Normal Macular Thickness Measurements in Normal Eyes Using Fourier Domain Optical Coherence Tomography

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Objective: *To report normal macular thickness measurements in Normal eyes using Fourier domain optical coherence tomography (FD-OCT)*

Methods: *Forty eyes from 20 Normal subjects underwent a complete ophthalmologic examination, including OCT. Six radial scans, 6 mm in length and centered on the fovea, were obtained using the FD-OCT. Retinal thickness was automatically calculated by OCT mapping software. Measurements were displayed as the mean and standard deviation for each of the 9 regions defined in the Early Treatment Diabetic Retinopathy Study.*

Results: *Foveal thickness (mean thickness in the central 1000-μm diameter area) and central foveal thickness (mean thickness at the point of intersection of 6 radial scans) on the OCT were 235.95(±21.91) and 290.92 (±11.54) μm, respectively. Macular thickness measurements were thinnest at the center of the fovea, thickest within 3-mm diameter of the center, and diminished toward the periphery of the macula. The temporal quadrant was thinner than the nasal quadrant. There was no correlation between age and foveal thickness (P = .23).*

Conclusions: *Mean foveal thickness measurements were 38 to 62 μm thicker than previously reported values, while mean central foveal thickness measurements were 20 to 49 μm thicker than previously published values. This discrepancy should be considered when interpreting OCT scans.*

Key words: Macula, OCT, Fovea, Nerve fiber layer, fast scan

I. Introduction

Macular edema is a common cause of visual loss. Abnormal fluid accumulation within the retina and a concomitant increase in retinal thickness usually result from the breakdown of the blood-retinal barrier. This process can be found in those with diabetic retinopathy, retinal vein occlusion, uveitis, and other ocular disorders. However, it has been observed repeatedly in clinical practice that the presence of macular edema does not necessarily preclude good vision.[1,2] Nussenblatt et al[3] were able to demonstrate that the degree of macular thickening, rather than the presence of macular edema, is significantly correlated with visual acuity. Traditional methods for evaluating macular edema, such as slit lamp biomicroscopy, stereoscopic photography, and fluorescein angiography, are relatively insensitive to small changes in retinal thickness and are qualitative at best.[4] The introduction of optical coherence tomography (OCT) has enabled clinicians to reliably detect and measure small changes in macular thickness and to quantitatively evaluate the efficacy of different therapeutic modalities.[5]

This study measures and defines normal macular thickness values in Normal eyes using OCT mapping software. To our knowledge, this is the first study to provide normative macular thickness data for the OCT system.

II. Material and methods

After obtaining clearance from Institutional ethics committee, the present study was carried out randomly selected subjects from the outpatient department of eye and Retina Clinic, Institute of Ophthalmology on the basis of routine ophthalmic examination. An informed consent was taken from each subject. Subjects were matched for age, sex, height and weight. Using the Snellen chart, vision was measured. The same experimenter measured the intraocular pressure three times in each eye with the Goldmann tonometer. The refractive error from the manifest refraction (MR) was adjusted to the spherical equivalent. The visual field was measured using the Humphrey field analyzer, with the central 30-2 SITA-standard program. Every patient was instilled with a drop of 1% tropicamide and 2.5% phenylephrine hydrochloride in each eye 3 times at 15 minute intervals to dilate the pupil. A fundus examination was precisely performed in all subjects.

Exclusion criteria for Normal eyes included any history or evidence of pathological features of the retina, diabetes mellitus or other systemic disease that could affect the eye, glaucoma or first-degree relative with glaucoma, intraocular pressure higher than 21 mm Hg, abnormal visual fields, intraocular surgery or laser therapy (although refractive surgery >1 year before enrollment was acceptable), best-corrected visual acuity worse than 20/32, and refractive error greater than 6.00 or less than −6.0 diopters.

In the present study, Macular thickness was measured by fourier domain optical coherence tomography. The fast macular thickness scanning protocol was used. The calculation of macular thickness was based on the 6mm retinal thickness map analysis printout. The map was composed of 9 sectorial thickness

measurements in three concentric circles with diameters of 1, 3, and 6 mm. The area bounded by the outer (6mm) and middle (3mm) circles formed the outer ring (parafoveal area) and the area bounded by middle (3mm) and inner circles (1mm) formed the inner ring (perifoveal area).

The perifoveal area and parafoveal area were divided into four quadrantic zone: temporal, superior, nasal and inferior. The central 1mm circular region represented the foveal area.

The relationship between foveal thickness and age was investigated using linear regression analysis. Statistical analysis was performed with a commercially available software program (SPSS 20 SPSS Inc, Chicago, 1ll).

III. Results

Forty Normal eyes from 20 Normal subjects were examined clinically and by the OCT. The patients were aged 10 to 40 years (median, 23 years). There were 14 women (70%) and 6 men (30%). The mean and standard deviation retinal thickness by sector are shown in Figure 1 and Table 1. The foveal thickness never exceeded 258 μm in any of the Normal eyes. As expected, macular thickness was thinnest at the center, thickest within 3-mm diameter of the center, and diminished toward the periphery of the macula. The temporal quadrant was thinner than the nasal quadrant. The superior and nasal quadrants were thickest overall.
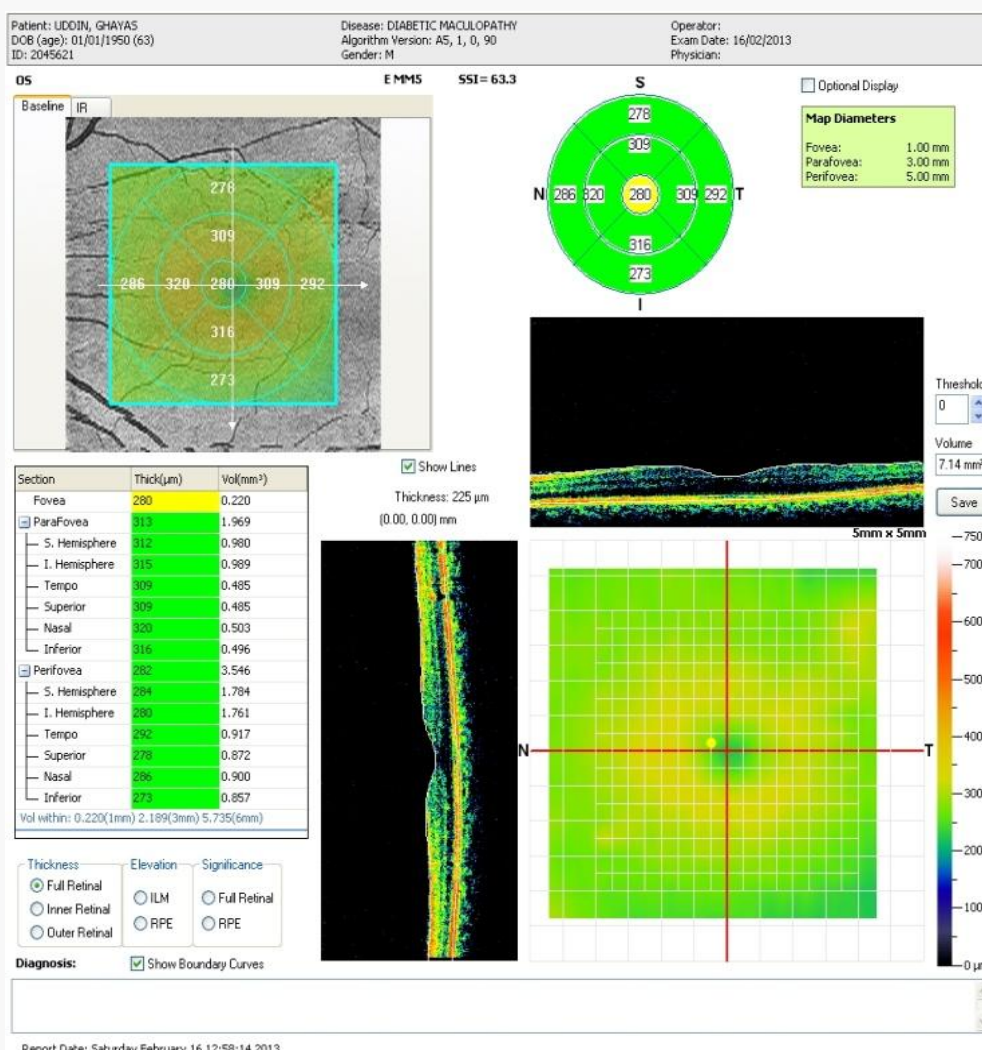

Figure1: Macular thickness scan of emmetropic or normal eye.

Table1: Macular thickness in emmetropic or normal eye (measured in μm).

Zone	Macula	Fovea	Parafovea	Perifovea
Averge	290.92 (±11.54)	235.95(±21.91)	304.85 (±22.92)	286.25 (±20.57)
Superior			312.57(±16.02)	282.15 (±18.70)
Inferior			307.42 (±14.09)	286.05 (±16.92)
Temporal			295.86 (±09.83)	279.72 (±16.90)
Nasal			312.55(±15.51)	304.99 (±17.67

By using linear regression analysis, we found no relationship between age and foveal thickness within the central 1000-μm diameter (P = .23).

IV. Discussion

Optical coherence tomography has emerged as a useful imaging technique by providing new high-resolution cross-sectional information about various pathological features of the macula.[5–9] It allows clinicians to quantitatively measure retinal thickness in a reliable and highly reproducible manner.[10,11,21] The introduction of the commercial OCT in 2002 provided faster imaging speed and better visualization of intraretinal morphological features compared with earlier versions of the instrument.

Our results are different from previously published values obtained using earlier versions of the device. In our study, the mean ± SD macular thickness (average thickness in the central 1000-μm diameter area) was 235.95 ± 21.9 μm, approximately 68 μm thicker than previously reported values. The mean ± SD macular thickness (average thickness at the point of intersection of 6 radial scans) was automatically determined to be 290.92 ± 11.54 μm, approximately 29 to 49 μm thicker than previously published values. Clinicians should be aware of these discrepancies when interpreting OCT images from different OCT models. These discrepancies may be a direct result of the greater resolution achieved by the more recent OCT systems. Less movement by the patient because of faster scanning times and more refined algorithms have allowed better image quality. We found that the thickness measurements in the 4 peripheral outer quadrants on the OCT were thinner than those reported in the literature. This may reflect the difference in scan length between the OCT and previous versions of the instrument.

Most of the OCT studies[6,8,11–15,17–20] in the literature report central foveal thickness only. Investigators have shown that central foveal thickness is significantly correlated with best-corrected visual acuity in Normal and diabetic eyes. However, foveal thickness may be more indicative of changes in the macula than central foveal thickness for several reasons. Foveal thickness is determined from many more data points than central foveal thickness. For example, each radial scan on the OCT is composed of a sequence of 512 A-scans. The macular thickness map scan protocol uses 6 radial scans per individual. Within the central 1000-μm diameter area, foveal thickness is determined from 512 data points, whereas central foveal thickness is determined from only 6 data points. In addition, we were able to manually measure the central foveal thickness from the raw data and compare this value with the computer output. We found the mean ± SD central foveal thickness to be 188 ± 18 μm, approximately 42 μm less than the value automatically obtained from the OCT software. This may reflect the difference in approach between the manual method and the automatic method of the OCT mapping software. The software automatically determined the mean and standard deviation thickness for the center point where all 6 scans intersected, whereas we manually located the minimum point on each separate radial scan and averaged those values. If the OCT scans were not perfectly centered on the patient's fixation point for all 6 scans, the point of intersection would not correspond to the center exactly. This may give falsely elevated values. Given that the awake human eye is in constant motion, the minimum point for each radial scan will virtually never converge at the center, despite faster OCT scanning speeds. Because the central point is the smallest area of measurement, it will be most affected by tiny eye movements, followed by the central foveal zone. As a result, the standard deviation for central foveal thickness is the largest. Consequently, foveal thickness may be a more practical and reliable indicator than central foveal thickness for changes in the macula. We believe future OCT studies should report foveal thickness, in addition to central foveal thickness, in the evaluation of the efficacy of different therapies for macular edema.

Lack of normative data on the OCT the study suggested that the cut off for the upper level of normal foveal thickness be 200 μm, based on their analysis of the existing literature. Our findings do not agree with their assessment. We use 2 SDs to define the cut offs for the upper and lower levels of normal foveal thickness. Therefore, macular thickening can be suspected if foveal thickness is greater than 325 μm and macular thinning can be suspected if foveal thickness is less than 172 μm when measured with the OCT. In the present study, the only 2 outliers were a young man who had a foveal thickness of 252 μm and a middle-aged woman who had a foveal thickness of 154 μm, both exceeding the normal value by more than 2 SDs.

Although it has been suspected that macular thickness might decline slightly with age, no statistically significant relationship could be found from this study. These findings are consistent with previous studies.[6,18,21] Our study also showed no significant difference in mean foveal thickness between men (224 μm; range, 154–252 μm) and women (237 μm; range, 173–257 μm). Future studies with larger sample sizes and a more even distribution of men and women may provide more useful information regarding differences by age, sex, and race.

In conclusion, normative values for macular thickness in a Normal population were obtained using commercially available OCT mapping software. Mean foveal thickness measurements were 38 to 62 μm thicker than previously reported values, while mean central foveal thickness measurements were 20 to 49 μm thicker than previously published values. This discrepancy should be considered when interpreting OCT scans.

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