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# COMPARATIVE ANALYSIS OF MORPHOMETRIC PARAMETERS OF THE RETINA AND OPTIC NERVE HEAD, OBTAINED WITH DIFFERENT TYPES OF OPTICAL COHERENCE TOMOGRAPHS

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✧ The article presents the results of a comparative analysis of central retinal thickness, macular volume and retinal nerve fiber layer thickness obtained with Stratus OCT 3000, Cirrus HD-OCT 4000 and Spectralis OCT. Statistically significant differences in central retinal thickness and macular volume were revealed. The absence of a difference pattern in retinal nerve fiber layer thickness measurements on different tomographs was found.

✧ ***Keywords:*** optical coherence tomography; Stratus OCT 3000; Cirrus HD-OCT 4000; Spectralis OCT.

# СРАВНИТЕЛЬНЫЙ АНАЛИЗ МОРФОМЕТРИЧЕСКИХ ПАРАМЕТРОВ СЕТЧАТКИ И ДИСКА ЗРИТЕЛЬНОГО НЕРВА, ПОЛУЧЕННЫХ НА РАЗЛИЧНЫХ ТИПАХ ОПТИЧЕСКИХ КОГЕРЕНТНЫХ ТОМОГРАФОВ

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✧ В статье представлены результаты сравнительного анализа толщины центральной зоны сетчатки, макулярного объёма и толщины слоя нервных волокон сетчатки, полученные на приборах Stratus OCT 3000, Cirrus HD-OCT 4000 и Spectralis OCT. Выявлены статистически значимые различия показателей толщины центральной зоны сетчатки и макулярного объёма. Обнаружено отсутствие закономерности различий в измерениях толщины слоя нервных волокон сетчатки на разных томографах.

✧ ***Ключевые слова:*** оптическая когерентная томография; Stratus OCT 3000; Cirrus HD-OCT 4000; Spectralis OCT.

## INTRODUCTION

Optical coherence tomography is the most sought after techniques nowadays for the retinal and optic nerve pathology diagnosis. However, the practical implementation on a large scale of various types of optical coherent tomographs (OCTs) hinders the patients' follow-up when repeated studies are performed in different institutions using different devices. Several studies have compared the results obtained from various types of OCTs [1–10]. The findings of these studies have highlighted significant data variability due to differences in the operating principles of modern tomographs and scanning protocols. However, most studies included only a small number of patients, and a comparative thickness analysis was conducted only in the central subfield (1.0 mm zone) [1, 2, 5, 11]. When comparing the morphometric parameters of the optic nerve head (ONH), some researchers con-

cluded that it is inaccurate to compare these figures directly [12]. Some researchers did not find any statistically significant differences in the ONH parameters between the time-domain and spectral-domain tomographs [13]. Significant discrepancies in data obtained using different OCTs [4], multicenter studies, and scientific publications that have not considered the differences between the different types of OCTs, while reporting findings of various OCTs, could lead to misinterpretation and unfounded conclusions. Owing to the variation in published findings, confirmatory studies are warranted.

Therefore, this study aimed to comparatively analyze the measurement results of the thickness of the central zone of the retina, macular volume, and thickness of the retinal nerve fiber layer (RNFL) obtained using three different optical coherence tomography devices.

## MATERIALS AND METHODS

To determine the retinal thickness and the macular volume, 90 eyes of 50 healthy volunteers (39 women and 11 men) aged 21–79 years (average age, 55.06 ± 21.28 years; median, 63 years) were examined. Participants with posterior segment diseases, opacification of the optical media, which impedes the visualization of the fundus and interferes with OCT, and high-degree myopia (spherical equivalent of refractive error ≥ −6.25 diopters) were excluded.

In addition to the complete standard ophthalmologic examination, all patients underwent optical coherence tomography of the macular area using three devices: the Stratus OCT 3000 (Carl Zeiss Meditec, USA) using the Fast Macula scan protocol; the Cirrus HDOCT 4000 (Carl Zeiss Meditec, USA) using the Macular cube 128 × 512 scan protocol, and the Spectralis OCT (Heidelberg Engineering, Germany) using the Fast Retina scan protocol. As a result of scanning, a macular map was formed, which consisted of nine sectors. The retinal thickness and the macular volume in each of the nine sectors were compared.

To determine the RNFL thickness of the ONH, 90 eyes of 50 healthy volunteers (39 women and 11 men) aged 21–79 years (average age, 52.91 ± 21.47 years; median, 61 years) were examined. The ONH was evaluated on the Stratus OCT 3000 using the Fast Optic disc scan protocol for tomography; the Cirrus HDOCT 4000 device using the Optic Disc Cube 200 × 200 scan protocol for tomography; and the Spectralis OCT using the RNFL scan protocol for tomography. The RNFL thickness in four sectors: superior (S), inferior (I), nasal (N), and temporal (T) was compared.

Statistical data analysis was performed using the SAS statistical program (version 9.4). Data of thickness and volume parameters measured on the three devices were compared using the mixed-design analysis of variance model. General pairwise comparisons of the individual devices were performed using the Tukey–Kramer test. Descriptive statistics of quantitative variables are presented in the form of means, standard deviations, and minimum and maximum values of indicators.

## RESULTS AND DISCUSSION

The mean values of the differences in the measurements of the macular retinal thickness for each of the nine sectors between the devices Spectralis OCT and Cirrus HD-OCT 4000 (Table 1), Cirrus HD-OCT4000 and Stratus OCT 3000 (Table 2), and Spectralis OCT and Stratus OCT 3000 (Table 3), which measured the thickness of the retinal slices, showed significant differences. Since the retinal thickness is measured from the internal limiting membrane (ILM) to the layer of the outer segments of photoreceptors, the smallest values were obtained using the Stratus OCT 3000. The spectral tomograph Cirrus HD-OCT 4000 device measured the retinal thickness from the ILM to the outer border of the pigment epithelium, and the Spectralis OCT measured the retinal thickness from the ILM to the Bruch's membrane.

The average difference in the thickness of the central subfield between the Cirrus HD-OCT 4000 and the Stratus OCT 3000 was 39.9 ± 2.48 μm, that between the Spectralis OCT and the Cirrus HD-OCT 4000 was 16.55 ± 2.47 μm, and that between the Spectralis OCT and the Stratus OCT 3000 was 56.45 ± 2.05 μm ($p < 0001$). The overall average difference in the central retinal zone thickness between the Cirrus HD-OCT 4000 and the Stratus OCT 3000 was 32.12 ± 3.77 μm, that between the Spectralis OCT and the Cirrus HD-OCT 4000 was 18.78 ± 2.08 μm, and that between the Spectralis OCT and the Stratus OCT 3000 was 50.9 ± 4.47 μm ($p < 0001$). These differences must be taken into account when comparing data obtained using different OCTs.

It is noteworthy that with low visual acuity and in the absence of central fixation of gaze in a patient, the subsequent repeated scanning of the macular area in the same area is possible only with the same tomography device, having a function that allows for automatic positioning of the scan in the place same

*Table 1 / Таблица 1*

**Indices of the difference in measurements of retinal thickness in the macular area for each of the 9 zones between Spectralis OCT and Cirrus HD-OCT 4000**
**Показатели разницы в измерениях толщины сетчатки в макулярной области для каждой из девяти зон между приборами Spectralis OCT и Cirrus HD-OCT 4000**

| Scope of research | Difference in indices (μm) | Minimum value (μm) | Maximum value (μm) | Adj P (Tukey-Kramer) |
|---|---|---|---|---|
| 1 | 16.5556 | 14.0812 | 19.0299 | < .0001 |
| 2 | 21.1778 | 18.3146 | 24.0409 | < .0001 |
| 3 | 19.3778 | 17.2182 | 21.5374 | < .0001 |
| 4 | 18.7667 | 16.2275 | 21.3058 | < .0001 |
| 5 | 21.7222 | 17.5172 | 25.9272 | < .0001 |
| 6 | 16.8222 | 14.7349 | 18.9096 | < .0001 |
| 7 | 15.8444 | 13.6566 | 18.0323 | < .0001 |
| 8 | 18.4444 | 16.6003 | 20.2886 | < .0001 |
| 9 | 20.3333 | 17.884 | 22.7826 | < .0001 |

*Table 2 / Таблица 2*

**Indices of the difference in measurements of retinal thickness in the macular area for each of the 9 zones between Cirrus HD-OCT 4000 and Stratus OCT 3000**
**Показатели разницы в измерениях толщины сетчатки в макулярной области для каждой из девяти зон между приборами Cirrus HD-OCT 4000 и Stratus OCT 3000**

| Scope of research | Difference in indices (μm) | Minimum value (μm) | Maximum value (μm) | Adj P (Tukey-Kramer) |
|---|---|---|---|---|
| 1 | 39.9 | 37.4256 | 42.3744 | < .0001 |
| 2 | 34.1111 | 31.248 | 36.9743 | < .0001 |
| 3 | 35.1222 | 32.9626 | 37.2818 | < .0001 |
| 4 | 30.9222 | 28.3831 | 33.4614 | < .0001 |
| 5 | 31.7444 | 27.5394 | 35.9494 | < .0001 |
| 6 | 28.0889 | 26.0015 | 30.1762 | < .0001 |
| 7 | 29.0556 | 26.8677 | 31.2434 | < .0001 |
| 8 | 28.5222 | 26.6781 | 30.3664 | < .0001 |
| 9 | 31.6333 | 29.184 | 34.0826 | < .0001 |

*Table 3 / Таблица 3*

**Indices of the difference in measurements of retinal thickness in the macular area for each of the 9 zones between Spectralis OCT and Stratus OCT 3000**
**Показатели разницы в измерениях толщины сетчатки в макулярной области для каждой из девяти зон между приборами Spectralis OCT и Stratus OCT 3000**

| Scope of research | Difference in indices (μm) | Minimum value (μm) | Maximum value (μm) | Adj P (Tukey-Kramer) |
|---|---|---|---|---|
| 1 | 56.4556 | 53.9812 | 58.9299 | < .0001 |
| 2 | 55.2889 | 52.4257 | 58.152 | < .0001 |
| 3 | 54.5 | 52.3404 | 56.6596 | < .0001 |
| 4 | 49.6889 | 47.1497 | 52.228 | < .0001 |
| 5 | 53.4667 | 49.2617 | 57.6717 | < .0001 |
| 6 | 44.9111 | 42.8238 | 46.9985 | < .0001 |
| 7 | 44.9 | 42.7122 | 47.0878 | < .0001 |
| 8 | 46.9667 | 45.1225 | 48.8108 | < .0001 |
| 9 | 51.9667 | 49.5174 | 54.416 | < .0001 |

*Table 4 / Таблица 4*

**Indices of the difference in measurements of macular volume between Spectralis OCT, Stratus OCT 3000 and Cirrus HD-OCT 4000**
**Показатели разницы в измерениях объёма сетчатки в макулярной области между приборами Spectralis OCT, Stratus OCT 3000 и Cirrus HD-OCT 4000**

| Devices | Difference in indices (μm) | Minimum value (μm) | Maximum value (μm) | Adj P (Tukey-Kramer) |
|---|---|---|---|---|
| Cirrus HD-OCT 4000 vs. Spectralis OCT | 1.396 | 1.3434 | 1.4486 | < .0001 |
| Cirrus HD-OCT 4000 vs. Stratus OCT 3000 | 2.7638 | 2.7111 | 2.8164 | < .0001 |
| Spectralis OCT vs. Stratus OCT 3000 | 1.3678 | 1.3151 | 1.4204 | < .0001 |

*Table 5 / Таблица 5*

**Indices of the difference in measurements of retinal nerve fibre layer thickness in 4 zones of peripapillary area between Spectralis OCT and Cirrus HD-OCT 4000**
**Показатели разницы в измерениях толщины слоя нервных волокон сетчатки в четырёх секторах перипапиллярной зоны между приборами Spectralis OCT и Cirrus HD-OCT 4000**

| Scope of research | Difference in indices (μm) | Standard deviation | Adj P (Tukey-Kramer) |
|---|---|---|---|
| Superior sector | 2.2667 | 0.9484 | 0.0468 |
| Nasal sector | –0.5222 | 1.1573 | 0.8939 |
| Inferior sector | 2.4222 | 0.9977 | 0.0426 |
| Temporal sector | 4.6556 | 0.8253 | < .0001 |

*Table 6 / Таблица 6*

**Indices of the difference in measurements of retinal nerve fibre layer thickness in 4 zones of peripapillary area between Stratus OCT 3000 and Cirrus HD-OCT 4000**
**Показатели разницы в измерениях толщины слоя нервных волокон сетчатки в четырёх секторах перипапиллярной зоны между приборами Stratus OCT 3000 и Cirrus HD-OCT 4000**

| Scope of research | Difference in indices (μm) | Standard deviation | Adj P (Tukey-Kramer) |
|---|---|---|---|
| Superior sector | 2.5889 | 0.9484 | 0,019 |
| Nasal sector | 5.6333 | 1.1573 | < .0001 |
| Inferior sector | 7.1667 | 0.9977 | < .0001 |
| Temporal sector | 4.8111 | 0.8253 | < .0001 |

as that at the first visit. Moreover, in the advanced stages of certain diseases, due to gross changes in the architecture of the retina, tomographs cannot accurately determine the boundaries of the layers. In such cases, it is inaccurate to compare the results obtained using different devices, and case follow-up of patient should be performed using the same device.

The macular retina volumes obtained using all the three devices were compared. The average retinal volume measured using the Stratus OCT 3000 was 7.1 $mm^3$ (max–min, 7.19–7.01 $mm^3$), that using the Cirrus HD-OCT 4000 was 9.86 $mm^3$ (max–min, 9.95–9.77 $mm^3$), and that using the Spectralis OCT was 8.46 $mm^3$ (max–min, 8.55–8.37 $mm^3$), detailed data is presented in Table 4. The retinal volume obtained using the Cirrus HD-OCT 4000 was larger compared with those obtained using the Stratus OCT 3000 and the Spectralis OCT. This may be attributed to the screening protocol of scanning on the Cirrus HD-OCT 4000 that provided for a more detailed macular area map, which leads to an increase in the macular volume, due to the greater number of scans than in other two tomographs. Conversely, the Spectralis OCT provided the largest retinal thickness reading. This discrepancy may be associated not only with the aspects of retinal thickness measurement but also with the difference in the number of slices used for each device, which form the macular area map.

Unlike various principles of determining the retinal thickness on different OCTs, the algorithms for estimating the RNFL thickness are equal. The RNFL thickness is determined on all tomographs on a circular section with a diameter of 3.46 mm. The RNFL thickness between devices was compared in the four sectors, S, I, N, and T. Tables 5–7 represent the average differences in the measurements of the RNFL thickness for each of the four sectors between the

*Table 7 / Таблица 7*

**Indices of the difference in measurements of retinal nerve fibre layer thickness in 4 zones of peripapillary area between Stratus OCT 3000 and Spectralis OCT**
**Показатели разницы в измерениях толщины слоя нервных волокон сетчатки в четырёх секторах перипапиллярной зоны между приборами Stratus OCT 3000 и Spectralis OCT**

| Scope of research | Difference in indices (μm) | Standard deviation | Adj P (Tukey-Kramer) |
|---|---|---|---|
| Superior sector | 0.3222 | 0.9484 | 0.9384 |
| Nasal sector | 6.1556 | 1.1573 | < .0001 |
| Inferior sector | 4.7444 | 0.9977 | < .0001 |
| Temporal sector | 0.1556 | 0.8253 | 0.9806 |

Spectralis OCT and the Cirrus HD-OCT 4000, the Cirrus HD-OCT 4000 and the Stratus OCT 3000, the Spectralis OCT and the Stratus OCT 3000, respectively.

Differences in the RNFL thickness measured with different devices were assessed, assuming that the indicators of the devices should be the same or their difference should be minimal. The differences in the indicators varied from 0.15 to 7.1 μm. It is plausible that the scatter of the data obtained is due to the inability to position the scan area in the same place as in another tomograph. In the Stratus OCT 3000 and the Spectralis OCT devices, there is no function of automatic detection of the ONH center, and in some cases it is necessary to manually position the scanning area. Consequently, a circular cut of the retina can be performed in the mismatched areas. The absence of a consistent pattern in the identified differences in measuring the RNFL thickness does not allow the creation of a mathematical recalculation algorithm for comparing the results obtained using various OCTs. Thus, case follow-up should only be conducted on the same device.

## CONCLUSIONS

Significant differences in the indicators of the retinal thickness and macular volume were established. The difference in the retinal thickness measurement between the Cirrus HD-OCT 4000 and the Stratus OCT 3000 was $32.12 \pm 3.77$ μm, that between the Spectralis OCT and the Cirrus HD-OCT 4000 was $18.78 \pm 2.08$ μm, and that between the Spectralis OCT and the Stratus OCT 3000 was $50.9 \pm 4.47$ μm. These differences must be taken into account when comparing data obtained using different OCTs.

The average difference in the measurements of the macular volume between the Cirrus HD-OCT 4000 and the Stratus OCT 3000 was 2.77 $mm^3$, that between the Cirrus HD-OCT 4000 and the Spectralis OCT was 1.40 $mm^3$, and that between the Spectralis OCT and the Stratus OCT 3000 was 1.37 $mm^3$. There was an absence of a consistent pattern of differences in the measurements of the RNFL thickness using various OCTs. In this regard, for individual case follow-up, it is inaccurate to compare the results obtained using different devices.

## PRACTICAL RECOMMENDATIONS

1. If it is necessary to compare the results of the retinal thickness and macular volume of the retina in the macular region obtained using various types of OCTs, it should be remembered that the measurements taken may focus on different anatomical structures. The correction factors proposed in this study can be used for an approximate comparison of the data from these studies over time. However, it is noteworthy that with low visual acuity and the absence of central fixation of gaze in a patient, as well as with gross retinal changes, the correction coefficients determined in this study have very limited application because the significance of the comparison between the results in such cases would be extremely low.

2. For case follow-up or multicenter clinical studies, comparison of the results of the measurement of the RNFL thickness obtained using different types of OCTs is unnecessary.

***Authors' contribution:***

*Yu. S. Astakhov* was involved in the concept and design of the study;

*S.G. Belekhova* performed collection and processing of material, analysis of data obtained, and drafting of the manuscript.

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