Comparison of retinal thickness measurements and segmentation performance of four different spectral and time domain OCT devices in neovascular age-related macular degeneration

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Comparison of retinal thickness measurements and segmentation performance of four different spectral and time domain OCT devices in neovascular age-related macular degeneration

Running head: Spectral and time domain OCTs in wet AMD


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ABSTRACT

**Aims:** To evaluate the reliability of different optical coherence tomography (OCT) devices and scanning patterns in the assessment of retinal thickness and segmentation performance in neovascular age related macular degeneration (nAMD).

**Methods:** 28 eyes with nAMD and 10 healthy eyes were imaged using conventional time domain (TD) OCT as well as three spectral-domain (SD) OCT systems. Radial scans of 6mm in size were compared between Stratus and Topcon OCT, in addition to raster scans of all three SD-OCT devices. Retinal thickness values were analyzed.

**Results:** Spectralis SD-OCT demonstrated highest values of all OCT devices in central millimetre thickness (CMMT) and Topcon OCT raster scans showed lowest values. Significant correlations could be found between the central mm thickness (CMMT) measurements of Cirrus and Spectralis OCT \( (r=0.87) \). Analyses showed best segmentation for Cirrus and Spectralis SD-OCTs. Cirrus 200x200x1024 scans showed 4% and Stratus OCT 38% moderate or severe segmentation errors.

**Conclusion:** Retinal thickness values were generally higher in SD-OCT analysis. Different performances of automatic retinal thickness analysis indicate the potential of different software algorithms to quantify retinal morphology in nAMD. Further development of current algorithms may improve quantification of retinal thickness detection in the future even further.
INTRODUCTION

Since optical coherence tomography (OCT) has been used in clinical ophthalmology, [1,2] several parameters have been introduced to quantify retinal morphology and have been investigated in chorioretinal disease.[3-6]

Among quantitative parameters, retinal thickness (RT), which has been defined as the distance between the inner- and outer retinal surface including subretinal fluid, was identified to be of specific interest to monitor retinal response to pathology and treatment.

Some studies have shown a correlation between RT and visual acuity (VA).[7] Other studies have reported RT to be a sensitive parameter to monitor the response of therapeutic interventions quantitatively.[8-14]

Recently, a new generation of OCT devices relying on spectral domain technology (SD-OCT) has been introduced by different manufacturers. This technology allows for higher resolution imaging and an improved scanning speed, enabling for retinal raster scans of the macular region with more than 120 B-scans.[15] Precise registration and localization of pathologic features in surface maps can be achieved by different registration methods using a scanning laser ophthalmoscope (SLO) or fundus camera.[16,17]

However, the plethora of new systems using different software analysis to identify RT implicates the need for a comparative study evaluating the specific performance of RT measurements.

Stratus OCT software has recently been tested for its reliability in RT measurements and showed significant errors in the detection of RT values due to segmentation errors and scan misalignment in chorioretinal disease.[18-21]

At this time, literature evaluating the performance of RT analysis in SD-OCT devices of different manufacturers in comparison to Stratus OCT is still rare.
Since increase in RT >100µm was one of the retreatment criteria in an OCT guided treatment regimen published by Fung et al, correct assessment of RT in neovascular age related macular degeneration (nAMD) is of particular relevance especially for follow up examinations in nAMD. Since more and more different OCT devices are currently available on the marked, a study comparing the segmentation performance of these different devices in nAMD is urgently needed.

It therefore is the aim of this study to evaluate the performance of different segmentation algorithms used in some of the most popular SD-OCT devices in patients with nAMD.

**PATIENTS AND METHODS**

**Patient inclusion**

Following a standardised ophthalmologic examination procedure comprising SNELLEN visual acuity test, dilated pupil ophthalmoscopy, fluorescence angiography and OCT imaging, 28 eyes of 26 consecutive patients met the inclusion criteria were included in this observational prospective, cross-sectional clinical study between January and May 2008. Indocyanine angiography was performed in selected cases. A retina specialist was responsible for the clinical identification of active choroidal neovascularisation (CNV). Ten eyes without any retinal disease were included to evaluate the performances of automatic retinal thickness analysis and the potential of the different software algorithm in eyes with healthy macula.

All examinations were conducted at the Department of Ophthalmology, Medical University of Vienna, Austria. The study followed the tenets of the Declaration of Helsinki and was approved by the local ethics committee. Before inclusion, all
patients signed an informed consent after a detailed discussion explaining the potential risks and benefits of the examination procedures.

For inclusion, patients had to present with newly diagnosed, angiographically documented, previously untreated, active subfoveal CNV secondary to nAMD. All angiographic lesion types were allowed. Exclusion criteria were a history of ocular disease other than AMD, previous intraocular surgery within the last 6 months, laser treatment, glaucoma, diabetic retinopathy, amblyopia or marked refractive media opacities.

**OCT Imaging**

Non-invasive and non-contact OCT imaging was performed in all patients following a standardised order using commercially available equipments. Three different examiners, following a strict scanning protocol, carried out all OCT examinations. Patients had time to rest between the examination procedures to avoid exhaustion to influence the results.

**Stratus OCT:**

Stratus OCT (Carl Zeiss Meditec, Dublin, CA) is supposed to be the most frequently used OCT device in current clinical practice. It relies on time domain OCT technology, achieving an axial resolution of 10-20µm. Scan length was set to 6mm. Scanning speed was 400 A-scans per second. Retinal thickness analysis was performed using 6 individual B-scans, which are arranged in a radial pattern.

**Topcon OCT:**

Topcon OCT (3D OCT-1000; Topcon Corp, Tokyo, Japan) is a SD-OCT system with an integrated non-mydriatic retinal camera. The device allows for fundus registration
of raster scans using a fundus photo. Scanning speed is 18000 A-scans per second. Axial resolution is 6µm. In this study, we used the raster scan containing 128 B scans as well as a radial pattern, comprising 6 scans which are arranged similar to the pattern used in Stratus OCT.

Cirrus OCT:
Cirrus SD-OCT (Carl Zeiss Meditec, Dublin, CA) achieves an axial resolution of approximately 5µm. Scanning speed is ~27000 A-scans per second. For registration, scans are registered to an scanning laser ophthalmoscope (SLO) image, which is performed with the scan. The scanning area measured 6x6mm. In this study we used the 512x128x1024 as well as the 200x200x1024 scan to image nAMD.

Spectralis OCT:
Spectralis HRA+OCT (Heidelberg Engineering, Inc., Heidelberg, Germany) combines high resolution cross-sectional OCT imaging of the retina with the ability to perform angiography and infrared and autofluorescence measurements with the same device. Scanning speed is ~40000 B-scans per second. B scans, are registered to the fundus using the simultaneously acquired SLO mode. A macular raster scan consisting of 37 or 49 B-scans was performed to image the foveal region in this study. Scanning patterns were chosen to suit the compliance of the individual patient, since more dense raster scans need longer time to perform the entire examination.

Segmentation analysis criteria
Two different readers analyzed all scans of all OCT devices. To analyze segmentation performance, we focused on the correct identification of the inner limit
of the neurosensory retina and the retinal pigment epithelium (RPE). The greatest error present in a single B-scan determined the classification of the error type in this scan. All scans included in a retinal raster scan were individually analyzed and classified into one of three consistent categories of increasing error severity. Errors in length scan were graded as negligible (≤50µm), moderate (50-200µm) and severe (≥200µm) errors and errors in width scan as negligible (≤0.5mm), moderate (0.5-2mm) and severe (≥2mm). The values for length and width scans for negligible, moderate and severe errors were selected based on our clinical opinion without statistical meaning. Figure 1 shows examples for segmentation errors in three categories according to deviation from normal in scan length and width for all OCT devices. Both readers were blinded to the others results as well as to patients identity lesion type. Frequency and severity of errors identified in an individual raster scan were added and entered into a database after the analysis was completed.

Statistics

All data were entered into a Microsoft Excel spreadsheet. For correlation and thickness deviation analysis, we used central 1 mm thickness (CMMT) and 3mm ETDRS-ring (nasal, temporal, superior and inferior) values since these values were performed in all OCT devices. The level of statistical significance and the correlation between the four methods were calculated by the Wilcoxon matched-pairs signed rank test, chi square test and Pearson correlation coefficients. Bland-Altman plots were used to find a potential dependency between differences and means of two measurements. P values of less than .05 were considered to be statistically significant. Statistical analysis was performed by Microsoft Excel and SPSS 12.0 software (SPSS Inc, Chicago, Illinois, USA).
RESULTS

Demographic data

In the study group, 28 eyes of 26 patients were examined. 10 patients were female. Eighteen right and 10 left eyes were included. The mean age of patients was 77±7.0 years. Mean visual acuity was 0.48±0.25 snellen lines. Mean, median, standard deviation, minimum, maximum, and 95% of confidence interval of different scanning patterns measuring of CMMT and the areas of 3mm ETDRS-ring are shown in Table 1. The mean (±standard deviation) age of control group patients with healthy eyes was 65±10 years.

Differences in retinal thickness measurements

Spectralis OCT retinal thickness measurements demonstrated the highest values of all OCT devices in (p<0.01 compared to all other OCT devices, tables 1 and 2). CMMTs differed by -56µm for Cirrus 512x128x1024, -56µm for Cirrus 200x200x1024, -122µm for Topcon OCT raster, -110µm for 3D OCT radial and -111µm for Stratus OCT when compared to Spectralis. Table 2 shows mean differences of the OCT pairs for CMMT. Second highest retinal thickness values were identified in Cirrus OCT (p<0.01, tables 1 and 2) followed by Topcon OCT (p<0.01, tables 1 and 2). Stratus OCT showed lowest retinal thickness values (p>0.5 compared to Topcon raster OCT, and p<0.01 compared to other scanning patterns, tables 1 and 2).

Similarly, in the healthy eyes group, the automatic analysis showed also that Spectralis OCT demonstrated the highest mean values of all OCT devices in the five central quadrants of the ETDRS ring followed by Cirrus OCT, Topcon OCT and of Stratus OCT (Figure 2).
Table 1: Central retinal thickness values measured with all OCT devices at central 1 mm thickness (CMMT), nasal, temporal, superior and inferior of 3mm ETDRS-ring. SD: standard deviation, min:minimum, max:maxmum, CI:confidence interval.

<table>
<thead>
<tr>
<th>CMMT</th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
<th>95%CI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stratus OCT</strong></td>
<td>272.75</td>
<td>257.00</td>
<td>72.53</td>
<td>193.00</td>
<td>473.00</td>
<td>15.2</td>
</tr>
<tr>
<td><strong>Topcon Raster</strong></td>
<td>261.82</td>
<td>254.50</td>
<td>84.63</td>
<td>22.00</td>
<td>427.00</td>
<td>17.7</td>
</tr>
<tr>
<td><strong>Topcon Radial</strong></td>
<td>273.93</td>
<td>277.00</td>
<td>74.69</td>
<td>118.00</td>
<td>533.00</td>
<td>15.6</td>
</tr>
<tr>
<td><strong>Cirrus 200x200x1024</strong></td>
<td>327.43</td>
<td>300.50</td>
<td>83.97</td>
<td>235.00</td>
<td>559.00</td>
<td>17.5</td>
</tr>
<tr>
<td><strong>Cirrus 512x128x1024</strong></td>
<td>327.25</td>
<td>305.00</td>
<td>81.98</td>
<td>232.00</td>
<td>559.00</td>
<td>17.1</td>
</tr>
<tr>
<td><strong>Spectralis OCT Raster</strong></td>
<td>383.54</td>
<td>363.50</td>
<td>89.91</td>
<td>273.00</td>
<td>582.00</td>
<td>18.8</td>
</tr>
</tbody>
</table>

**Nasal of 3mm ETDRS-ring**

<table>
<thead>
<tr>
<th>CMMT</th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
<th>95%CI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stratus OCT</strong></td>
<td>292.68</td>
<td>276.00</td>
<td>46.77</td>
<td>231.00</td>
<td>420.00</td>
<td>9.8</td>
</tr>
<tr>
<td><strong>Topcon Raster</strong></td>
<td>307.00</td>
<td>293.00</td>
<td>83.06</td>
<td>98.00</td>
<td>536.00</td>
<td>17.4</td>
</tr>
<tr>
<td><strong>Topcon Radial</strong></td>
<td>302.61</td>
<td>300.00</td>
<td>55.92</td>
<td>126.00</td>
<td>411.00</td>
<td>11.7</td>
</tr>
<tr>
<td><strong>Cirrus 200x200x1024</strong></td>
<td>345.71</td>
<td>330.50</td>
<td>49.27</td>
<td>262.00</td>
<td>430.00</td>
<td>10.3</td>
</tr>
<tr>
<td><strong>Cirrus 512x128x1024</strong></td>
<td>344.68</td>
<td>342.00</td>
<td>47.88</td>
<td>261.00</td>
<td>422.00</td>
<td>10.0</td>
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<tr>
<td><strong>Spectralis OCT Raster</strong></td>
<td>380.96</td>
<td>370.00</td>
<td>52.62</td>
<td>288.00</td>
<td>465.00</td>
<td>11.0</td>
</tr>
</tbody>
</table>

**Temporal of 3mm ETDRS-ring**

<table>
<thead>
<tr>
<th>CMMT</th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
<th>95%CI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stratus OCT</strong></td>
<td>281.21</td>
<td>266.50</td>
<td>42.13</td>
<td>219.00</td>
<td>359.00</td>
<td>8.8</td>
</tr>
<tr>
<td><strong>Topcon Raster</strong></td>
<td>284.82</td>
<td>282.00</td>
<td>59.61</td>
<td>104.00</td>
<td>406.00</td>
<td>12.5</td>
</tr>
<tr>
<td><strong>Topcon Radial</strong></td>
<td>282.21</td>
<td>278.50</td>
<td>56.41</td>
<td>151.00</td>
<td>396.00</td>
<td>11.8</td>
</tr>
<tr>
<td><strong>Cirrus 200x200x1024</strong></td>
<td>333.96</td>
<td>320.50</td>
<td>58.83</td>
<td>254.00</td>
<td>500.00</td>
<td>12.3</td>
</tr>
<tr>
<td><strong>Cirrus 512x128x1024</strong></td>
<td>330.25</td>
<td>319.50</td>
<td>52.06</td>
<td>255.00</td>
<td>455.00</td>
<td>10.9</td>
</tr>
<tr>
<td><strong>Spectralis OCT Raster</strong></td>
<td>369.04</td>
<td>352.00</td>
<td>63.36</td>
<td>274.00</td>
<td>525.00</td>
<td>13.2</td>
</tr>
</tbody>
</table>

**Superior of 3mm ETDRS-ring**

<table>
<thead>
<tr>
<th>CMMT</th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
<th>95%CI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stratus OCT</strong></td>
<td>285.79</td>
<td>270.50</td>
<td>39.27</td>
<td>240.00</td>
<td>386.00</td>
<td>8.2</td>
</tr>
<tr>
<td><strong>Topcon Raster</strong></td>
<td>275.11</td>
<td>274.00</td>
<td>74.69</td>
<td>7.00</td>
<td>408.00</td>
<td>15.6</td>
</tr>
<tr>
<td><strong>Topcon Radial</strong></td>
<td>265.82</td>
<td>280.00</td>
<td>81.44</td>
<td>23.00</td>
<td>385.00</td>
<td>17.0</td>
</tr>
<tr>
<td><strong>Cirrus 200x200x1024</strong></td>
<td>329.07</td>
<td>322.50</td>
<td>41.61</td>
<td>266.00</td>
<td>416.00</td>
<td>8.7</td>
</tr>
<tr>
<td><strong>Cirrus 512x128x1024</strong></td>
<td>325.39</td>
<td>321.00</td>
<td>39.60</td>
<td>266.00</td>
<td>420.00</td>
<td>8.3</td>
</tr>
<tr>
<td><strong>Spectralis OCT Raster</strong></td>
<td>372.89</td>
<td>360.00</td>
<td>56.89</td>
<td>301.00</td>
<td>526.00</td>
<td>11.9</td>
</tr>
</tbody>
</table>

**Inferior of 3mm ETDRS-ring**

<table>
<thead>
<tr>
<th>CMMT</th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
<th>95%CI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stratus OCT</strong></td>
<td>296.57</td>
<td>279.50</td>
<td>49.55</td>
<td>234.00</td>
<td>409.00</td>
<td>10.4</td>
</tr>
<tr>
<td><strong>Topcon Raster</strong></td>
<td>305.21</td>
<td>287.50</td>
<td>93.68</td>
<td>7.00</td>
<td>482.00</td>
<td>19.6</td>
</tr>
<tr>
<td><strong>Topcon Radial</strong></td>
<td>284.61</td>
<td>299.50</td>
<td>87.27</td>
<td>22.00</td>
<td>478.00</td>
<td>18.2</td>
</tr>
<tr>
<td><strong>Cirrus 200x200x1024</strong></td>
<td>344.32</td>
<td>329.50</td>
<td>58.77</td>
<td>275.00</td>
<td>517.00</td>
<td>12.3</td>
</tr>
<tr>
<td><strong>Cirrus 512x128x1024</strong></td>
<td>345.50</td>
<td>328.50</td>
<td>61.02</td>
<td>270.00</td>
<td>543.00</td>
<td>12.7</td>
</tr>
<tr>
<td><strong>Spectralis OCT Raster</strong></td>
<td>373.29</td>
<td>350.50</td>
<td>60.18</td>
<td>302.00</td>
<td>507.00</td>
<td>12.6</td>
</tr>
</tbody>
</table>
**Table 2**: Comparison and correlation of central 1 mm thickness values between all methods of measuring retinal thickness.

<table>
<thead>
<tr>
<th>Pair</th>
<th>Difference [mean ±SD (p value)]</th>
<th>Pearson correlation coefficient [r (p value)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stratus OCT &amp; Cirrus OCT 512x128x1024</td>
<td>54.5±38.0 (&lt;0.001)</td>
<td>0.89 (&lt;0.001)</td>
</tr>
<tr>
<td>Stratus OCT &amp; Cirrus OCT 200x200x1024</td>
<td>54.7±42.7 (&lt;0.001)</td>
<td>0.86 (&lt;0.001)</td>
</tr>
<tr>
<td>Stratus OCT &amp; Topcon OCT Raster</td>
<td>10.9±94.6 (0.55)</td>
<td>0.28 (0.145)</td>
</tr>
<tr>
<td>Stratus OCT &amp; Topcon OCT Radial</td>
<td>-1.2±77.6 (0.94)</td>
<td>0.44 (0.018)</td>
</tr>
<tr>
<td>Stratus OCT &amp; Spectralis OCT Raster</td>
<td>-110.8±47.9 (&lt;0.001)</td>
<td>0.85 (&lt;0.001)</td>
</tr>
<tr>
<td>Cirrus OCT 512x128x1024 &amp; Cirrus OCT 200x200x1024</td>
<td>-0.2±22.6 (0.97)</td>
<td>0.96 (&lt;0.001)</td>
</tr>
<tr>
<td>Cirrus OCT 512x128x1024 &amp; Topcon OCT Raster</td>
<td>65.4±91.4 (0.001)</td>
<td>0.40 (0.036)</td>
</tr>
<tr>
<td>Cirrus OCT 512x128x1024 &amp; Topcon OCT Radial</td>
<td>53.3±69.0 (&lt;0.001)</td>
<td>0.62 (&lt;0.001)</td>
</tr>
<tr>
<td>Cirrus OCT 512x128x1024 &amp; Spectralis OCT Raster</td>
<td>-56.3±83.2 (&lt;0.001)</td>
<td>0.87 (&lt;0.001)</td>
</tr>
<tr>
<td>Cirrus OCT 200x200x1024 &amp; Topcon OCT Raster</td>
<td>65.6±95.3 (0.001)</td>
<td>0.36 (0.059)</td>
</tr>
<tr>
<td>Cirrus OCT 200x200x1024 &amp; Topcon OCT Radial</td>
<td>62.0±82.2 (&lt;0.001)</td>
<td>0.36 (0.001)</td>
</tr>
<tr>
<td>Cirrus OCT 200x200x1024 &amp; Spectralis OCT Raster</td>
<td>-56.1±40.9 (&lt;0.001)</td>
<td>0.89 (&lt;0.001)</td>
</tr>
<tr>
<td>Topcon OCT Raster &amp; Topcon OCT Raster</td>
<td>-12.1±100.0 (0.53)</td>
<td>0.22 (0.270)</td>
</tr>
<tr>
<td>Topcon OCT Raster &amp; Spectralis OCT Raster</td>
<td>-121.7±94.9 (&lt;0.001)</td>
<td>0.41 (0.030)</td>
</tr>
<tr>
<td>Topcon OCT Radial &amp; Spectralis OCT Raster</td>
<td>-109.6±78.6 (&lt;0.001)</td>
<td>0.56 (0.002)</td>
</tr>
</tbody>
</table>
Correlation of retinal thickness measurements:

Significant correlations could be found between the CMMT measurements of Cirrus and Spectralis OCT (table 2, \( r = 0.87 \) for Cirrus 512x128x1024 and Spectralis OCT, \( r = 0.89 \) for Cirrus 200x200x1024 and Spectralis). The best concordance could be found between both Cirrus raster scans (200x200x1024 and 512x128x1024 \( r = 0.96, p<0.001 \)). An \( r < 0.4 \) could be found for correlation of Cirrus and Topcon OCT. Stratus and Topcon OCT correlated with an \( r = 0.44 \), Spectralis OCT and Topcon OCT with an \( r = 0.41 \), respectively. No statistically significant correlations were found between Stratus- and Cirrus OCT scans and between Stratus- and Spectralis OCT (table 2). Figures 3 and 4 show Bland-Altman plots comparing mean and difference CMMT values between OCT devices.

Performance of automatic segmentation procedures

All B-scans of all OCT and SD-OCT devices were analyzed for correct segmentation e.g. identification of the inner retinal surface and the RPE.

These analyses showed best segmentation performance for Cirrus SD-OCT raster scans. Data showed no significant difference between Cirrus 512x128x1024 and the 200x200x1024 raster scan. Second best performance could be seen in Spectralis SD-OCT with 2% severe and 25% moderate segmentation errors. Topcon OCT performed worse with 22% severe errors and 10% moderate errors.

Analyzing the radial scan patterns of Stratus and 3D-OCT devices, Stratus OCT showed a better performance with 3% severe and 35% moderate errors. 25% moderate and 20% severe errors were found to be present in 3D-OCT (Figure 5).
The automatic segmentation in the healthy eyes was excellent without any segmentation error.

**DISCUSSION**

The present study was performed to investigate the comparability of retinal thickness measurements and to assess the segmentation performance of current OCT and SD-OCT devices from different manufacturers in patients with active, untreated nAMD. For this purpose, we examined patients with untreated subfoveal CNV using some of the most frequently used OCT devices which are commercially available.

In apart from new SD-OCT technology, custom software analyses seem to play an important part correct delineation of the retinal thickness structures. In this study, Cirrus 200x200x1024 showed best segmentation performance compared to other SD-OCT imaging modality with absence severe of segmentation errors. Advanced segmentation software is most likely the reason for better segmentation performance, since axial resolution and scanning speed are similar among competing devices. Topcon OCT showed most segmentation errors. Spectralis OCT tends to make more errors in segmentation procedures (25% moderate segmentation errors). This might to be related to the inferior segmentation software of Spectralis OCT, which is not yet able to profit from the outstanding image quality of the Spectralis OCT device.

The total number of B-scans in the scanning area is another important factor which affects the segmentation performance. In contrast to the raster scans which are performed by SD-OCT devices, only 6 scans are performed in Stratus OCT. Therefore, segmentation errors can affect the final result negatively since most of the
area is interpolated between the scans. In our study, we found excellent concordance between different Cirrus raster scans which has to be suggested since the same software analysis were applied to the both scans. We also observed a good correlation between Cirrus OCT and Spectralis which might to be related to the superior image quality of both devices. This result indicates that resolution, scanning speed and image quality might be most important to assess retinal thickness correctly.

It is well known that time domain Stratus OCT detects the inner cone – outer cone segment barrier of the outer photoreceptors and not the RPE. This implicates that CMMT measurements should be lower when compared to measurements between the retinal surface and the true RPE [21] and might also explain, why CMMT measurements were significantly lower in Stratus OCT compared to all other devices in our study. In contrast, the segmentation software of Spectralis OCT delineates the RPE in a deeper layer than Cirrus OCT, which detects the innermost hyperreflective RPE layer. This might be the reason for higher retinal thickness values in Spectralis OCT analysis. The delineation of the outer retinal border at the level of inner side of RPE renders Spectralis more sensitive and relevant to the detection of any pigment epithelium detachment (Spectralis example). It should therefore be a suggestion for optimization of segmentation procedures to locate the outer line of segmentation at the level of RPE.

Advanced software analysis and dense retinal imaging due to the raster scanning mode allowed for precise detection and topographically reliable visualization of retinal structures and retinal thickness values. Nevertheless, significant differences still exist between SD-OCT retinal thickness analysis and segmentation procedures which should be addressed in advanced software development.
OCT manufacturers should be asked to support universal and transparent data interfaces since relevant differences between OCT devices may aggravate patient follow up and study analysis.
REFERENCES


**Figure Legend:**

**Figure 1:** Segmentation errors in three categories according to deviation from normal in scan length and width.

**Figure 2:** Mean retinal thickness values measured with all OCT devices in healthy eyes within the nine Early Treatment Diabetic Retinopathy Study-type regions optical coherence tomography imaging. Left eyes were converted so that the temporal hemifield is represented on the left hand side in all panels.

**Figure 3:** Bland-Altman plots comparing mean and difference central 1 mm thickness values between spectral domain OCT devices.

**Figure 4:** Bland-Altman plots comparing mean and difference central 1 mm thickness values between Stratus OCT and the spectral domain OCT devices.

**Figure 5:** Segmentation error frequency analysis of used OCT devices.
Figure 2:

A

348
348 274 333
343

Spectralis OCT Raster

B

327
328 244 312
325

Cirrus 200x200 SD-OCT

C

327
328 256 315
327

Cirrus 512x128 SD-OCT

D

293
297 224 274
289

Topcon Raster

E

294
296 220 280
292

Topcon Radial

F

274
274 198 254
272

Stratus OCT