Comparison of Macular Thickness Between Cirrus HD-OCT and Stratus OCT

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BACKGROUND AND OBJECTIVE: To compare macular thicknesses in healthy subjects measured with spectral domain optical coherence tomography (SD-OCT) (Cirrus; Carl Zeiss Meditec, Inc., Dublin, CA) with measurements using time domain (TD-OCT) (Stratus; Carl Zeiss Meditec, Inc.).

PATIENTS AND METHODS: Macular thickness was measured five times in the same eye of 10 healthy subjects with both Cirrus and Stratus to assess reliability and then once in the same eye of 50 healthy subjects with both Cirrus and Stratus to compare the average obtained by each device.

RESULTS: Using TD-OCT, the coefficient of variations (CV) of the macular thicknesses within a 1-mm central area ranged from 0.7% to 3.3% (mean, 1.33%); with SD-OCT, the range was 0.2% to 1.3% (mean, 0.66%). The mean CV with SD-OCT was significantly smaller than with TD-OCT (P < .05). The average macular thicknesses with TD-OCT and SD-OCT were 197.2 ± 17.8 µm and 257.6 ± 19.6 µm, respectively. However, the correlation was significant (correlation coefficient, 0.916, P < .001).

CONCLUSION: Cirrus showed better reliability than Stratus. Using SD-OCT, the macula was 60-µm thicker than when measured with TD-OCT. Attention should be given to comparing data obtained using different OCT machines.

In spectral domain OCT (SD-OCT), light beams returning from the sample and reference paths are combined at the detector, a spectrometer that resolves the interference signals throughout the depth of each A-scan without varying the length of the reference path. This is possible because the spectrometer resolves the relative amplitudes and phases of the spectral components backscattered from all depths of each A-scan simultaneously using Fourier transformation. This allows SD-OCT to acquire retinal images approximately 50 times faster compared with TD-OCT. The substantial increase in scan speed makes it possible to acquire 3D datasets.

More reliable data might be obtained by using SD-OCT compared with TD-OCT because more information can be obtained with SD-OCT. We evaluated the reproducibility and correlated the retinal thickness measurements between TD-OCT and SD-OCT.

**PATIENTS AND METHODS**

To evaluate the reproducibility of the retinal thickness measurements with TD-OCT (Stratus OCT; Carl Zeiss Meditec, Inc., Dublin, CA) and with SD-OCT (Cirrus HD-OCT; Carl Zeiss Meditec, Inc.), the retinal thicknesses were measured five times in 10 eyes of 10 healthy subjects. The mean patient age was 29.3 ± 5.9 years (range, 22-38 years), and four patients were men. The CV, ie, the ratio of the SD to the mean, was calculated in each case.

The macular thickness was measured in 50 eyes of 50 healthy subjects with the two OCT instruments to determine the correlation of the retinal thickness between them. The mean patient age was 49.9 ± 18.0 years (range, 22-78 years), and 29 were men. No subject had an ocular disease or diabetes mellitus, and a best-corrected visual acuity was 20/20 or better. With Stratus OCT, macular thickness data were obtained using the Fast Macular Thickness scan pattern (Fig. 1). This scan pattern acquires six linear B-scans in a continuous, automated sequence. The scans are centered at the fovea in a radial pattern and separated by 30° increments. Each B-scan consists of 128 A-scans. The axial resolution of TD-OCT is less than 10 μm and that of SD-OCT is 5 μm. The macular cube 200 × 200-scan pattern in SD-OCT generates a

**Figure 1.** Top, Fast Macular Thickness scan pattern with TD-OCT. Bottom, Mean retinal thickness at the central 1-mm circle was 192 μm in a 36-year-old healthy woman with a best-corrected visual acuity of 20/20.
cube of data through a 6-mm-square grid by acquiring a series of 200 horizontal scan lines, each comprising 200 A-scans (Fig. 2). The axial resolution of SD-OCT is 5 μm. The average retinal thickness at the central 1-mm area was analyzed. Approximately 128 points were measured in a 1-mm circle with TD-OCT and approximately 872 points with SD-OCT. The macular thickness of each subject was measured with the two OCT instruments on the same day. These measurements were performed by three operators.

RESULTS

Both TD-OCT and SD-OCT had good reproducibility. The CVs of the macular thickness measurement with TD-OCT ranged from 0.7% to 3.3% (mean, 1.33%), whereas that with SD-OCT ranged from 0.2% to 1.3% (mean, 0.66%). The mean CV with SD-OCT was significantly smaller than with TD-OCT ($P < .05$, paired $t$-test) (Table).

The mean macular thickness in 50 healthy subjects measured with TD-OCT was 197.2 ± 17.8 μm (mean ± SD; range, 158-235 μm), and that measured with SD-OCT was 257.6 ± 19.6 μm (range, 211-313 μm). The mean macular thickness with SD-OCT was approximately 60 μm thicker than with TD-OCT, and the difference was significant ($P < .001$, paired $t$-test). The macular thickness measured with TD-OCT correlated well with that measured with SD-OCT (Pearson product moment correlation, $r = 0.916$, $P < .001$) (Fig. 3).

The relationship between age and the retinal thickness also was evaluated; however, no correlation was found (Pearson product moment correlation, TD-OCT, $r = -0.1$; $P > .05$; SD-OCT, $r = -0.15$; $P > .05$) (Fig. 4).

Apparent segmentation failures were not found in any cases in both TD-OCT and SD-OCT.

DISCUSSION

Reproducibility is one of the most important factors with any measurements, which is why we first measured it in this study. Both the TD-OCT and the SD-OCT had good reproducibility. The CV values of the macular thicknesses measured with TD-OCT ranged from 0.7% to 3.3% (mean, 1.33%), and those measured with SD-OCT ranged from 0.2% to 1.3% (mean, 0.66%). The mean CV with SD-OCT was significantly smaller than with TD-OCT ($P < .05$, paired $t$-test). Approximately 128 points were measured within the central 1-mm circle using TD-OCT, and approximately 872 points were measured using SD-OCT. It is reasonable that the difference in the number of data points
measured with SD-OCT could be the cause of the difference in reproducibility between the two instruments. Although the reproducibility with TD-OCT was slightly worse than with SD-OCT, the two machines provided reliable data compared with reports in which OCT-2000 was used to measure the retinal thickness. The number of A-scans per second is fixed at 100, axial resolution is 20 μm, and measurement density is 10 to 20 μm with OCT-2000. Hagimura et al. measured the foveal thicknesses more than 20 times in eight patients using OCT-2000, and the CV values ranged from 2% to 9%.14 Kanai et al. measured the foveal thicknesses five times in five patients using OCT-2000, and the CV was 5.2%.15

### TABLE

<table>
<thead>
<tr>
<th>Case</th>
<th>TD-OCT Macular Thickness (µm, mean + SD)</th>
<th>CV (%)</th>
<th>SD-OCT Macular Thickness (µm, mean + SD)</th>
<th>CV (%)</th>
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<tbody>
<tr>
<td>1</td>
<td>210.6 + 3.21</td>
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<td>272.0 + 1.22</td>
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<tr>
<td>5</td>
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<tr>
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<tr>
<td>10</td>
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<td>0.7</td>
<td>273.8 + 0.84</td>
<td>0.3</td>
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</table>

CV = the ratio of the standard deviation to the mean; TD-OCT = time domain optical coherence tomography; SD-OCT = spectral domain optical coherence tomography; SD = standard deviation.

*Figure 3.* The difference between TD-OCT and SD-OCT average retinal thicknesses in a central 1-mm area is approximately 60 μm. These two datasets are well correlated (correlation coefficient, 0.916; P < .001; Pearson product moment correlation).

*Figure 4.* No correlation is seen between age and retinal thickness.
measurement density is 5 μm with Cirrus. The reproducibility of the current data was better compared with these reports, probably because Stratus OCT and Cirrus HD-OCT have a greater capacity to measure and analyze the retinal thickness.

In this study, the average retinal thickness measured with TD-OCT was 197.2 ± 17.8 μm. Goebel and Franke reported that the average retinal thickness in healthy eyes in a 1-mm foveal circle using TD-OCT data was 197.1 ± 16.4 μm.16 Because their data were similar to ours, there may be little difference in the retinal thicknesses among several TD-OCT instruments, and there may be no difference in the retinal thicknesses between white and Japanese patients. However, the average retinal thickness measured with the SD-OCT was 257.6 ± 19.6 μm, approximately 60 μm thicker than that measured with TD-OCT. The difference in the definition of retinal thickness between the two OCT machines may explain the difference in the retinal thicknesses. TD-OCT defines retinal thickness as the distance from the surface of the inner limiting membrane to the boundary between the inner and outer segments of the photoreceptors (Fig. 1). However, SD-OCT defines the retinal thickness as the distance from the surface of the inner limiting membrane to the surface of the retinal pigment epithelium13 (Fig. 2). The different algorithms would be the cause of differences in the result. Indeed, the distance between the inner and outer segments of the photoreceptors and the retinal pigment epithelium measured with SD-OCT was approximately 54 μm (data not shown), which could explain the difference in retinal thickness between the two OCT instruments.

The retinal thickness measured using SD-OCT correlated strongly with that measured using TD-OCT. The good reproducibility of the two machines achieved a good correlation in retinal thickness between the two OCT machines. Attention should be given to the retinal thickness when data from different machines are compared.

Goebel and Franke16 also measured retinal thickness using the retinal thickness analyzer (RTA; Talia Technology, Mevaseret Zion, Israel); the average retinal thickness in a 1-mm circle was 172.9 ± 29.9 μm (range, 120–229 μm). The retinas of healthy subjects reported previously with OCT were thicker than those with the RTA.17 Neubauer et al. reported that the retinal thickness obtained with the RTA were thicker than that with OCT.18 Therefore, attention should be given to the machines used to measure retinal thickness when comparing retinal thickness among reports.

When we evaluated the relationship between age and retinal thickness, the macular thickness obtained with the TD-OCT and the SD-OCT were independent of age (Fig. 4). This result is supported by previous reports using OCT 200015 or RTA.19

In conclusion, both TD-OCT and SD-OCT had good reproducibility, although SD-OCT achieved better reproducibility. The mean retinal thickness measured with SD-OCT was approximately 60 μm thicker than that measured with TD-OCT. Care should be taken when comparing retinal thickness between the two OCT machines.

REFERENCES


