Evaluation of Central Macular Thickness and Retinal Nerve Fiber Layer Thickness using Spectral Domain Optical Coherence Tomography in a Tertiary Care Hospital

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ABSTRACT

Purpose: To evaluate the normative data of macular thickness and retinal nerve fiber layer thickness (RNFL) among normal subjects using spectral domain optical coherence tomography (OCT).

Materials and methods: Normal subjects presenting to a tertiary medical hospital were included in the study. All patient underwent clinical examination followed by study of macular thickness and RNFL thickness by spectral domain Topcon OCT. The data was collected and analyzed for variations in gender and age. The data was also compared with available literature.

Results: Total numbers of patients enrolled in the study were 154 (308 eyes). Numbers of males were 79 (158 eyes) and numbers of females were 75 (150 eyes). The mean age among males was 42.67 ± 12.15 years and mean age among females was 42.88 ± 11.73 years.

Overall the mean macular thickness (central 1 mm zone) with SD-OCT was 241.75 ± 17.3 microns. The mean macular volume was 7.8 cu. mm ± 0.33. On analysis of the RNFL thickness, we observed that the RNFL was thickest in the inferior quadrant (138.58) followed by superior (122.30) nasal (116.32) and temporal quadrant (73.04).

Gender-wise comparison of the data revealed no statistically significant difference for age, macular thickness parameters, volume and RNFL values except outer temporal thickness among males and females. No age-related difference was noted in the above parameters. On comparison with available normative data from India and elsewhere, we found significant variations with different machines.

Conclusion: The study is the first to provide normative data using SD-OCT from central India. The data from spectral domain OCT correlated well with the values obtained from similar studies with SD-OCT. Values obtained from time domain OCT machines are different and are not comparable.

Keywords: Spectral Domain OCT, Normative data, Central India.

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INTRODUCTION

Optical coherence tomography is a standard noninvasive diagnostic test today to visualize the morphology of retina. It provides high-resolution, cross-sectional, quantitative image of the retina and helps us measure the thickness of retina at various points. Central macular thickness can be measured with OCT and correlated with clinical examination and visual function.1,2 Similarly, retinal nerve fiber layer thickness (RFNL) around the disc (peripapillary RFNL) can be measured with the OCT and correlated with the health of neural retinal rim of the optic nerve head and visual fields of the patient.3,4 With evolution and refinement of technology now we have moved from time domain to spectral domain OCT. This has lesser image acquisition time and provides high resolution images which help us delineate pathology from normal tissues.5-8 There are very few large studies on the normative data for macular thickness using the spectral OCT. The macular thickness measurement for diagnostic function may differ with the population used as a database. There are differences in normative data with respect to age, sex, gender and race.9,10 Such differences need to be taken into account while interpreting raw data. Most of the newer generation machines have inbuilt normative data and hence, are able to differentiate normal values from abnormal and represent it in a color coded manner. However, apart from color coding representation of data; knowledge of normal absolute values is also essential which may vary between different machines. The absolute cut-off values of central macular thickness may be a deciding factor to treat the macular edema, which may vary according to the machine being used. Similarly, in certain scenarios absolute values of RFNL may be deciding factor in diagnosis of glaucoma.11,13

Thus, it is essential for the operator and ophthalmologist to have complete knowledge of normative data of the machine being used to examine the respective patient. Most of the studies of normative data of macular thickness and retinal nerve fiber thickness (RFNL) were done in northern14,15.
or southern\textsuperscript{16,17} India using time domain OCT. This study was done to establish the normal macular thickness and RFNL parameters using spectral domain OCT (3D OCT 2000, Topcon corporation, Tokyo, Japan) in central India at a tertiary medical college.

**AIM**

To evaluate the central macular thickness (CMT) and retinal nerve fiber layer (RFNL) thickness in normal subjects presenting at tertiary care hospital using spectral domain optical coherence tomography (OCT).

**MATERIALS AND METHODS**

**Materials**

Our study was conducted at ophthalmology department and healthy volunteers presenting to eye out patient department were included in this cross-sectional study. This study was approved from the research and ethics committee of the institute. Informed consent was obtained. All subjects underwent vision, refraction, examination of eye with slit-lamp, Goldmann applanation tonometry, gonioscopy and fundus examination with plus 90D lens.

Inclusion criteria were age > 18 years, healthy volunteers constituting attendants of patients, hospital staff, contralateral normal eye of patients were included in this cross-sectional study. Exclusion criteria were family history of glaucoma, history of prior photocoagulation, history of prior ocular disease, history of intraocular surgery, previous ocular trauma, vertical asymmetry of cup: disk (C:D) ratio (>0.2) between the two eyes, high C:D ratio (>0.6), disk hemorrhages, disk pallor, and localized RNFL defects, refractive error of > ±4 diopter, intraocular pressure >22 mm Hg. Optical coherence tomography was performed using 3D OCT 2000 (Topcon corporation, Tokyo, Japan), with software version 3.

**Methods of Evaluation**

Eyes that fulfilled both exclusion and inclusion criteria were selected for analysis, if both eyes fulfilled the criteria, both the eyes were included. After complete clinical examination, each eye was dilated with tropicamide 1% before recording the images, and scans were performed with a minimum pupillary diameter of 5 mm. After entry of details of patient including age, sex, race (Asian) specific examination modes were selected.

**Central Macular Thickness**

The macular evaluation mode was selected from the computer console. The scan was performed with 3D 6.0 × 6.0 protocol. The image was taken with green cross as the internal fixation target. After saving the computer image the analyzed data values using inbuilt protocol was noted. The report generated by the machine gives the color image of central macular with image centered at the fovea. The macular thickness is depicted as concentric circles of 1, 3, and 6 mm from the center of fovea. All the values of macular thickness and macular volume were noted, tabulated and analyzed.

**For RFNL Analysis**

The glaucoma evaluation mode was selected from the computer console. The scan was performed with 3D 6.0 × 6.0 protocol. The image was taken with green cross as the internal fixation target. After saving the computer image the analyzed data values using inbuilt protocol was noted. The report generated by the machine gives the color image of optic nerve head surrounded by 3.4 mm green centration ring. It gives the peripapillary RFNL thickness of superior, inferior, nasal and temporal quadrants along with total average RFNL thickness. All these values were noted and analyzed.

**RESULTS**

Total numbers of patients enrolled in the study were 154 (308 eyes). Numbers of males were 79 (158 eyes) and numbers of females were 75 (150 eyes). The mean age among males was 42.67 ± 12.15 years and mean age among females was 42.88 ± 11.73 years.

Overall, the mean macular thickness (central 1 mm zone) with SD-OCT was 241.75 ± 17.3 microns. The mean macular volume was 7.6 ± 0.33 cu. mm. On analysis of the RNFL thickness, we observed that the RNFL was thickest in the inferior quadrant (138.58) followed by superior (122.30) nasal (116.32) and temporal quadrant (73.04) (Table 1).

Gender-wise comparison of the data revealed no statistically significant difference age, macular thickness parameters, volume and RFNL values except outer temporal thickness (OTT) among males and females (Table 2). The standard deviation (SD) of OTT among males is 5.35 and among females is 10.21. This difference of SD is responsible for statistical significance among the two groups.

To study age-related change in macular thickness and RNFL values, the data was divided into two groups with age < 40 years (152 eyes) and second group age ≥ 40 years (156 eyes). No statistically significant difference was noted in macular thickness parameters, volume, and RFNL values (Table 3).
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Table 1: Normative data of OCT parameters of 154 subjects (308 eyes)

| Parameter                          | N           | Minimum | Maximum | Mean     | Std. deviation |
|------------------------------------|-------------|---------|---------|----------|----------------|
| Average macular thickness          | 154 (308 eyes) | 269.00  | 295.00  | 279.4277 | 7.17867        |
| Outer nasal thickness              | 154 (308 eyes) | 261.00  | 308.00  | 283.7143 | 8.34659        |
| Outer temporal thickness           | 154 (308 eyes) | 244.00  | 285.00  | 260.6039 | 12.1557        |
| Outer superior thickness           | 154 (308 eyes) | 245.00  | 259.00  | 254.0455 | 11.37842       |
| Inner nasal thickness              | 154 (308 eyes) | 290.00  | 339.00  | 306.7078 | 10.46059       |
| Inner temporal thickness           | 154 (308 eyes) | 285.00  | 308.00  | 298.7597 | 5.64304        |
| Inner superior thickness           | 154 (308 eyes) | 284.00  | 308.00  | 303.3442 | 12.14906       |
| Inner inferior thickness           | 154 (308 eyes) | 278.00  | 308.00  | 296.9026 | 10.79323       |
| Central macular thickness          | 154 (308 eyes) | 212.00  | 296.00  | 241.7532 | 17.30553       |
| Total volume                       | 154 (308 eyes) | 7.13    | 8.20    | 7.6056  | 0.33822        |
| Average RNFL                       | 154 (308 eyes) | 103.75  | 125.50  | 112.5601 | 5.19968        |
| Superior RNFL                      | 154 (308 eyes) | 101.00  | 133.00  | 122.2987 | 9.48968        |
| Inferior RNFL                      | 154 (308 eyes) | 125.00  | 153.00  | 138.5844 | 7.52226        |

Table 2: Difference of parameters according to gender

| Parameter                          | Gender         | N (158 eyes) | Mean     | Std. deviation | Significance |
|------------------------------------|----------------|--------------|----------|----------------|--------------|
| Average macular thickness          | Male           | 79           | 279.3082 | 7.33188        | 0.833        |
|                                   | Female         | 75           | 279.5536 | 7.06081        |              |
| Outer nasal thickness              | Male           | 79           | 283.3165 | 13.37386       | 0.697        |
|                                   | Female         | 75           | 284.1333 | 12.5510        |              |
| Outer temporal thickness           | Male           | 79           | 251.5316 | 5.35852        | 0.001        |
|                                   | Female         | 75           | 255.8674 | 10.21564       |              |
| Outer superior thickness           | Male           | 79           | 264.4694 | 12.71365       | 0.640        |
|                                   | Female         | 75           | 263.5467 | 11.60533       |              |
| Inner nasal thickness              | Male           | 79           | 306.9114 | 10.18318       | 0.805        |
|                                   | Female         | 75           | 306.4933 | 10.80692       |              |
| Inner temporal thickness           | Male           | 79           | 298.3797 | 5.79191        | 0.393        |
|                                   | Female         | 75           | 299.1600 | 5.49211        |              |
| Inner superior thickness           | Male           | 79           | 303.7848 | 12.29621       | 0.646        |
|                                   | Female         | 75           | 302.8800 | 12.05725       |              |
| Inner inferior thickness           | Male           | 79           | 267.0127 | 12.02934       | 0.280        |
|                                   | Female         | 75           | 265.0267 | 10.63520       |              |
| Central macular thickness          | Male           | 79           | 303.7848 | 12.29621       | 0.646        |
|                                   | Female         | 75           | 302.8800 | 12.05725       |              |
| Total volume                       | Male           | 79           | 7.6095   | 0.34302        | 0.884        |
|                                   | Female         | 75           | 7.6015   | 0.33534        |              |
| Average RNFL                       | Male           | 79           | 112.2722 | 4.81318        | 0.482        |
|                                   | Female         | 75           | 112.8633 | 5.86856        |              |
| Superior RNFL                      | Male           | 79           | 122.3544 | 9.75079        | 0.941        |
|                                   | Female         | 75           | 122.2400 | 9.27193        |              |
| Inferior RNFL                      | Male           | 79           | 138.4177 | 7.46892        | 0.779        |
|                                   | Female         | 75           | 138.7600 | 7.62436        |              |
| Nasal RNFL                         | Male           | 79           | 115.6329 | 14.21644       | 0.523        |
|                                   | Female         | 75           | 117.0267 | 12.72899       |              |
| Temporal RNFL                      | Male           | 79           | 72.6835  | 7.74521        | 0.608        |
|                                   | Female         | 75           | 73.4267  | 10.10509       |              |

DISCUSSION

Retinal thickness or macular thickness is important for diagnosis of early diabetic macular edema, cystoid macular edema, age-related macular degeneration and choosing appropriate management strategies in other cases of retinal diseases.\cite{18} Likewise, RNFL thickness assessment is important for detection of preperimetric glaucoma and damage to ganglion cell layer.\cite{19,21}
Table 3: Difference of parameters according to age

| Parameter                  | Age                  | N  | Mean       | Std. deviation | Significance |
|----------------------------|----------------------|----|------------|----------------|--------------|
| Average macular thickness  | Less than 40 years   | 76 | 280.2600   | 7.18721        | 0.156        |
|                           | More than equal 40   | 79 | 278.6168   | 7.12273        |              |
| Outer nasal thickness      | Less than 40 years   | 76 | 284.5921   | 12.69664       | 0.408        |
|                           | More than equal 40   | 78 | 282.8590   | 13.20933       |              |
| Outer temporal thickness   | Less than 40 years   | 76 | 254.9211   | 9.03292        | 0.053        |
|                           | More than equal 40   | 78 | 252.3205   | 7.45461        |              |
| Outer superior thickness   | Less than 40 years   | 76 | 264.7500   | 12.76153       | 0.463        |
|                           | More than equal 40   | 78 | 263.3077   | 11.57282       |              |
| Outer inferior thickness   | Less than 40 years   | 76 | 266.3684   | 11.08253       | 0.729        |
|                           | More than equal 40   | 78 | 265.7308   | 11.72263       |              |
| Inner nasal thickness      | Less than 40 years   | 76 | 308.0526   | 11.13301       | 0.116        |
|                           | More than equal 40   | 78 | 305.3974   | 9.65286        |              |
| Inner temporal thickness   | Less than 40 years   | 76 | 298.9605   | 5.82510        | 0.664        |
|                           | More than equal 40   | 78 | 298.5641   | 5.49046        |              |
| Inner superior thickness   | Less than 40 years   | 76 | 304.7632   | 12.61837       | 0.153        |
|                           | More than equal 40   | 78 | 301.9615   | 11.58755       |              |
| Inner inferior thickness   | Less than 40 years   | 76 | 297.9474   | 11.14682       | 0.237        |
|                           | More than equal 40   | 78 | 295.8846   | 10.11875       |              |
| Central macular thickness  | Less than 40 years   | 76 | 241.9868   | 16.05033       | 0.869        |
|                           | More than equal 40   | 78 | 241.5256   | 18.54844       |              |
| Total volume               | Less than 40 years   | 76 | 7.6428     | 0.33884        | 0.179        |
|                           | More than equal 40   | 78 | 7.5694     | 0.33582        |              |
| Average RNFL              | Less than 40 years   | 76 | 112.7599   | 5.23425        | 0.639        |
|                           | More than equal 40   | 78 | 112.3654   | 5.19251        |              |
| Superior RNFL             | Less than 40 years   | 76 | 122.9079   | 9.38535        | 0.433        |
|                           | More than equal 40   | 78 | 121.7051   | 9.61345        |              |
| Inferior RNFL             | Less than 40 years   | 76 | 138.6053   | 7.92478        | 0.973        |
|                           | More than equal 40   | 78 | 138.5641   | 7.15975        |              |
| Nasal RNFL                | Less than 40 years   | 76 | 116.7632   | 13.23618       | 0.683        |
|                           | More than equal 40   | 78 | 115.8718   | 13.79663       |              |
| Temporal RNFL             | Less than 40 years   | 76 | 72.7632    | 8.94408        | 0.701        |
|                           | More than equal 40   | 78 | 73.3205    | 9.00576        |              |

Methods to assess macular thickness are slit-lamp biomicroscopy, fundus photography, fundus fluorescein angiography and OCT. Among these, OCT alone provides quantitative assessment of macular thickness. OCT provides for accurate assessment of details of retina and nerve fiber layer with high reproducibility and can be correlated well with clinical disease state. All the information thus collected needs to be analyzed and interpreted considering age, gender and racial differences.

With various OCT machines available, we need to understand the normative data generated by both TD and SD-OCT machines before we can conclude about abnormalities and decide on management strategies. The color coding system of the analyzed report provides reasonable discrimination between normal and abnormal values. Our study done in central India provides for normative data of population visiting a tertiary care hospital and the data was collected using spectral domain OCT machine, which is a standard tool today.

In our study, the mean macular thickness (central 1 mm zone) with SD-OCT was 241.75 ± 17.3 microns. Compared with this, various studies done with time domain OCT reported macular thickness as 150 microns approximately. Massin P et al. and Muscat S et al. reported mean central macular thickness as 175 approximately, while Guedes V et al. reported 210 microns as mean central macular thickness.

Ibrahim MA et al. reported the mean thickness was 188 mm (SD ± 20 mm) in normal eyes with TD-OCT and 266 mm (SD ± 21 mm) on SD-OCT. The mean thickness in the subfields N, S, T and I was: 266, 268, 255 and 267 mm, respectively, when measured by TD-OCT and 340, 340, 327 and 336 mm, respectively, when measured by SD-OCT. The difference in average thickness as measured by both OCT technologies was statistically significant in all subfields (p < 0.01). This difference in measurements could be attributed to the difference in measurement protocols used by various machines. Time domain OCT machines measure...
retinal thickness from IS/OS to ILM. The Topcon SD-OCT used in our study measures retinal thickness between the ILM and the posterior border of RPE. Factors other than segmentation algorithm (for example, density of sections, acquisition method, and acquisition speed) may contribute to differences in thickness measurements among devices.

Cariñeto P et al\textsuperscript{36} reported significant difference in macular thickness measured by SD-OCT (approximately 227 microns) vs TD-OCT (approximately 144 microns) in 40 healthy subjects. Grover S et al\textsuperscript{37} reported a difference of approximately 70 microns in the value of that mean central macular thickness between TD-OCT and SD-OCT. This increased measurement corresponds to the inclusion of the outer segment-RPE-Bruch’s membrane complex by SD-OCT, which is relevant to studies using the newer SD-OCT for assessment of retinal thickness.

From above studies, it is evident that values of macular differ when measured using TD-OCT and SD-OCT. Thus, we conclude that while reviewing patients and retinal thickness, OCT machine, their protocols should be taken into account and values from different machines cannot be used interchangeably.

\textbf{RNFL}

In our study, the mean macular volume was 7.6 ± 0.33 cu mm. On analysis of the RNFL thickness, we observed that the RNFL was thickest in the inferior quadrant (138.58 ± 7.5) followed by superior (122.30 ± 10.6) nasal (116.32 ± 13.4) and temporal quadrant (73.04 ± 8.9) (Table 1). The mean RNFL from our study was similar to the data available from other studies (Table 4).

Sony P et al\textsuperscript{32} in a cross-sectional study of 146 patients of OCT analysis on quadrant-wise analysis of the RNFL thickness, they observed that the RNFL was thickest in the inferior (132.34 ± 14.70 µ) and superior (131.09 ± 14.13 µ) quadrants. The thickness was lesser in nasal (85.93 ± 17.89 µ) and temporal (67.1 ± 12.77 µ) quadrants according to them, the difference between inferior and superior quadrants was not statistically significant suggesting that the ISNT rule does not apply to Indian eyes.

Kanamori et al\textsuperscript{39} in their study of 160 normal eyes showed slightly higher values than ours. They found that superior thickness (145.5 ± 19.6 µ), was maximum followed by inferior RNFL thickness (143.1 ± 19.5 µ), temporal (98.7 ± 20.8 µ), and last in nasal quadrant (92.6 ± 20.4 µ). Their observation also did not follow the previously described ISNT rule.

Ramakrishnan R et al\textsuperscript{40} in their study (Stratus OCT 3000; Carl Zeiss Ophthalmic Systems-Humphrey Division, Dublin, CA, USA) found that RNFL thickness for superior, inferior, nasal, and temporal quadrants were 138.2 ± 21.74 (95% CI: 134.3-142.1), 129.1 ± 25.67 (95% CI: 124.5-133.7), 85.71 ± 21 (95% CI: 81.9-89.5), and 66.38 ± 17.37 (95% CI: 63.3-69.5) µm, respectively. The mean RNFL thickness was highest in the superior quadrant followed by inferior, nasal, and temporal quadrants (ISNT rule not followed).

Table 4 gives summary of RNFL values and their comparison using various machines. It is clear from the data (Table 4) that RNFL obtained from various machines cannot be used interchangeably.

Seibold LK et al\textsuperscript{41} in their study of RNFL thickness from 40 normal subjects using 3 SD-OCT machines and one TD-OCT machine. The mean RNFL thickness was 106.6 ± 12.8 µm for Spectralis, 98.7 ± 10.9 µm for Cirrus, 112.8 ± 13.2 µm for RTVue and 110.1 ± 12.8 µm for Stratus. Despite high correlations, RNFL values are significantly different between instruments and should not be used interchangeably.

It is evident from review of literature that RNFL values obtained using TD- and SD-OCT show correlation but are different. They may not be comparable and should not be used for follow-up and comparison.\textsuperscript{45-47}

Johnson DE et al\textsuperscript{48} studied RNFL thickness among 20 healthy volunteers using TD-OCT (Stratus) and SD-OCT (RTvue) and found that RNFL measurement with RTvue were thicker by approximately 20 microns as compared to values obtained with Stratus (TD-OCT), thus the technological difference does not allow direct comparison of data.

Lee ES et al\textsuperscript{49} in their study compared RNFL values of 108 open angle glaucoma patients and 46 controls using TD-OCT (Stratus) and SD-OCT (RTvue and Cirrus OCT).

| Machine                  | N (no. of subjects) | Mean  | Inferior | Superior | Nasal | Temporal |
|--------------------------|---------------------|-------|----------|----------|-------|----------|
| Current study Topcon SD-OCT 3000 | 154 | 112.5 ± 5.1 | 138.5 ± 7.5 | 122.2 ± 9.4 | 116.3 ± 13.4 | 73.0 ± 8.9 |
| George Kampougeris et al\textsuperscript{39} SD-OCT + SLO (Optos, UK) | 278 | 114.8 ± 13.3 | 134.5 ± 18.1 | 136.7 ± 18 | 107.2 ± 17.8 | 79.5 ± 15.3 |
| YM Tariq et al\textsuperscript{40} Cirrus SD-OCT | 152 | 99.4 ± 9.6 | 128.8 ± 17.1 | 124.7 ± 15.7 | 74.3 ± 12.8 | 69.9 ± 11.2 |
| Hirasawa et al\textsuperscript{41} Topcon SD-OCT | 251 | 101.9 ± 8.4 | 125.5 ± 13.1 | 123.9 ± 13.6 | 79.6 ± 13.6 | 78.6 ± 13.3 |
| Bendschneider et al\textsuperscript{42} Spectralis SD | 170 | 97.2 ± 9.7 | 123.7 ± 16.4 | 118.0 ± 14.5 | 76.4 ± 15 | 68.8 ± 11.1 |
| Hyunh et al\textsuperscript{43} Stratus TD-OCT | 2132 | 103.6 ± 10.6 | 128.3 ± 18.6 | 129.7 ± 17.5 | 82.0 ± 16.7 | 74.6 ± 12.8 |
RNFL measurements were more with the RTvue, followed by the Stratus, and finally by the Cirrus OCT ($p < 0.05$). However, the tendency was reversed or no longer present in severe glaucomatous eyes and nasal quadrant maps. Thus, the study concluded that direct comparisons of RNFL thickness measurements among OCT instruments should not be done.

In our study, no significant variation was noted in mean central macular thickness and RNFL with age, gender and refractive error. Subjects with high refractive errors were excluded from the study as per protocol. Similar results were reported by Gobel et al and Sony P et al.

The limitation of our study was relatively smaller sample size. Long-term studies with larger population base may be required to validate the results.

Thus, we highlight the fact that macular thickness values are different from TD-OCT and SD-OCT and are not comparable. However, RNFL values do not show such variation. To conclude our study gives data of macular thickness and RNFL in normal subjects using SD-OCT from central India which should form the basis for further studies.

REFERENCES

1. Puliafito CA, Hee MR, Lin CP, Reichel E, Schuman JS, Duker JS, Izzat JA, Swanston EA, Fujimoto JG. Imaging of macular diseases with optical coherence tomography. Ophthalmology 1995 Feb;102(2):217-229.

2. Hee MR, Puliafito CA, Duker JS, Reichel E, Coker JG, Wilkins JR, Schuman JS, Swanston EA, Fujimoto JG. Topography of diabetic macular edema with optical coherence tomography. Ophthalmology 1998 Feb;105(2):360-370.

3. Schuman JS, Hee MR, Arya AV, Pedut-Kloizman T, Puliafito CA, Fujimoto JG, Swanson EA. Optical coherence tomography: a new tool for glaucoma diagnosis. Curr Opin Ophthalmol 1995 Apr;6(2):89-95.

4. Jaffe GJ, Caprioli J. Optical coherence tomography to detect and manage retinal disease and glaucoma. Am J Ophthalmol 2004 Jan;137(1):156-169.

5. de Boer JF, Cense B, Park BH, Pierce MC, Tearney GJ, Bbruca BE. Improved signal-to-noise ratio in spectral-domain optical coherence tomography. Opt Let 2003 Nov;28(21):2067-2069.

6. Srinivasan VJ, Wojtkiewicz M, Witkin AJ, Duker JS, Ko TH, Carvalho M, Schuman JS, Kowalczyk A, Fujimoto JG. High-definition and 3-dimensional imaging of macular pathologies with high-speed ultra-high-resolution optical coherence tomography. Ophthalmology 2006 Nov;113(11):2054.e1-e14.

7. Sakamoto A, Hangai M, Yoshimura N. Spectral-domain optical coherence tomography with multiple B-scan averaging for enhanced imaging of retinal diseases. Ophthalmology 2008 Jun;115(6):1071-1078.e7.

8. Savini G, Carbonelli M, Barboni P. Spectral-domain optical coherence tomography for the diagnosis and follow-up of glaucoma. Curr Opin Ophthalmol 2011 Mar;22(2):115-123.

9. Adhi M, Aziz S, Muhammad K, Adhi MI. Macular thickness by age and gender in healthy eyes using spectral domain optical coherence tomography. PLos One 2012;7(5):e37638.

10. Grover S, Murthy RK, Brar VS, Chalam KV. Normative data for macular thickness by high-definition spectral-domain optical coherence tomography (spectralis). Am J Ophthalmol 2009 Aug;148(2):266-271.

11. Hong SW, Ahn MD, Kang SH, Im SK. Analysis of peripapillary retinal nerve fiber distribution in normal young adults. Invest Ophthalmol Vis Sci 2010 Jul;51(7):3515-3523.

12. Hong S, Kim SM, Park K, Lee JM, Kim CY, Seong GI. Adjusted color probability codes for peripapillary retinal nerve fiber layer thickness in healthy Koreans. BMC Ophthalmol 2014 Mar;14(1):38.

13. Knight OJ, Girklin CA, Budenz DL, Durbin MK, Feuer WJ. Effect of race, age and axial length on optic nerve head parameters and retinal nerve fiber layer thickness measured by Cirrus HD-OCT. Arch Ophthalmol 2012 Mar;130(3):312-318.

14. Tewari HK, Wagh VB, Sony P, Venkatesh P, Singh R. Macular thickness evaluation using the optical coherence tomography in normal Indian eyes. Indian J Ophthalmol 2004 Sep;52(3):199-204.

15. Sony P, Sihota R, Tewari HK, Venkatesh P, Singh R. Quantification of the retinal nerve fibre layer thickness in normal Indian eyes with optical coherence tomography. Indian J Ophthalmol 2004 Dec;52(4):303-309.
27. Kim JS, Ishikawa H, Sung KR, Xu J, Wollstein G, Bilonick RA, Hong S, Kim CY, Lee WS, Seong GJ. Reproducibility of peripapillary retinal nerve fiber layer thickness with spectral domain cirrus high-definition optical coherence tomography in normal eyes. Jpn J Ophthalmol 2010 Jan;54(1):43-47.

28. Muscat S, Parks S, Kemp E, Keating D. Repeatability and reproducibility of macular thickness measurements with the Humphrey OCT system. Invest Ophthalmol Vis Sci 2002 Feb;43(2):490-495.

29. Blumenthal EZ, Williams JM, Weinreb RN, Girkin CA, Berry CC, Zangwill LM. Reproducibility of nerve fiber layer thickness measurements by use of optical coherence tomography. Ophthalmology 2000 Dec;107(12):2278-2282.

30. Konno S, Akiba J, Yoshida A. Retinal thickness measurements with optical coherence tomography and the scanning retinal thickness analyzer. Retina 2001;21(1):57-61.

31. Hee MR, Puliafito CA, Wong C, Duker JS, Fujimoto JG. Quantitative assessment of macular edema with optical coherence tomography. Arch Ophthalmol 1995 Aug;113(8):1019-1029.

32. Guedes V, Schuman JS, Hertzmark E, Wolleston G, Correnti A, Mancini R, Lederer D, Voskanian S, Velazquez L, Pakter HM, et al. Optical coherence tomography measurement of macular thickness in normal and glaucomatous human eyes. Ophthalmology 2003 Jan;110(1):177-189.

33. Neubauer AS, Priglinger S, Ullrich S, Bechmann M, Thiel MJ, Ulbig MW, Kampik A. Comparison of foveal thickness measured with the retinal thickness analyzer and optical coherence tomography. Retina 2001;21(6):596-601.

34. Massin P, Vicaut E, Haoucheine B, Erginay A, Paques M, Gaudric A. Reproducibility of retinal mapping using optical coherence tomography. Arch Ophthalmol 2001 Aug;119(8):1135-1142.

35. Ibrahim MA, Sepah YJ, Symons RC, Channa R, Hatet E, Khwaja A, Bittencourt M, Heo J, Do DV, Nguyen QD. Spectral-and time-domain optical coherence tomography measurements of macular thickness in normal eyes and in eyes with diabetic macular edema. Eye (Lond) 2012 Mar;26(3):454-462.

36. Carpenito P, Nubile M, Toto L, Aharrhn Gama A, Marcucci L, Mastropasqua L, Ciancaglini M. Correlation in foveal thickness measurements between spectral-domain and time-domain optical coherence tomography in normal individuals. Eye (Lond) 2010 Feb;24(2):251-258.

37. Grover S, Murthy RK, Brar VS, Chalam KV. Comparison of retinal thickness in normal eyes using Stratus and Spectralis optical coherence tomography. Invest Ophthalmol Vis Sci 2010 May;51(5):2644-2647.

38. Kanamori A, Nakamura M, Escano MF, Seya R, Maeda H, Negi A. Evaluation of the glaucomatous damage on retinal nerve fiber layer thickness measured by optical coherence tomography. Am J Ophthalmol 2003 Apr;135(4):513-520.

39. Kampougeris G, Spyropoulos D, Mitropoulou A, Zografou A, Kosmides P. Peripapillary retinal nerve fibre layer thickness measurement with SD-OCT in normal and glaucomatous eyes: distribution and correlation with age. Int J Ophthalmol 2013 Oct 18;6(5):662-665.

40. Tariq YM, Li H, B Burlutsky G, Mitchell P. Retinal nerve fiber layer and optic disc measurements by spectral domain OCT: normative values and associations in young adults. Eye (Lond) 2012 Dec;26(12):1563-1570.

41. Hirasawa H, Tomidokoro A, Araie M, Konno S, Saito H, Iwase A, Shirakashi M, Abe H, Okubo S, Sugiyama K, et al. Peripapillary retinal nerve fiber layer thickness determined by spectral-domain optical coherence tomography in ophthalmologically normal eyes. Arch Ophthalmol 2010 Nov;128(11):1420-1426.

42. Bendschneider D, Tornow RP, Horn FK, Laemmer R, Roessler CW, Juenemann AG, Kruse FE, Mardin CY. Retinal nerve fiber layer thickness in normals measured by spectral domain OCT. J Glaucoma 2010 Sep;19(7):475-482.

43. Huyhn SC, Wang XY, Burlutsky G, Roochtchina E, Stapleton F, Mitchell P. Retinal and optic disc findings in adolescence: a population-based OCT study. Invest Ophthalmol Vis Sci 2008 Oct;49(10):4328-4335.

44. Seibold LK, Mandava N, Khakoo MY. Comparison of retinal nerve fiber layer thickness in normal eyes using time-domain and spectral-domain optical coherence tomography. Am J Ophthalmol 2010 Dec;150(6):807-814.

45. Savini G, Barboni P, Carbonelli M, Shreglia A, Deluigi G, Parisi V. Comparison of optic nerve head parameter measurements obtained by time-domain and spectral-domain optical coherence tomography. J Glaucoma 2013 Jun-Jul;22(5):384-389.

46. Chen HY, Chang CY, Lane HY. Correlation in retinal nerve fiber layer thickness between two OCT units. Optom Vis Sci 2011 Nov;88(11):1326-1332.

47. Lisboa R, Leite MT, Zangwill LM, Tafreshi A, Weinreb RN, Medeiros FA. Diagnosing preperimetric glaucoma with spectral domain optical coherence tomography. Ophthalmology 2012 Nov;119(11):2261-2269.

48. Johnson DE, El-Defrawy SR, Almeida DR, Campbell RJ. Comparison of foveal thickness measurements obtained by time-domain and spectral-domain optical coherence tomography. J Glaucoma 2013 Jun-Jul;22(5):384-389.

49. Lee ES, Kang SY, Choi EH, Kim JH, Kim NR, Seong GJ, Kim CY. Comparisons of nerve fiber layer thickness measurements between Stratus, Cirrus and RTVue OCTs in healthy and glaucomatous eyes. Optom Vis Sci 2011 Jun;88(6):751-758.

50. Göbel W, Hartmann F, Haigis W. Determination of retinal thickness in relation to the age and axial length using optical coherence tomography. Ophthalmologe 2001 Feb;98(2):157-162. (Ger).