Optical Coherence Tomography Grid Decentration and Its Effect on Macular Thickness Measurements

Khalil Ghasemi Falavarjani, MD[1] • *Joobin Khadamy, MD[2]* • *Nasser Karimi, MD, MPH[2]*
Anis Alsadat Jazayeri, MD[3] • *Foad Amirkourjani, MSc[4]*

Abstract

Purpose: To evaluate the rate of optical coherence tomography (OCT) grid decentration in a routine practice and its effect on thickness measurements

Methods: Topcon spectral domain OCT scans from various macular diseases including age related macular degeneration, diabetic macular edema, macular pucker and central serous chorioretinopathy (CSCR) were studied in all patients visited during seven consecutive days. In each scan, the macular EDTRS grid was evaluated for decentration. After grid adjustment, the changes in central subfield thickness (CST) measurements were recorded. Differences >1 μm and >8.5 μm between automatically determined and manually adjusted CST measurements were recorded as grid decentration and significant grid decentration.

Results: Ninety-three OCT scans of 93 eyes were evaluated. Thirty-three scans were unreliable for grid adjustment. In the remaining 60 eyes, grid decentration was found in 32 eyes (53.3%). The mean change in CST after grid adjustment was 41.1±55.01 (3-251) microns. Clinically significant CST changes were found in 24 eyes (40%). No significant relationship was found between underlying disease and corrected CST, and grid decentration.

Conclusion: Abnormal retinal thickness map was found in a significant number of scans. Topcon OCT scans should be evaluated routinely for grid decentration.

Keywords: Optical Coherence Tomography, Retinal Thickness, Artifact

1. Associate Professor of Ophthalmology, Eye Research Center, Rassoul Akram Hospital, Iran University of Medical Sciences, Tehran, Iran
2. Resident in Ophthalmology, Eye Research Center, Rassoul Akram Hospital, Iran University of Medical Sciences, Tehran, Iran
3. Researcher, Eye Research Center, Rassoul Akram Hospital, Iran University of Medical Sciences, Tehran, Iran
4. Ophthalmic Technician, Eye Research Center, Rassoul Akram Hospital, Iran University of Medical Sciences, Tehran, Iran

Introduction

Optical coherence tomography (OCT) is a non-invasive imaging instrument that provides high-resolution, cross-sectional images of the retina as well as automatic measurement of retinal thickness. It has significantly improved the management of various ocular diseases including age related macular degeneration, diabetic retinopathy, retinal vascular occlusions, and vitreomacular interface disorders.[1]

Despite the advantages of OCT compared to older imaging modalities, interpretation of OCT images may be affected by significant artifacts.[2-7] Although different types of artifacts including operator-induced acquisition errors, patient motion or eccentric fixation were reported, most of studies focused on segmentation errors.[3-12]

Retinal thickness measurement is calculated based on the segmented inner and outer boundaries of the retina and averaged in each subfield of a 1-, 3-, 6-mm-diameter macular grid.[13] Average of retinal thickness in central 1 mm diameter of macular grid, is considered as central subfield thickness (CST). It has been used in determining patient eligibility and for follow-up of patients in various clinical trials.[1] Imprecise and off-center registration, or decentration, of the macular grid on the anatomic center of the fovea may lead to significant error in CST measurements.[14]

In this study, we evaluated the frequency of OCT grid decentration and its effect on CST measurements in a clinical practice.

Methods

In this retrospective study, the retinal thickness maps of all patients who underwent OCT imaging in Rassoul Akram Hospital during seven consecutive working days in July 2013 were evaluated. The study was approved by the local institutional ethics committee and adhered to the tenets of the Declaration of Helsinki.

The OCT scans were retrieved from the instrument data set. For OCT imaging, a Topcon instrument (Topcon 3D-OCT 1000; Topcon Corp.) with a 6*6 mm 3D macular scan protocol was used. An expert examiner (F.A.) performed all OCT imagings. 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. OCT scans were segmented automatically by the segmentation algorithms incorporated in the Topcon OCT 1000 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 CST of the automatically-registered EDTRS grid over the topographic map was recorded. If the EDTRS grid was not properly placed over fovea, the grid was manually moved to the correct position (Figure 1. A-D). The correct location of the central fovea was determined by one expert retina specialist (K.G.F.) using the color fundus and black and white images. The course of perifoveal vascular capillaries were followed to find the foveal avascular zone. In the center of this area, the geometry of the inner retinal layers was evaluated to find the point that was best matched with the known anatomical configuration of the foveola.

Scans with a quality factor <40 and blinking during the scanning process were excluded. Also, when the exact location of the central fovea could not be clearly determined, the scans were excluded.

Data were analyzed using a SPSS software (version 15, SPSS Inc. Chicago, IL) and student t test, paired t test and χ^2 test were used for analysis. Differences >1 μm between automatically determined CST and manually determined CST after grid adjustment were recorded as grid decentraion. Differences of >8.5 μm in CST were recorded as significant grid decentration.[14] A $p<0.05$ was considered significant. Bland-Altman plot was generated to facilitate comparisons between pre- and postadjustment CST measurements.
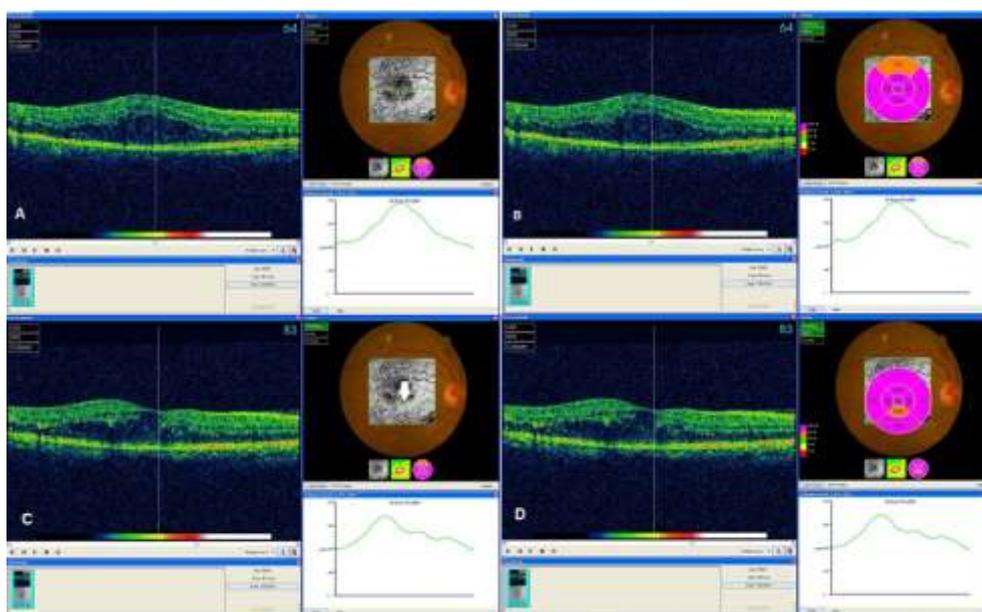
Figure 1. (A) The course of retinal vessels on the black and white image shows that scan overlay has properly registered on color fundus image. (B) The automatically registered grid shows a central subfield thickness of 512 microns. (C) The correct location of central fovea is shown by white arrow. (D) When the grid is moved to the correct location, the central subfield thickness value is changed to 403 microns.
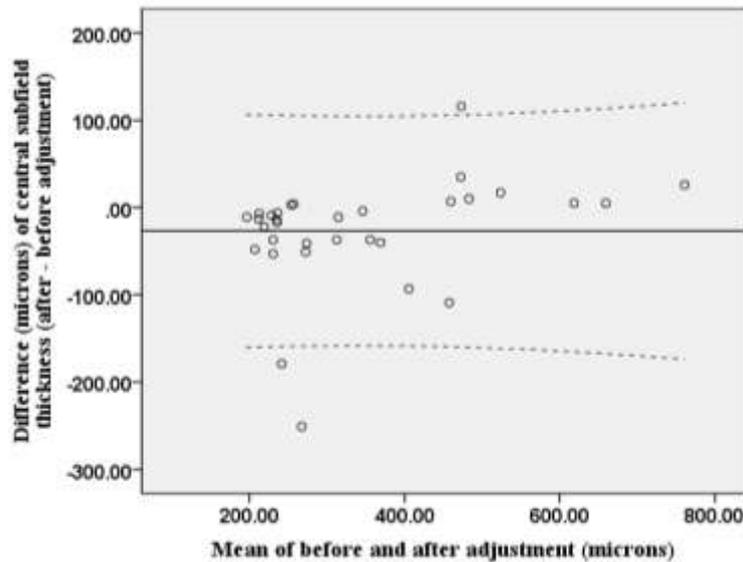
Results

Ninety-three scans of 93 eyes were evaluated. The mean age of the patients was 86±16 years. Ocular pathologies included neovascular and dry age related macular degeneration, diabetic macular edema, retinal vascular obstruction, cystoid macular edema, central serous chorioretinopathy (CSCR), and epiretinal membrane. Ten scans belong to the normal eyes.

Thirty-three scans were excluded because of inability to find the center of fovea. In the remaining 60 eyes, grid decentration was found in 32 eyes (53.3%). In eyes with grid decentration, a decrease in CST after grid adjustment was found in 22 scans (68.7%). The mean change in CST after grid adjustment was 41.1±55.01 (3-251) microns (μ). CST was 351.7±137.5 and 337.3±147.6 μ before and after grid adjustment, respectively (p=0.02). Clinically significant CST changes were found in 24 eyes (40%). No significant relationship was found between the underlying disease and the presence of either grid decentration or clinically significant grid decentration (Table 1, p=0.8 and p=0.2, respectively). No significant difference was found in corrected CST between eyes with and without grid decentration (330.8±160.4 and 344.7±136.4 μ, respectively, p=0.7) and between eyes with and without clinically significant grid decentration (314.2±153.8 and 352.7±147.1 μ, respectively, p=0.3). A Bland-Altman plot comparing the difference between pre- and postadjustment CST measurements is shown in figure 2.

Table 1. Grid decentration in different underlying pathologies

Underlying pathology	Eyes with/without grid decentration (>1 μ)	Eyes with/without clinically significant grid decentration (>8.5 μ)	Mean±SD of central subfield thickness decentration (μ)
Diabetic macular edema	14/11	11/14	55.7±65.9
Wet age related macular degeneration	3/1	3/1	25.6±23.6
Dry age related macular degeneration	4/3	4/3	61±79.4
Epiretinal membrane	2/5	1/6	20.5±23.3
Cystoids macular edema	2/1	2/1	55±53.7
Central serous chorioretinopathy	2/2	0/4	4±1.4
Normal	5/5	3/7	11.6±6.5

Figure 2. Bland-Altman plot of central subfield thickness before and after adjustment. Solid horizontal line: simple mean difference (-14.3 µm). Dashed horizontal lines: 95% limits of agreement.

Discussion

In Topcon OCT instrument, a fundus image is captured automatically at the end of OCT examination. The examiner routinely evaluates the black and white scan overlay on color fundus image and if there is any misalignment, manually transposes the scan overlay over the correct imaging area (Figure 1. A). This process allows the clinician to see the actual location of the scan in the macular area. Although the scan area should ideally be centered on the foveola, this may not occur in all patients. The ETDRS grid of the retinal thickness map is automatically registered on the scan area. Consequently, if the scan is not centered on foveola, the thickness measurement on the grid is incorrect (Figure 1. B). In busy clinical practice, the correction of the grid decentration is not routinely performed.[14]

Several studies have reported that OCT errors may occur in as much as 92% of scans. The error rate is affected by many factors including OCT type, analysis method, and the type of retinal disease.[4,5,7,15] The focus of these reports is mainly on misidentification of inner and outer retinal boundaries also known as segmentation error. Our study shows that errors caused by OCT grid decentration occurred in 53.3% of scans and should be considered as one of the major sources of

imaging artifacts in OCT data acquisition. Sull et al[15] evaluated the reproducibility of retinal thickness measurements using various OCT instruments in healthy subjects and found off-center error in 7.6% of Topcon 3D OCT scans. The corresponding figure in our study was 50%. Considering the exclusion of low quality scans and those that fovea was hard to locate, the actual decentration rate might be even higher. The discrepancy between these results may be explained by the definition of the artifact. Sull et al[15] considered off-center artifacts when the foveal center was misidentified as being >250 µm away from the true fovea based on the topographic map. Including scans with as small decentration as 1 um, may also lead to high decentration rate artifact reported in the current study.

Few studies evaluated the effect of the moving of the fixation center in OCT scans on CST measurements. Campbell et al[16] reported that decentration of 500 µm resulted in statistically significant difference in foveal thickness measurements in time domain OCT scans. Pak et al[14] reported the threshold for the statistically significant error in the CST measurements is a displacement distance of 200 µm. They showed that the minimum measurement error of CST at the threshold of statistically significant decentration was

approximately 8.5 μm. This was consistent for both healthy and pathological eyes, regardless of retinal thickness or foveal contour. Although we did not measure the distance between foveola and center of the grid, our study showed a 40% rate of a change of >8.5 μm after grid adjustment. Previous studies have reported higher rates of scan artifacts in eyes with various pathologies.[5,7,17] We did not find any association between the underlying disease and the error rate. We excluded the scans in which the precise location of the central fovea was not clear. This may exclude a subset of eyes with more severe ocular pathologies and cause the association to be statistically non-significant.

Our study has several limitations. Since this was a retrospective study, we did not have the records of visual acuity for all eyes. We did not analyze other artifact types in OCT scans. Also, aligning scans with fovea based on color fundus image is very subjective specially considering that 1 μm was recorded as decentration. Additionally, the disease categories have small number of patients within them. Despite these limitations, we reported a high occurrence of OCT grid decentration and consequent CST measurement error in a sample of patients with various vitreoretinal diseases visited during seven consecutive days.

Conclusion

As CST values are very important for follow-up purposes, it is important to have consistent grid registration and CST readings between multiple imaging sessions.

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