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Deviation in the Position of Foveal Bulge from Foveal Center in Normal Subjects Measured Using Spectral-Domain OCT

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Purpose: To report a deviation in the position of the foveal bulge (FB) from the foveal center and to analyze its relationship with the foveal shape in normal subjects using spectral-domain (SD) OCT.

Design: Cross-sectional study.

Participants: A total of 146 clinically normal subjects.

Methods: Macular Cube 512 × 128 was used to obtain the cross-sectional images of the macula in Cirrus HD-OCT (Carl Zeiss Meditec, Inc, Dublin, CA). The foveal center was identified manually as the deepest point within the foveal dip, which was termed the "manually identified foveal center" (MFC). The position of the FB with respect to the MFC was noted, and the radial distance between them was measured. The foveal center detected by the inbuilt auto-fovea finder algorithm was considered as the automatically detected foveal center (AFC), and the distance between the AFC and the FB was measured. The radial distances of the FB from the MFC and the AFC were compared, and its direction of deviation from the foveal center was noted. All OCT measurements were adjusted for the ocular magnification factor. The amount of deviation was correlated with the foveal shape parameters, such as foveal radius.

Main Outcome Measures: Radial distance between FB and foveal center and its direction of deviation.

Results: Mean age of the subjects was 43.9±14.4 years. The position of the FB was deviated from the foveal center in 125 subjects (85.6%). Median radial distance between the FB and the MFC was 58.6 μm (35.16–75.04 μm) with the maximum separation of 222.68 μm. From the AFC, the FB was separated by a median of 58.6 μm (46.88–84.51 μm), maximum separation being 181.94 μm. The direction of deviation of the FB from foveal center was nasal in a majority of subjects (n = 75, 51% in MFC). The separation between the FB and the foveal center was not associated with age ($P = 0.149$), gender ($P = 0.762$), or axial length ($P = 0.25$).

Conclusions: The position of the FB did not coincide with the foveal center and was deviated in the direction of the optic disc in a majority of normal subjects. Further studies are required to correlate this anatomic deviation with the fixation locus of the individuals. *Ophthalmology Retina 2017;■:1–6 © 2017 by the American Academy of Ophthalmology*

The fovea is a specialized structure in the retina that is known for its unique morphology. Identified by a depression at its center with displaced inner retinal layers, lack of retinal blood vessels, and highest cone photoreceptor density, fovea is regarded as an area of high acuity, giving sharp vision at the line of sight.[1]

Spectral-domain (SD) OCT, with its highly resolved cross-sectional images of the retina, has given a deeper understanding of the ultrastructure of the retinal layers.[2] Quantitative measurements such as foveal thickness, which correlates with visual acuity, are of clinical importance in monitoring the disease condition. Identification of the foveal center on OCT is critical for an accurate measurement of the foveal thickness. Various landmarks have been used in the literature to identify the foveal center. Some studies have used the central foveal light reflex[3,4] or the deepest point of the fovea,[3] and other studies have taken the point of increased outer segment layer thickness[5–7] or increased thickness of the outer nuclear layer and absence of inner retinal layers.[4] The dome-shaped structure of the ellipsoid layer where the thickness of the outer segment is increased is termed the "foveal bulge" (FB), which is said to correspond to the foveal center.[8] The FB is considered as a good marker for predicting the foveal function. We observed that the FB did not correspond precisely with the foveal center in some normal subjects, and there was a small deviation in its position with respect to the foveal center. In this article, we considered the deepest point of the fovea as the foveal center. We analyzed the association of this deviation with other parameters, such as foveal radius, age, and axial length. Also, we compared the 2 methods of localizing the foveal center.

Methods

Macular scans of 146 randomly selected subjects recruited for the normative foveal morphology study conducted at our institution

http://dx.doi.org/10.1016/j.oret.2017.08.002
ISSN 2468-6530/17

were reviewed. The study was approved by the Institutional Review Board and adhered to the tenets of the Declaration of Helsinki. The study population included employees of the institution, their relatives and friends, and patients who came for a routine eye examination. Written informed consent was obtained from all subjects before enrolling in the study.

Subjects with best-corrected visual acuity of 6/9 or above, age between 18 and 80 years, refractive error between −3.00 and +4.00 diopter sphere, and cylindrical error less than −2.00 diopter cylinder were included in the study. Ocular diseases, such as strabismus, retinal pathology, or optic nerve pathology, in either eye were excluded. The SD-OCT images with signal strength <6 of 10 units and artifacts including slanted image, decentered scan, and motion artifacts were excluded.

Data on age, refractive error, and visual acuity were taken from subjects' medical records. Axial length was measured using Ocuscan RxP (Alcon Laboratories, Inc, Irvine, CA).

Spectral-Domain OCT

Macular scanning was performed using Macular Cube 512 × 128 scan protocol on Cirrus HD-OCT (Model 4000, Version 6, Carl Zeiss Meditec, Inc, Dublin, CA). Macular Cube 512 × 128 is a 6 × 6-mm cube scan consisting of 128 B-scans, with each B-scan consisting of 512 A-scans. The subjects were instructed to maintain steady fixation at the internal fixation target and to keep their head fixed at the head rest to prevent rotations in the field of view. Raster scans also were taken to visualize both the foveal center and the FB in a single B-scan, especially when the FB was located at angles other than horizontal to the foveal center. Scans were acquired by centering it on the fovea, that is, the deepest point of the foveal depression. The OCT beam entry point was positioned such that the scans were aligned straight.[9] The scan quality was improved by optimizing the polarization and correcting the patient's refractive error in the machine.

In the SD-OCT analysis, the B-scan that contained the foveal center was identified manually on the basis of the deepest point of the fovea and the widest foveal floor. The exact location of the foveal center was found by taking the center of the foveal floor, and it was denoted as manually identified foveal center (MFC). To compare the study results with an automated measurement, the foveal center that was detected by the inbuilt auto fovea finder algorithm was taken and denoted as the automatically detected foveal center (AFC). This algorithm identifies the foveal center by looking for reduced reflectivity below the retina. The central point of the region where the thickness of the outer segments of photoreceptors was seen to be highest was the FB (Fig 1). The B-scan and A-scan numbers at the foveal center (MFC and AFC) and the FB were noted (Fig 1). The distance between the positions of the FB and the foveal center was found in terms of A-scan and B-scan numbers and then converted to microns. Before that, the nominal OCT scan length of 6 mm was corrected for the ocular magnification factor as described by Parthasarathy and Bhende.[10] From the corrected scan length, the spacing between 2 A-scans and 2 B-scans was found, having known that in a Macular Cube 512 × 128, one horizontal B-scan and a vertical scan consist of 512 pixels and 128 pixels, respectively. Thus, the radial distance of the FB from the foveal center was calculated, and the direction of the FB with respect to the foveal center was noted. A case example summarizing the calculations is given in Appendix 1. These measurements were made in both eyes for 89 randomly selected subjects to check for interocular symmetry. A single observer was involved in all OCT-related measurements.

To analyze the possible associations for the observed deviation of the FB from the foveal center, we measured parameters such as the foveal radius, that is, the distance of the foveal rim from the foveal center using an algorithm written in MATLAB (The Mathworks Inc, Natick, MA). Raw data of retinal thickness at all A-scan positions of the macular cube scan were imported into MATLAB. The retinal thickness data from the horizontal B-scan representing the foveal center were taken and fitted with polynomials such that the root mean square error was <1. Nasal and temporal foveal rims where the retinal thickness is maximum were located automatically,[7] and the distance of the rims from the foveal center was extracted. Likewise, the superior and inferior rim distances were extracted from the vertical scan.

Statistical Analysis

Statistical analysis was performed with SPSS (SPSS Inc, Version 14, Chicago, IL) and MedCalc (MedCalc Software, Version 12.5, Ostend, Belgium). All parameters except the radial distance of FB from foveal center were normally distributed, tested using the Kolmogorov−Smirnov test. Comparison of the 2 methods of finding the foveal center, MFC and AFC, was made using the Bland−Altman plot. Difference in foveal rim distances was tested with paired t test. Alpha error was kept at 5%.

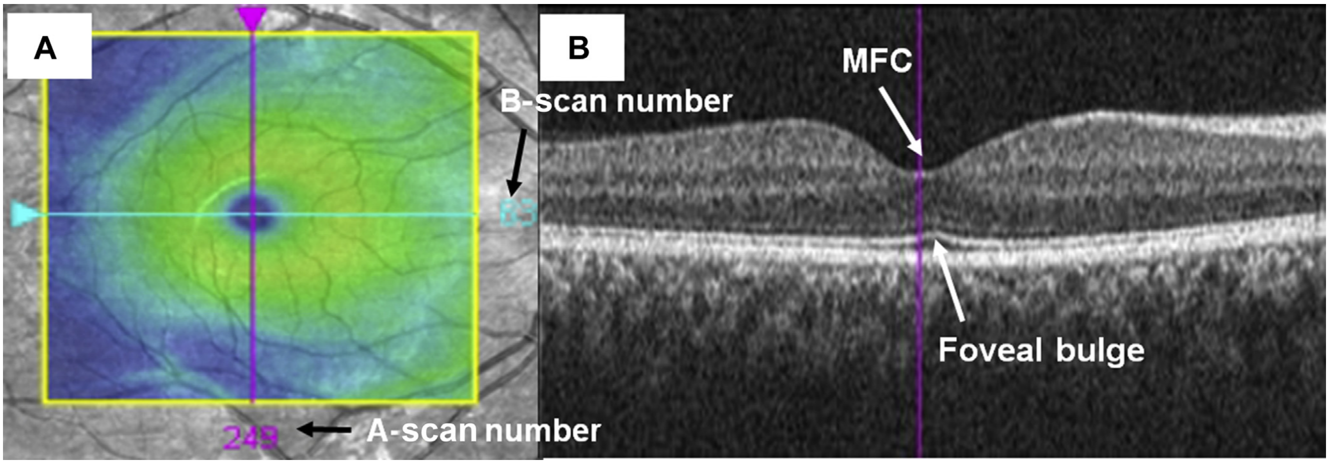

Figure 1. **A**, Retinal thickness map overlay on the fundus image of the right eye shows the position of foveal center at the intersection of cyan and magenta slice navigators that give B-scan and A-scan numbers, respectively. **B**, Grayscale OCT image along the cyan line shows positions of the manually identified foveal center (MFC) and the foveal bulge.