Repeatability and Reproducibility of Subfoveal Choroidal Thickness in Normal Eyes of Japanese Using Different SD-OCT Devices

Toshifumi Yamashita, Takehiro Yamashita, Makoto Shirasawa, Noboru Arimura, Hiroto Terasaki, and Taiji Sakamoto

PURPOSE. To compare subfoveal choroidal thickness (SCT) measurements of three different commercially available spectral-domain optical coherence tomography instruments with healthy eyes of Japanese.

METHODS. A prospective, cross-sectional study was performed at a single institution. SCT of the right eye of 43 normal subjects was measured using three different SD-OCTs: Heidelberg Spectralis-OCT (Spectralis), Cirrus HD-OCT (Cirrus), and Topcon 3D OCT-1000 Mark II (Topcon). Two separate measurements were performed for the same eye with a maximum by a single examiner. SCT was defined as the distance from the posterior edge of the retinal pigment epithelium to the choroid/sclera junction. After manual segmentation, measurements were made using calipers equipped on each machine by masked raters. Intraclass, interrater, and intermachine agreements were assessed.

RESULTS. Forty-three subjects (mean age, 30.5 years) were enrolled. Of 43 eyes, the SCT of 39 eyes (90.7%) could be measured using each machine. Intraclass correlation coefficients (95% confidence intervals) were 0.976 (0.954–0.987), 0.958 (0.919–0.978), and 0.939 (0.895–0.971) with Spectralis, Cirrus, and Topcon, respectively. Interrater correlation coefficients (95% confidence interval) were 0.944 (0.893 to 0.971), 0.956 (0.831 to 0.983), and 0.924 (0.825 to 0.964) with Spectralis, Cirrus, and Topcon, respectively. The average SCT was 272.6, 272.8, and 269.2 μm with Spectralis, Cirrus, and Topcon, respectively. The intermachine correlation coefficient was significantly high among the machines (P < 0.001, Spearman). 0.97 (Spectralis-Cirrus), 0.96 (Cirrus-Topcon), and 0.98 (Topcon-Cirrus). Bland–Altman plot analysis showed no typical trend among the machines.

CONCLUSIONS. SCT measurements obtained with three different SD-OCTs were highly correlated and could be used interchangeably. (http://upload.umin.ac.jp number, UMIN000005287.) (Invest Ophthalmol Vis Sci. 2012;53: 1102–1107) DOI:10.1167/iovs.11-8836

The accumulating evidence shows that the choroid plays an important role in the pathogenesis of various retinal diseases. For example, a choroidal abnormality is often noted in age-related macular degeneration examined with indocyanine green angiography.1,2 In diabetic retinopathy, choroidal pathology is sometimes associated with retinal changes, which are found in histology or angiography.3,4 Although a qualitative and quantitative evaluation of choroidal morphology has not been easy to obtain in a clinical setting.

Optical coherence tomography (OCT) has become an essential tool not only for diagnosing various retinal diseases, but also for determining their effective treatment. Above all, paradigms have changed rapidly since the emergence of a new generation of Fourier domain (FD) and spectral domain (SD)-OCT. These OCT machines perform scans much faster, allowing systematic raster scanning associated with a higher resolution, thus providing more extensive morphologic details. Spaide et al.5 recently reported adequate examination and measurement of choroidal thickness in normal and pathologic states with enhanced depth imaging (EDI)-OCT, which has brought great progress to the field of retinochoroidal pathophysiology. Indeed, many reports on choroidal pathology were published subsequently using this EDI-OCT and examination of the choroid with OCT is becoming a standard method for evaluating ocular diseases.6–16 At the same time, the technique of averaging images contributed the reduction of speckle noises, which improved the continuity of retinal structures. Cirrus HD-OCT and Topcon OCT have this image averaging.

Currently, it is recognized that the algorithms of commercially available machines differ and the results of each machine for retinal thickness evaluation are not interchangeable.17–22 Many commercially available SD-OCT machines are applicable for choroidal examinations. To our knowledge, however, there are few studies comparing choroidal thickness measurements taken with different commercially available SD-OCT machines in a standardized and prospective way,23 and it is necessary to know the characteristics of each machine, including interexamination and interdevice reproducibility.

The aim of this study was to take choroidal thickness measurements of normal eyes with three frequently used SD-OCT machines—Heidelberg Spectralis-OCT, Cirrus HD-OCT, Topcon 3D OCT-1000 Mark II—and compare the results.

METHODS

All the investigations followed the tenets of the Declaration of Helsinki. Written informed consent was obtained from all the subjects in this study. The study was approved by the Ethics Committee of Kagoshima University Hospital (Kagoshima, Japan) and registered with university hospital medical network (UMIN)–clinical trials registry.

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### Subjects
This is a cross-sectional prospective observational study. Originally, the number of enrollment eyes was projected to be 40 from March 15 to April 30, 2011. Primary outcome measured was the difference in choroidal thickness examined with three different OCT machines: Heidelberg Spectralis-OCT (Spectralis; Heidelberg Engineering, Heidelberg, Germany), Cirrus HD-OCT (Cirrus; Carl Zeiss Meditec Inc., Dublin, CA), and 3D OCT-1000 Mark II (Topcon; Topcon Corp., Tokyo, Japan).

Volunteers with no known eye disease were used to evaluate the ability to image and measure the thickness of the choroid. Only the right eye of each volunteer was examined. Eligibility criteria were as follows: 18 years of age or older and 40 years of age or younger, eyes considered normal that were examined by funduscopy and OCT. Exclusion criteria included eyes with known ocular diseases such as glaucoma, and diabetic retinopathy; subjects with known systemic diseases such as hypertension and diabetes; subjects with highly myopic eyes of $-6.0$ D or more spherical equivalent; subjects with a history of intraocular surgery or injection; and eyes in which the ocular fundus could not be observed due to media opacities. No eye was excluded due to poor OCT image quality because of poor fixation.

### Measurement of Subfoveal Choroidal Thickness
Before measurement, all eyes received ocular examinations, which included slit-lamp examination for anterior eye and funduscopic examination for ocular fundus. Intraocular pressure was measured with a pneumotonometer (CT-80; Topcon). Best-corrected visual acuity was examined after determining refractive power with autorefractor keratometer (RM8900; Topcon).

All eyes were examined without mydriasis and two separate measurements were performed by a single examiner (TY) using Spectralis, Cirrus, and Topcon. The order of OCT examinations was chosen randomly for each patient. The order of second OCT examinations was also chosen randomly. Because there are significant diurnal or daily fluctuations of choroidal thickness, all examinations of a single patient were done within 3 hours on the same day.24-25

### Optical Coherence Tomography Scanning Protocols
All OCT examinations were performed according to the analysis protocol and variables for each device (Table 1). After each examination, the best image was projected onto a computer screen and evaluated by three independent masked graders (TY, MS, NA). When two or more graders determined that both inner and outer borders of the choroid of the image were clearly distinguishable, the image was deemed acceptable and used for the following analysis. Measurement of choroidal thickness (rating) was done in a masked fashion by a single rater (HT) with no information of eyes. For interrater comparison, each image was measured by two independent raters (TS, HT) with no information of eyes or the results by the other rater, as the previous report.23 These two groups of data were used for the analysis.

In the following procedures, the measurement of choroidal thickness (rating) was done on the OCT screen. Since the original OCT images were generally too small to differentiate lines of retinal pigment epithelium (RPE) or other structures, the images were zoomed onto the OCT screen as described in the following text.

#### Spectralis
The choroidal image was obtained according to the previous method.5 In this study, the protocol of OCT star was performed centering on the fovea. This protocol consisted of 30° (length) cross lines with 768 A-scans/B-scans and averaged 100 B-scans per image (ART = 100). The device was positioned close enough to the eye to create an inverted image near the top of the display. Sufficient separation from the top of the display was ensured to avoid image ambiguity from image folding with respect to zero depth. After the B-scan scale was adjusted to 1:1 and imaging size was doubled, the observer determined subfoveal choroidal thickness perpendicular from the outer edge of the hyperreflective RPE to the inner sclera centered on the fovea using a measuring tool built-in linear measuring tool. The thickness of the choroid at the areas, 750 μm temporal to the fovea and 750 μm nasal to the fovea, was also examined. The average thickness of vertical scans and horizontal scan was referred to as the subfoveal choroidal thickness (Fig. 1).

### Table 1. Scanning Protocols of Optical Coherence Tomography Instruments

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Protocol</th>
<th>Scan Areas, Lines</th>
<th>A-Scans per B-Scan</th>
<th>Averaging or Overlapping per Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectralis</td>
<td>OCT Star (Enhanced Depth Imaging)</td>
<td>30 degrees (length) cross lines</td>
<td>768</td>
<td>100</td>
</tr>
<tr>
<td>Cirrus</td>
<td>HD 5 Line Raster</td>
<td>6-mm parallel lines spaced 0.25 mm</td>
<td>1024</td>
<td>4</td>
</tr>
<tr>
<td>Topcon</td>
<td>CROSS (Enhanced Choroidal Mode)</td>
<td>6-mm cross lines</td>
<td>1024</td>
<td>4</td>
</tr>
</tbody>
</table>

### Figure 1. Representative choroidal images of each SD-OCT machines obtained from case 1. (A) Original image of Spectralis. (B) Screen image of measurement of choroidal thickness using the “measure tool,” which is built in Spectralis. (C) Original image of Cirrus. (D) Screen image of measurement of the choroidal thickness using the “Caliper tool,” which is built in Cirrus. (E) Original image of Topcon. (F) Screen image of measurement of the choroidal thickness using the “Caliper Function,” which is built in Topcon.
Cirrus. The choroidal image was obtained according to the previous method. In this study, the protocol of HD 5 Line Raster spaced at 0.25 mm was performed centering on the fovea. This protocol consisted of 6-mm parallel lines with 1024 A-scans/B-scans and averaging 4 B-scans per image. The images were not inverted to bring the choroid into closer proximity to the zero-delay line because image inversion using Cirrus software results in a low-resolution, pixelated image. To be included in this study, images had to be taken as close to the fovea as possible, by choosing to image the thinnest point of the macula, with the understanding that slight differences in positioning could affect the measured thicknesses. After approximately doubling the size of imaging, the observer determined subfoveal choroidal thickness perpendicularly from the outer edge of the hyperreflective RPE to the inner sclera, centering on the fovea using a “caliper tool,” that is, a built-in linear measuring tool. The thickness of the horizontal scan centered on the fovea was referred to as subfoveal choroidal thickness. The thickness of the choroid at the areas, 750 μm temporal to the fovea and 750 μm nasal to the fovea, was also examined (Fig. 1).

Topcon. The protocol of the enhanced choroidal mode cross scan was performed centering on the fovea. This protocol consisted of 6-mm cross lines with 1024 A-scans/B-scans and overlapping 4 B-scans per image and direct B-scan observation was available. After the B-scan scale was adjusted to 1:1 and approximately doubling the size of imaging, the observer determined subfoveal choroidal thickness perpendicular from the outer edge of the hyperreflective RPE to the inner sclera, centered on the fovea using a “caliper function,” that is, a built-in linear measuring tool. The thickness of the choroid at the areas, 750 μm temporal to the fovea and 750 μm nasal to the fovea, was also examined. The average thickness of vertical and horizontal scans was referred to as the subfoveal choroidal thickness (Fig. 1).

Statistical Analysis

All statistical analyses were performed with a commercial analytical package (SPSS statistics 19 for Windows; SPSS Inc., IBM, Somers, NY). The subfoveal choroidal thickness measurements from each machine were compared with those of two of three machines (Spectralis versus Cirrus, Cirrus versus Topcon, Topcon versus Spectralis) using paired t-tests. Spearman correlations between subfoveal choroidal thicknesses of two of three machines were also calculated. The intraclass and interrater correlation coefficients using a two-way mixed-effects model for measurements of absolute agreement were computed. The coefficient of variation (SD/average) was also calculated. Two-way ANOVA with Bonferroni's post-test correction was used to compare choroidal thickness at the different locations examined (subfoveal, nasal, and temporal). Bland–Altman plots were generated to assess agreement of measurements between two of three machines. Differences in thickness between machines were plotted against mean choroidal thickness measurements on these graphs. A value of $P < 0.05$ was considered to be statistically significant.

RESULTS

During the study period, 50 volunteers, all Japanese, were screened for this project, but 7 eyes were excluded because of high myopia. As a result, 43 eyes were studied and 39 of these eyes gave clear choroidal images. Age ranged from 19 to 40 years (mean ± SD: 27.5 ± 7.8 years). Twenty subjects were females. Refractive errors were −3.1 ± 1.8D (mean ± SD). The subfoveal choroidal thickness measured with Spectralis was 66.15 ± 61.15 μm at the first examination and 271.31 ± 61.12 μm at the second examination. The choroidal thickness measured with Cirrus was 276.59 ± 69.82 μm at the first examination and 269.08 ± 61.97 μm at the second examination. The choroidal thickness measured with Topcon was 269.05 ± 63.54 μm at the first examination and 260.75 ± 61.67 μm at the second examination. At the first examination, choroidal thickness could not be measured in 39/43 eyes (90.7%), with each of Spectralis, Cirrus, or Topcon. Eyes for which choroidal thickness could not be measured were common in the second examination (Cases 6, 34, 35, and 42). In these eyes, neither the first nor the second examination showed sufficiently clear imaging for choroidal thickness evaluation, whereas clear imaging was obtained in both the first and the second examinations in the other 39 eyes.

Repeatability of Examinations: Intraclass Comparison

Coefficient of variance was 0.23 or 0.24 for all three machines except for the nasal area. Results of choroidal thickness measurements were significantly well correlated with two ratings.

Table 1. Intraclass Correlation Coefficient

<table>
<thead>
<tr>
<th>Location</th>
<th>Spectralis</th>
<th>Cirrus</th>
<th>Topcon</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nasal</td>
<td>0.27 (0.957 to 0.989)</td>
<td>0.28 (0.941 to 0.984)</td>
<td>0.26 (0.706 to 0.980)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Subfoveal</td>
<td>0.23</td>
<td>0.24</td>
<td>0.23</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Temporal</td>
<td>0.904 (0.803 to 0.951)</td>
<td>0.918 (0.835 to 0.958)</td>
<td>0.893 (0.700 to 0.953)</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

ICC, intraclass correlation coefficient; CI, confidence interval.

Table 2. Intraclass Correlation Coefficient

<table>
<thead>
<tr>
<th>Location</th>
<th>Spectralis</th>
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<th>$P$</th>
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 ICC, intraclass correlation coefficient; CI, confidence interval.

Table 3. Intermachine Comparison

<table>
<thead>
<tr>
<th>Instruments</th>
<th>Mean Difference (μm)</th>
<th>Range of Difference (μm)</th>
<th>SD</th>
<th>95% CI</th>
<th>$P$ Value, Welch’s t-Test</th>
<th>ICC</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectralis–Cirrus</td>
<td>−0.23</td>
<td>−40.0 to 39.5</td>
<td>16.39</td>
<td>−5.54 to 5.08</td>
<td>0.93</td>
<td>0.968</td>
<td>0.940 to 0.983</td>
</tr>
<tr>
<td>Cirrus–Topcon</td>
<td>3.60</td>
<td>−39.0 to 48.5</td>
<td>18.13</td>
<td>−2.28 to 9.48</td>
<td>0.22</td>
<td>0.958</td>
<td>0.922 to 0.978</td>
</tr>
<tr>
<td>Topcon–Spectralis</td>
<td>−3.37</td>
<td>−27.5 to 47.0</td>
<td>13.73</td>
<td>−7.82 to 1.08</td>
<td>0.13</td>
<td>0.975</td>
<td>0.952 to 0.987</td>
</tr>
</tbody>
</table>

Mean difference: the average difference on each eye. Each difference was calculated by subtracting the data of machine 1 from data of machine 2.
The intraclass correlation coefficient was high with each machine (Table 2).

**Interrater Comparison of Subfoveal Thickness**

Subfoveal choroidal thickness examined with any two of three machines correlated well with each other (Table 3). The intraclass correlation coefficient was >0.95 for any combination. Choroidal thickness measurement with Cirrus was 0.23 μm larger than that with Spectralis, but it did not reach statistical significance (P = 0.93). Choroidal thickness measurement with Cirrus was 3.6 μm larger than that with Topcon, with no statistical significance (P = 0.22). Choroidal thickness measurement with Spectralis was 3.37 μm larger than that with Topcon, with no statistical significance (P = 0.13). The maximum values for the differences were −40.0 μm in Spectralis–Cirrus, 48.5 μm in Cirrus–Topcon, and 47.0 μm in Topcon–Spectralis (Table 3).

The correlation of choroidal thickness measured by these three machines was well preserved in the different areas such as nasal or temporal to the fovea (Table 4).

**Reproducibility of Examinations: Interrater Comparison**

Coefficient of variance was 0.22 to 0.23 for all three machines in the subfoveal area. Results of choroidal thickness measurements were significantly well correlated by two raters. The intrarater correlation coefficient was high with each machine (Table 5).

**Bland–Altman Plot Analysis**

There was no typical trend, such as a proportional error or variation of at least one method depending strongly on the magnitude of measurements, in the Bland–Altman plots (Fig. 2).

**Cases with No Choroidal Thickness Measurements**

None of the three machines gave clear images of SD-OCT for choroidal measurements in the following four eyes. The cases were as follows: a 34-year-old male with refractive errors of −4.25 D (Case 6); a 33-year-old female with refractive errors of −0.25 D (Case 4); a 24-year-old female with −0.50 D of refractive errors (Case 35); and a 31-year-old male with refractive errors of −4.25 D (Case 42). All had a large choroidal thickness >500 μm (Fig. 3).

**DISCUSSION**

In this study, we compared three different commercially available SD-OCT machines—Spectralis, Cirrus, and Topcon—in a head-to-head study of normal subjects to measure subfoveal choroidal thickness in a prospective manner. Two separate examinations showed good reproducibility with each machine.

There are many reports showing head-to-head comparisons of different SD-OCT for normal subjects, but they focus on retinal nerve fiber layer thickness or retinal thickness.17–22 To the best of our knowledge, this is the only report on a head-to-head analysis of different commercially available machines regarding choroidal thickness measurements; in their report, they studied three machines, which are different from the present machines.23 Since the first report of EDI-OCT, OCT imaging of the choroid has attracted the interest of clinicians and studies of the choroid using EDI-OCT are increasing in number.5 Because of the current commercial availability of various SD-OCT machines and the more frequent use of these machines in ongoing and planned longitudinal studies of choroid, we believe this report is of value to shed light on the usefulness and limitations that might exist when using data obtained by various SD-OCT machines.

We found that all three SD-OCTs have a very high correlation to each other for subfoveal and parafoveal choroidal thickness measurements. Pearson correlation coefficients were exceptionally high for average choroidal thickness and did not differ among machines. Of note, in previous studies of intermachine comparisons of retinal nerve fiber layer thickness or retinal thickness, the data from each machine were neither completely compatible nor interchangeable.17–22 There were consistent differences in retinal thickness measurements among machines. It was hypothesized that the segmentation of outer retina differed among machines, which led to the intermachine difference; that is, the inner retinal border was not different, but the outer border was different (e.g., the outer border of the retina was set at the RPE for Cirrus, whereas it was set at the photoreceptor outer segment tip for Topcon).17,22 Thus, it is easy to understand that the macular thick-
ness of a normal eye was approximately 20 to 40 μm larger with Cirrus than with Topcon.\textsuperscript{17,22}

On the other hand, recently, Heussen et al.\textsuperscript{27} reported that manual correction of the outer retinal boundary to a standardized reference location could yield similar retinal thickness measurements across Cirrus, Spectralis, and Topcon 3D OCT-2000. Our present result is in accord with their results, although they measured retinal thickness, not choroidal thickness. Indeed, we drew the boundaries of the choroid manually in this study, resulting in each machine being identical. The results of the present study and Heussen’s report strongly support the hypothesis that the fixed bias among machines when measuring with SD-OCT is attributable mainly to the segmentation algorithm.

Of importance is that the Bland–Altman plots show maximum differences of up to 50 μm and a fair number of points >20 μm between the machines. The 95% limits of agreement indicate a spread of >30 μm between the Cirrus and both other machines. We could not figure out the exact reason for this result. Compared with the retinal configuration on SD-OCT, the border of choroid/sclera was not clear on SD-OCT. In addition, the choroidal measurement was performed in a strictly masked fashion in this study. These factors might have something to do with this result. It is possible that an 80-μm range of difference seems high. However, the range was almost the same as that reported by Branchini and colleagues.\textsuperscript{25} In their manuscript, the range of difference between Cirrus and Spectralis was +12.81% to −13.33% and the range was 26.14%. The average choroidal thickness of their result was 345 μm. As a result, the range was approximately 89 μm, which is equal to that of the present study. This similarity would support the credibility of these two studies. Additionally, we could not find any specific factor to cause the difference between machines. Therefore, the subtle change of choroidal thickness on SD-OCT might not be meaningful for clinical trials.

Among the 43 examined eyes, choroidal thickness measurements could not be done successfully in 4 eyes, which were common to the three machines. Thus, the machines were not the factor; rather, it was the individual eyes. The images of these eyes showed a clear retinal configuration and inner border of the choroid, but an obscure choroid boundary. The subfoveal choroidal thicknesses of these eyes were all >500 μm, although the exact thickness was not measurable. Thus, eyes with a thick choroid, probably with deep pigmentation as well, might not be suitable for choroidal imaging with the present machines. For these eyes, a high-penetration OCT machine with a longer wavelength would be necessary.\textsuperscript{15,28} Furthermore, the present results do not mean that the three machines have an equal sensitivity. Rather, these exceptional cases might have been included coincidentally in this study. To compare the sensitivity of the three machines correctly, intermachine comparison should be done on many more cases by more graders. In the previous report, subfoveal choroidal thickness could be measured in all subjects: 18 White, 5 Asians, 3 Hispanics, and 2 African Americans.\textsuperscript{23} We cannot figure out why the measurability was so different. This might be a characteristic of Asian populations with moderate pigmentation and thick choroid. It should be noted that the present subjects were all Japanese; thus, the results might differ from subjects of other ethnic populations.

Retinal thickness is one of the major treatment criteria for age-related macular degeneration or diabetic macular edema. Therefore, it is particularly important to know the characteristics of each OCT machine in a clinical setting. At present, choroidal thickness is not yet used as a major criterion to determine treatment. Rather, it is used for investigating the pathology of diseases. However, according to increasing information on the choroid from studies using OCT, it will be a treatment criterion for ocular diseases in the very near future. For example, the choroidal thickness of Vogt–Koyanagi–Harada disease is reduced after successful steroid treatment; thus, it would be expected to be an indicator for performing or not performing steroid treatment.\textsuperscript{11} Choroidal thickness is influenced by intraocular pressure and it might become a criterion for glaucoma treatment, although the results are still controversial.\textsuperscript{10,24} Because SD-OCT is noninvasive to examiners, it might be used for evaluating systemic conditions as well. One may argue that manual segmentation is time-consuming and troublesome in a clinical setting. However, because choroidal thickness was measured easily with a caliper equipped on each machine, the present method using manual segmentation is practical even in clinical practice.

For a clinical setting, the quality of images and the ease of obtaining clear images would be important factors in choosing a machine. Although there was some tendency, we could not conclude which machine is superior because of lack of objective method to quantitate these factors. This issue should be studied in the near future.

**Figure 2.** Bland–Altman plots for choroidal thickness of each machine. Solid line indicates the average mean difference, whereas dotted lines delineate 95% confidence limits of agreement. There is not a specific tendency to cause the difference between machines.

**Figure 3.** An immeasurable SD-OCT choroidal image on Spectralis. Although retinal structure is clearly identifiable and RPE layers are evident, the outer border of the choroid is obscured. The exact thickness of the subfoveal choroid could not be measured. The presumed choroidal thickness is >500 μm.
Strengths of the study include its prospective design, which recruited a number of healthy subjects with a wide range of choroidal thicknesses. Scans of each eye were performed within a limited time, which minimized the possibility of choroidal thickness change caused by diurnal variations, fluctuations of intraocular pressure, and circulating catecholamines. Limitations of this study are that scans were acquired from young healthy subjects with no ocular pathology and did not reflect those of patients seen in a routine outpatient setting. For instance, the clarity of images of patients could be hindered by an ocular pathology such as significant media opacity or masking of choroidal reflectance by intraocular tissue. These issues, especially the age interval, should be remembered in interpreting the present results. Second, there are always concerns about manual segmentation approaches, which might cause an uncontrollable bias among examiners. We performed interrater comparison in this study, which was found to be sufficiently high. However, the raters of the present study were well trained. If the agreement ratio of many different raters is proven to be high on each device, the present results should be more generalized and the present machines could be used interchangeably with confidence. Third, we evaluated the specific scanning protocol of only three SD-OCT machines commonly used now. It is uncertain whether our observations can be generalized for other SD-OCT machines or other scanning protocols. Besides, the present results can apply to the choroidal thickness of the subfoveal or parafoveal areas. We do not have any evidence of the choroidal thickness of other areas. This should also be kept in mind when interpreting the present data.

In conclusion, the subfoveal choroidal thickness measurements obtained with Spectralis, Cirrus, and Topcon would be almost identical and interchangeable. Because it is an easy, reproducible, and noninvasive examination, it can be used more often in a clinical setting. The data could provide a better understanding of ocular diseases, which will further increase the value of this examination.

References