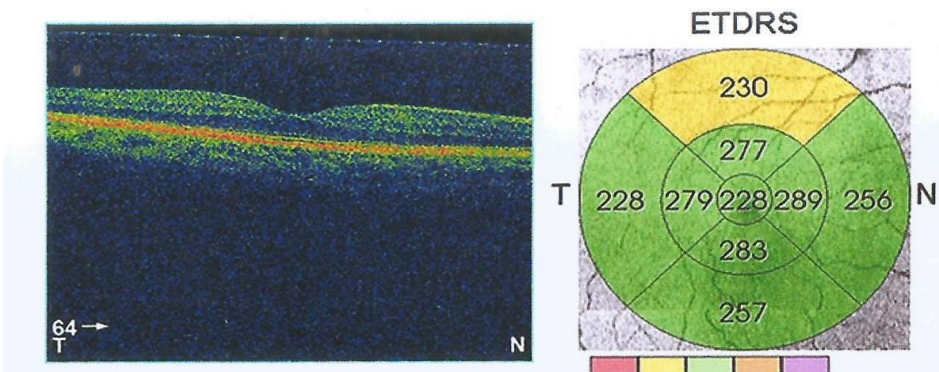
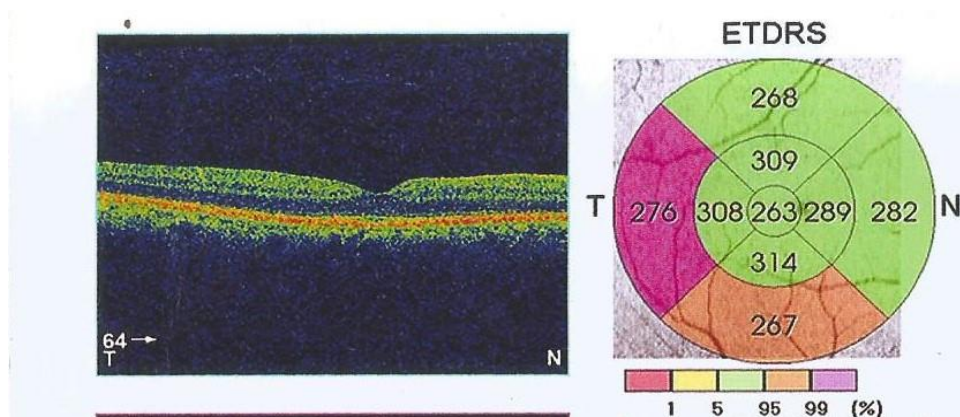**Figure (2): OCT of a case of no DR showing that CST was 195 µm, the measured HbA1c was 7.0% in the same patient**
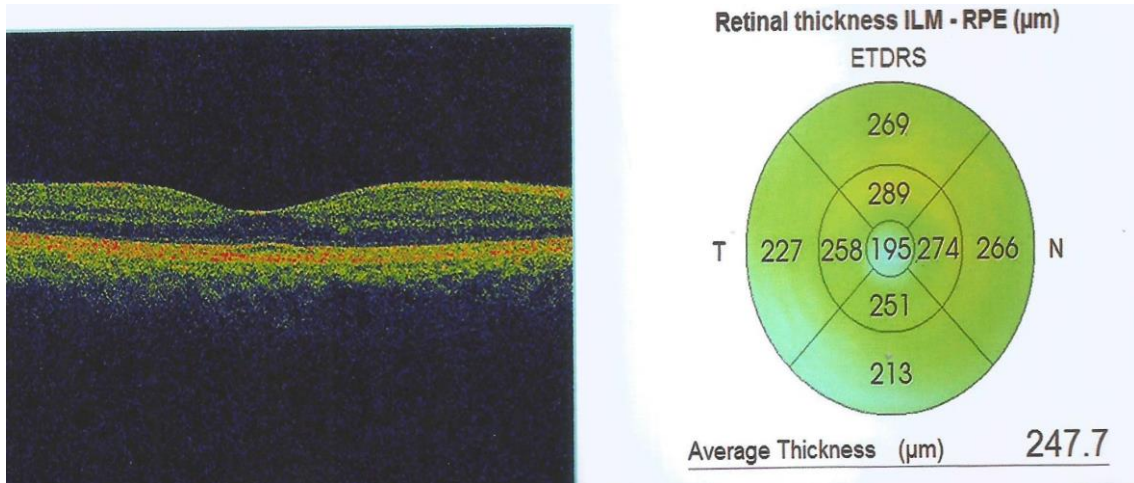
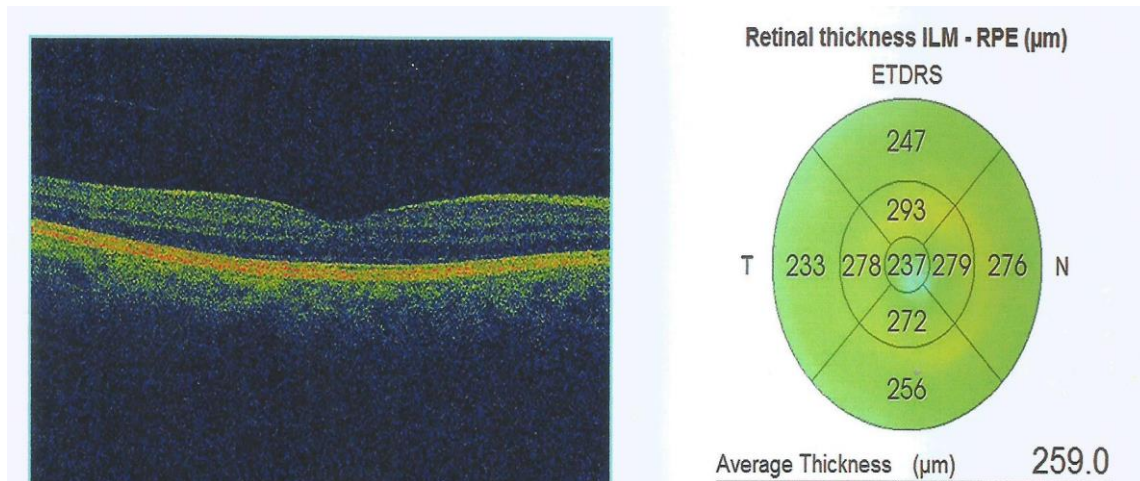**Figure (3): OCT of a case of no DR showing that CST was 212 µm, the measured HbA1c was 7.5% in the same patient**

Figure (4): OCT of a case of no DR showing that CST was 228 µm, the measured HbA1c was 7.8% in the same patient

Figure (5): OCT of a case of no DR showing that CST was 263μm, the measured HbA1c was 8.8% in the same patient

Figure (6): OCT of a case of NPDR showing that CST was 237 μm, the measured HbA1c was 7.8% in the same patient
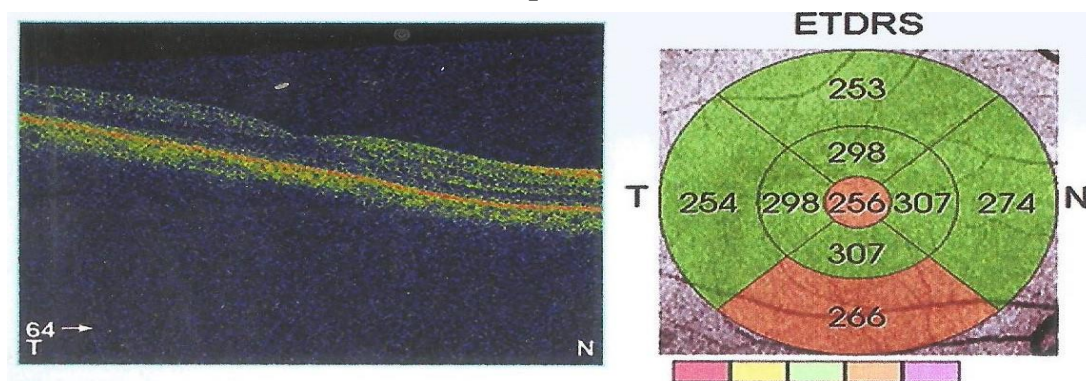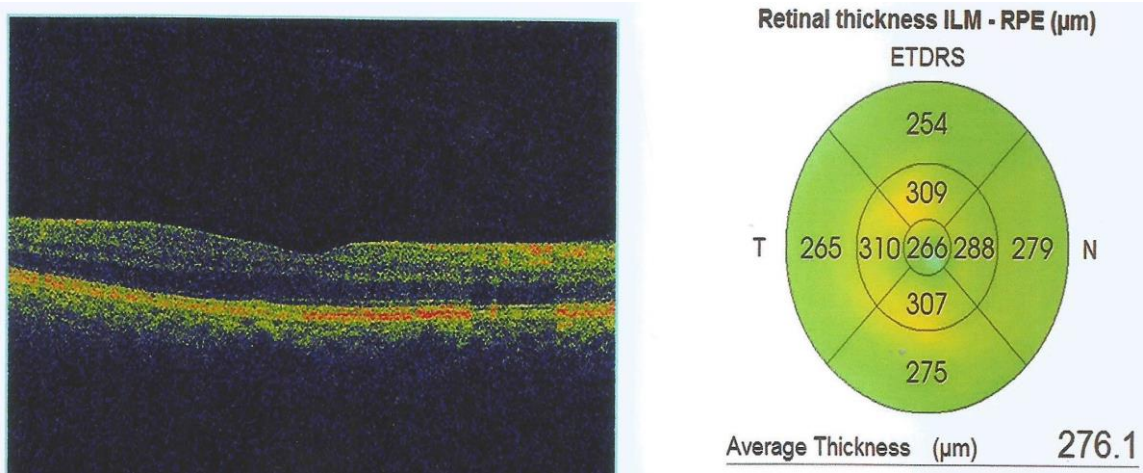

Figure (7): OCT of a case of NPDR showing that CST was 256 μm, the measured HbA1c was 8.5% in the same patient
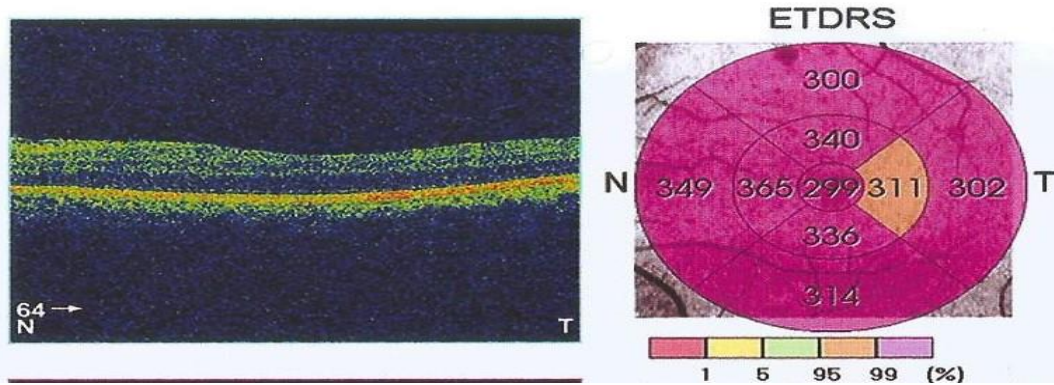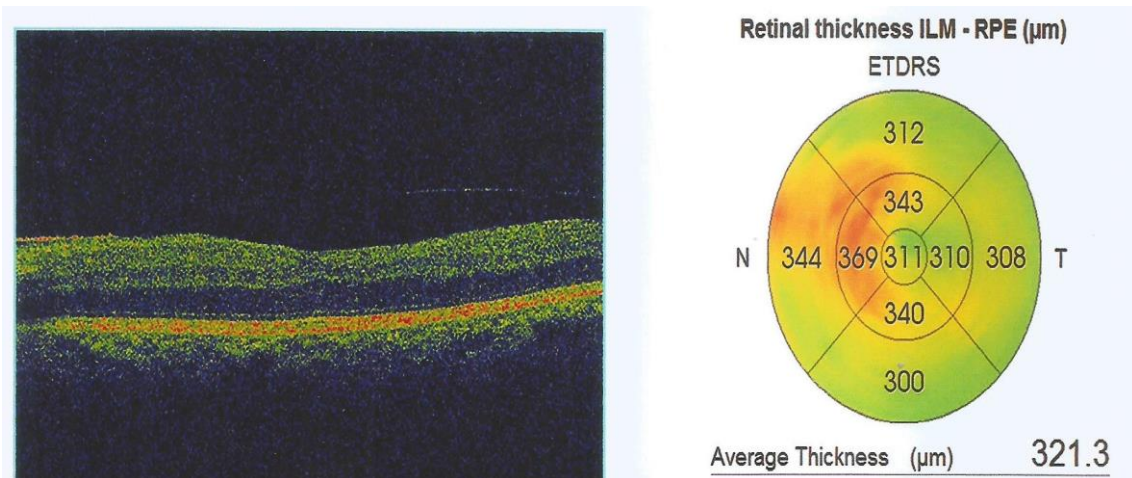
Figure (8): OCT of a case of NPDR showing that CST was 266 μm, the measured HbA1c was 9% in the same patient

Figure (9): OCT of a case of NPDR showing that CST was 299 μm, the measured HbA1c was 10% in the same patient

Figure (10): OCT of a case of NPDR showing that CST was 311 μm, the measured HbA1c was 11% in the same patient

There was a statistically significant difference between ≤8 and >8 at HbA1c level % according to CST in NPDR group **(Table 4)**.

Table (4): **Comparison between ≤8 and >8 at HbA1c level % according to CST in the NPDR group (n=50)**

HbA1c level %	No.	CST (μm)
≤8	15	224.60±15.90
>8	35	267.83±29.95
p-value		<0.001

There was a statistically significant relation between the severity of NPDR and HbA1c level % **(Table 5)**.

Table (5): **Comparison between stages of non-proliferative diabetic retinopathy (NPDR) according to HbA1c level %**

HbA1c %	Mild NPDR (n=12)	Moderate NPDR (n=16)	Severe NPDR (n=22)	p-value
7-8 % (n=15)	9 (75.0%)	4 (25.0%)	2 (9.1%)	<0.001
8-9 % (n=13)	2 (16.7%)	8 (50.0%)	3 (13.6%)	
9-10 % (n=12)	1 (8.3%)	3 (18.8%)	8 (36.4%)	
10-11 % (n=10)	0 (0.0%)	1 (6.3%)	9 (40.9%)	

x2-Chi-square test

DISCUSSION

In our study the 2 groups of no diabetic retinopathy (DR) and non-proliferative diabetic retinopathy (NPDR) were comparable regarding age, and the mean age of the 2 groups was > 50 years old.

In agreement with our study *Yang et al. (2013)* reported no association between age and DR. In contrast to our study, *Al-Sarraf et al. (2010)* reported a greater chance of diabetic retinopathy (DR) in individuals aged 50–59 years and ≥60 years and *Raman et al. (2012)* also reported the significance of age as a risk factor for DR.

In our study, the 2 groups of no DR and NPDR were comparable regarding sex, but in group of no DR (60%) patients were male and in NPDR group (52%) patients were male. In agreement with our study *Kajiwara et al. (2014)* reported greater chance of DR among females. In contrast to our study, *Raman et al. (2011)* reported greater chance of DR among males. In our study the 2 groups were comparable regarding BCVA. It is interesting that, although increased macular thickness and volume were noted in patients with DR. The subgroups did not differ significantly in terms of VA. Some studies have shown that macular thickness is related to VA, but functionally significant loss of vision is less likely to occur when central subfield macular thickness is <300μm. All our patients had CST < 300 μm and thus it is reasonable to assume that their VA had not been affected by macular changes at this stage *(Sakata et al., 2011)*.

Our study results showed that the mean duration of DM is longer in NPDR group than group of no DR. The total macular volume (TMV) was higher in the NPDR group than group of no DR. In contrast to our study, *Yeung et al. (2010)* reported that total macular volume is higher in diabetic patients without diabetic retinopathy than diabetic patients with non-proliferative diabetic retinopathy. In our study the average macular thickness and macular thickness of all of the 9 standard ETDRS subfields was higher in the NPDR group than group of no DR. In agreement with our study, *Yeung et al. (2010)* reported that central subfield macular thickness is higher in diabetic patients without diabetic retinopathy than diabetic patients with diabetic retinopathy.

In our study, the mean HbA1c level was significantly higher in the NPDR group than group of no DR. We found that the number of patients with HbA1c level above 8.0 % was significantly higher in the NPDR group than no DR group, while we found that the number of patients with HbA1c level lower than 8.0% was significantly higher in group of no DR than NPDR group, so we concluded that HbA1c level of 8.0% was a cut-off point for increased risk of diabetic retinopathy development. In our study we assessed the relation between the HbA1c level and central subfield macular thickness (CST) in both groups of no DR and NPDR separately. In the group of no DR, we found that there was significant association between HbA1c and CST.

Cho et al. (2020) reported that progression from no diabetic retinopathy in diabetic patients to NPDR stage was associated with higher HbA1c level.

Alabdulwahhab (2019) Reported that HbA1c level was significantly higher in patient with DR than patients without DR. In contrast to our study, *Jiang et al. (2018)* concluded that there's negative correlation between HbA1c level and central subfield macular thickness in diabetic patients without diabetic retinopathy.

In our study, we found significant association between CST and HbA1c level in the NPDR group. In agreement with our study *Altintas et al. (2018)* observed the change of both HbA1c level and central subfield macular thickness (CST) in diabetic patients with NPDR through follow-up visits; they found that there was a statistically significant correlation between HbA1c and CST.

In another study, *Subrayan et al. (2015)* also reported that central subfield macular thickness was positively correlated with HbA1c level. In contrast to our study, *Asefzadeh et al. (2012)* reported that there was no significant relation between retinal thickness and HbA1c level.

In our study, we found that incidence of DME was associated with increased HbA1c level and longer duration of DM. In agreement with our study, *Klein et al. (2010)* reported that the incidence of macular edema over the 10-year period was associated with higher levels of glycosylated hemoglobin and more severe retinopathy in both younger- and older-onset groups. *Moreira et al. (2010)* also reported that HbA1c was the only variable that showed a significant association with macular edema in diabetic retinopathy patients.

In our study, results showed that the increase in the value of HbA1c level significantly affects the severity of diabetic retinopathy stages. Hence, it showed a highly significant positive correlation. In agreement with our study *Meena et al. (2019)* found positive significant correlation between HbA1c level and severity of diabetic retinopathy stages.

In our study, results showed that macular thickness in all of the 9 standard ETDRS subfields is positively correlated with the severity of diabetic retinopathy stages. In agreement with the present study, *Browning and Fraser (2010)* concluded that with increased retinopathy severity, the probability of macular thickening detected by OCT but not detected by clinical examination increased.

In our study, we divided both groups of no DR and NPDR into subgroups according to duration of DM and compared them regarding HbA1c level. We found that the no DR subgroups showed positive significant correlation between duration of DM and HbA1c level. We also found that the NPDR groups showed positive significant correlation between duration of DM and HbA1c level. In agreement with our study, *de Waard et al. (2018)* concluded that in both the radius and the tibia study population, participants with higher diabetes duration had a significantly higher HbA1c level than those with lower diabetes duration.

In the same study, in contrast to our study, *de Waard et al. (2018)* reported that microvascular disease subgroup showed no significant correlation between duration of diabetes and HbA1c level. In another study, *Verma et al. (2010)* reported that the results obtained indicated that the HbA1c levels showed a significant increase with the duration of diabetes.

HbA1c level was significantly lower in insulin using group than group of no insulin use. In agreement with our study *Weitzman et al. (2010)* found that there was significant inverse relation between HbA1c level and insulin intake in type 2 diabetic patients. In our study we found that insulin using diabetic patients had significantly lower risk of developing diabetic retinopathy than diabetic patients without insulin intake. In agreement with our study *Shrote and Diagavane (2015)* study showed an inverse association between the insulin intake and the presence of DR.

This study had some limitations. Firstly, the participants were all type 2 DM patients, and the results we discovered in this study might not apply to patients with type 1 DM. Secondly, we only observed the difference between the two groups at one point in time. Other changes may exist during the times we did not observe. Thirdly, our study didn't include follow up of patients that would provide us with more information about the effect of changes in HbA1c on macular thickness in the same studied diabetic patients when we follow them through months' interval visits.

CONCLUSION

Intensive glycemic control in type II diabetic patients might affect retinal vasculature and decrease ischemia, and affect the development and progression of non-proliferative diabetic retinopathy.

Glycosylated hemoglobin of 8 or above increased the risk of incidence of DR and macular edema. Optical coherence tomography was a sensitive and noninvasive diagnostic tool in the evaluation of macular thickness.

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تقييم سمك ماقولة الشبكية بإستخدام التصوير المقطعي بالتماسك البصري في اطار العلاقة مع الهيموجلوبين السكري في مرضي إعتلال الشبكية السكري غير التكاثري

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خلفيــة البحــث: إعـتلال الشـبكية السـكري المعـروف أيضـا باسـم مـرض العـين السـكري هـو تلـف يحـدث فـي الشـبكية بسـبب مـرض السـكري, و قـد يـؤدي إلـى العمـى فـي النهاية.

الهـدف مـن البحـث: تقيـيم علاقـة سـمك البقعـة بـالهيموجلوبين الجليكـوزيلاتي فـي المرضى الذين يعانون من إعتلال الشبكية السكري غير التكاثري.

المرضـي وطـرق البحـث: تضـمنت الدراسـة مائـة عـين مـن مائـة مـريض مصـاب بمـرض السـكري مـن النـوع الثـاني. وتـم تقسـيم المرضـى إلـى مجمـوعتين متسـاويتين: المجموعـة الأولـى تشـمل مرضـى السـكري مـن النـوع الثـاني دون اعـتلال شـبكية سـكري و المجموعـة الثانيـة تشـمل مرضـى السـكري مـن النـوع الثـاني المصـابين باعتلال الشبكية السكري غير التكاثري.

نتـائج البحـث: كـان سـمك الشـبكية أقـل فـي المجموعـة الغيـر المصـابة بـاعتلال الشـبكية السـكري و كـذلك نسـبة الهيموجلـوبين السـكري, وكانـت أقـل مـن المجموعـة المصـابة بـاعتلال الشـبكية السـكري غيـر التكـاثري. وقـد أوضـحت نتـائج الدراسـة أن زيـادة نسـبة الهيموجلـوبين السـكري بالـدم فـي مرضـى السـكري مـن النـوع الثـاني يصـاحبه زيـادة فـي نسـبة حـدوث إعـتلال الشـبكية السـكري غيـر التكـاثري و أيضـا يصـاحبه زيـادة سـمك الشـبكية و كـذلك زيـادة نسـبة الإصـابة بارتشـاح ماقولـة العـين. لـذلك فـإن السـيطرة علـى مسـتوى السـكر بالـدم مـن الممكـن أن يـؤثر علـى كفـاءة الأوعيـة الدمويـة بالشـبكية و علـى تطـور مـرض إعـتلال الشـبكية السـكري فـي مرضـى السـكري, وأن نسـبة الهيموجلـوبين السـكري بالـدم بـدءا مـن 7.5 فـأكثر تزيـد مـن نسـبة حـدوث إعـتلال

الشــبكية الســكري الغيــر تكــاثري وحــدوث إرتشــاح بماقولــة العــين. و التصــوير المقطعي البصري عامل رئيسي و آمن لقياس سمك الشبكية.

الاسـتنتاج: التصــوير المقطعــي البصــري و قيــاس نسـبة الهيموجلــوبين الســكري بالــدم بصـفة دوريــة مـن الممكـن أن يعطيـان معلومـات كافيـة عـن التغيـرات التـي تحـدث فـي سمك الشبكية.

الكلمــات الدالــة: ســمك البقعــة الصــفراء، إعـتلال الشـبكية السـكري غيـر التكـاثري، الهيموجلوبين الجليكوزيلاتي.