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Characteristics of Optic Disc Rotation in Myopic Eyes

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Purpose: To investigate the characteristics of optic disc rotation and ocular parameters affecting optic disc rotation in healthy myopic eyes.

Design: Cross-sectional, comparative study.

Participants: A total of 220 participants with healthy myopic eyes.

Methods: Spherical equivalent (SE) refractive error, axial length, central corneal thickness, and intraocular pressure (IOP) were evaluated. Optic disc tilt ratio, degree of optic disc rotation, and area of β-zone parapapillary atrophy (PPA) were measured. Optic nerve head (ONH) parameters and thickness of the peripapillary retinal nerve fiber layer (pRNFL) and macular ganglion cell-inner plexiform layer (mGCIPL) were measured using Cirrus optical coherence tomography (Carl Zeiss Meditec Inc., Dublin, CA). Subjects were divided into 2 groups, group 1 with superior rotation and group 2 with inferior rotation of the optic disc, and various parameters were compared. Linear regression analysis was performed to evaluate the relationships between the degree of optic disc rotation and several parameters.

Main Outcome Measures: Degree of optic disc rotation.

Results: Among 220 eyes, 147 showed superior rotation of the optic disc and 73 showed inferior rotation. The mean tilt ratio and rotation degree were 1.16 and −19.51°, respectively, in group 1 and 1.20 and 28.93°, respectively, in group 2, showing significant differences between the groups ($P = 0.028$ and $P = 0.035$, respectively). There were also significant between-group differences in IOP (15.59 vs. 16.34 mmHg), SE refractive error (−4.05 vs. −5.66 diopters [D]), axial length (25.51 vs. 26.26 mm), and area of β-zone PPA (0.32 vs. 0.70 mm^2). Overall, a multivariate linear regression analysis showed that IOP, axial length, and area of β-zone PPA were significant parameters related to the degree of optic disc rotation ($P = 0.011$, $P = 0.043$, and $P = 0.030$, respectively). Group 2 showed thinner pRNFL and mGCIPL thickness in general compared with group 1.

Conclusions: In healthy myopic eyes, superior rotation of the optic disc was more prevalent than inferior rotation. As the optic disc rotates inferiorly, there was a significant positive correlation with IOP, axial length, and area of the β-zone PPA. Conversely, a significant negative correlation with pRNFL and mGCIPL thickness was observed. *Ophthalmology 2015;■:1–8 © 2015 by the American Academy of Ophthalmology.*

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Myopia is a common ocular condition and continues to increase in prevalence, particularly in Asian populations.[1–3] Because axial elongation in the myopic eye is associated with posterior scleral remodeling, myopic eyes demonstrate various characteristic features of the optic nerve head (ONH), including marked parapapillary atrophy (PPA), shallow disc cupping, a macrodisc with an abnormal elongation, optic disc tilt, and torsion.[4–9] Recently, these morphologic features of the optic disc have become candidates for the explanation of the high prevalence of glaucoma in myopic eyes. Among them, optic disc torsion has been recognized as a new area of concern. It has been reported that optic disc torsion was highly prevalent in Asian populations and associated with visual field (VF) defects.[9–13] Park et al[10] reported that the direction of optic disc torsion was a strong predictor of VF defect location in normal-tension glaucoma (NTG). Likewise, Lee et al[12] found a significant correlation between the amount of optic disc torsion and the VF defect severity based on the mean deviation in young myopic eyes.

Traditionally, torsion has been a term used to describe the rotation of the optic disc. Because the optic nerve extends from the optic disc to the chiasm, rotation of the optic disc, which is 1 end of the optic nerve, may result in optic nerve twisting. Until now, however, none of the studies have demonstrated actual twisting of the optic nerve in eyes with optic disc torsion. Moreover, Lee et al[14] recently suggested that optic disc torsion is another form of optic disc tilt centered on the oblique axis. Therefore, we used the term "optic disc rotation," which only describes the anatomic variation of the optic disc and retinal vessels, rather than the term "optic disc torsion" in this study.

To date, most studies have focused on optic disc rotation in glaucomatous eyes,[9–13] and few have reported on the features of optic disc rotation in healthy subjects. Thus, the aim of this study was to characterize optic disc rotation and evaluate ocular parameters affecting optic disc rotation in healthy myopic eyes.

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Methods

Subjects

The study protocol adhered to the tenets of the Declaration of Helsinki and was approved by the institutional review board of the Chonnam National University Hospital. The participants were informed about the study objectives, and signed informed consent was obtained from all participants.

Healthy volunteers were prospectively and consecutively recruited from February to August 2014. The subjects were selected from students attending the Chonnam National University Medical School. All subjects underwent complete ophthalmic examination including measurement of best-corrected visual acuity, intraocular pressure (IOP) by Goldmann applanation tonometry, manifest refraction, slit-lamp examination, anterior chamber angle examination by gonioscopy, ONH and retinal nerve fiber layer (RNFL) examination by color stereoscopic disc photography and red-free RNFL fundus photography, and the Swedish Interactive Threshold Algorithm standard 30-2 perimetry with a Humphrey Field Analyzer (Carl Zeiss Meditec Inc., Dublin, CA). All IOP measurements were made between 5:00 and 7:00 PM. Axial length, central corneal thickness, and anterior chamber depth were measured by optical low-coherence reflectometry (Lenstar; Haag-Streit AG, Koeniz, Switzerland). A detailed medical history was also recorded for each subject.

The following inclusion criteria were used: healthy subjects aged between 20 and 40 years, a spherical equivalent (SE) refractive error between −9.0 and −0.5 diopters (D), astigmatism within ±2 D, best-corrected visual acuity ≥20/25, IOP ≤21 mmHg, normal anterior chamber angles, nonglaucomatous ONHs on stereoscopic photographs (an intact neuroretinal rim without peripapillary hemorrhage, thinning, or localized pallor), absence of any RNFL abnormalities on red-free fundus photographs, and normal VF results in both eyes. Because myopic refractive error can be affected by lenticular changes, and aging may increase the incidence of glaucoma, we excluded subjects older than 40 years of age. To increase the yield of healthy myopic eyes, we also excluded extremely highly myopic eyes with an SE <−9.0 D, because it is known that various pathologic changes on the myopic fundus, such as staphyloma, lacquer cracks, and so forth, increase in prevalence with increasing myopic refractive error. Normal VF presentation was defined as a glaucoma hemifield test result within normal limits, as well as mean and pattern standard deviation values associated with probabilities of normality greater than 5%. Some eyes had an enlarged blind spot associated with a large area of PPA, and such eyes were also included in this study. Patients with a family history of glaucoma in a first-degree relative, history of intraocular or refractive surgery, pathologic myopia (patch chorioretinal atrophy, lacquer crack lesions, intrachoroidal cavitations, choroidal neovascularization), other evidence of retinal pathology, or opaque media were excluded. Eligibility was determined by 2 glaucoma specialists (M.S.S. and S.W.P.), who evaluated optic disc appearance on stereoscopic disc photographs and RNFL defects on red-free fundus photographs. Evaluators were masked to all other patient and ocular data, and an eye was excluded from study analyses if a consensus could not be reached. The right eye was selected for the analyses.

Optical Coherence Tomography Imaging

The ONH, peripapillary RNFL (pRNFL), and macular ganglion cell-inner plexiform layer (mGCIPL) parameters were measured using a Cirrus high-definition optical coherence tomography (HD-OCT) device (Carl Zeiss Meditec). All measurements were performed by the same examiner who was experienced in taking OCT images.

The Optic Disc Cube 200×200 protocol provides the results obtained from 200 horizontal B-scans (200 A-scans per B-scan) and measures pRNFL thickness in a cube of 6×6×2 mm. The average pRNFL thickness was measured within a 3.46-mm−diameter circle, the center of which was manually positioned at the optic disc center. Quadrant pRNFL thickness values were used in our analysis. The Macular Cube 200×200 protocol provides the results obtained from 200 horizontal B-scans (200 A-scans per B-scan) over 1024 samplings within a cube (6×6×2 mm) centered at the fovea. The ganglion cell analysis algorithm in the 6.0 software version of Cirrus HD-OCT reports the combined thickness of the retinal ganglion cell and inner plexiform layers by identifying the outer boundaries of the RNFL and the inner plexiform layer. The average, minimum (lowest mGCIPL thickness over a single meridian crossing the annulus), and 6 sectoral (superotemporal, superior, superonasal, inferonasal, inferior, and inferotemporal) mGCIPL thicknesses were measured within a 14.13-mm^2 elliptical annulus area (vertical inner and outer radii of 0.5 mm and 2.0 mm, respectively; horizontal inner and outer radii of 0.6 and 2.4 mm, respectively) centered on the fovea within the cube. Subjects with any abnormalities (including an extremely large PPA) in the circumpapillary region that affected the scan ring where the OCT RNFL thickness measurements were obtained were excluded.

Measurements of Optic Disc Tilt, Rotation, and Parapapillary Atrophy Area

Digital retinal photographs centered on the optic disc and macula were obtained using standard settings with a nonmydriatic retinal camera (Canon, Tokyo, Japan). Each photograph was exported to a desktop computer as a TIFF image file. Using public-domain Java-based image processing software developed by the National Institutes of Health (ImageJ, version 1.4.1; Wayne Rasband; National Institutes of Health, Rockville, MD), the optic disc tilt, rotation, and area of β-zone PPA were measured by 2 independent examiners. Average data were used in the final analysis.

The definition of optic disc tilt and its measurement have been described.[10–13] Briefly, optic disc tilt was measured as the tilt ratio, defined as the ratio between the longest and shortest diameters of the optic disc. Optic discs were classified as tilted in those with tilt ratios exceeding 1.30. Optic disc rotation was defined as the deviation of the long axis of the optic disc from the reference line, 90° from a horizontal line connecting the fovea and the center of the optic disc. The angle between the long axis of the optic disc and the reference line was termed the "degree of rotation." The optic disc was classified as having significant rotation when the degree of rotation exceeded 15°. All eyes were divided into 2 groups according to the direction of optic disc rotation. Eyes with superior rotation of the optic discs were defined as group 1, and eyes with inferior rotation of the optic discs were defined as group 2. Because all eyes included in the analysis were right eyes, superior rotation indicated clockwise rotation of the optic disc and inferior rotation indicated counterclockwise rotation of the optic disc. Superior rotation was presented as a negative value, and inferior rotation was presented as a positive value.

The presence of the β-zone PPA was defined as marked atrophy of the retinal pigment epithelium and a horizontal width of the choriocapillaris apparently larger than the diameter of the major retinal vein at the optic disc edge. The areas of β-zone PPA (an inner crescent of chorioretinal atrophy with visible sclera and choroidal vessels) were determined as the total number of pixels using the ImageJ software in a circumferential pattern. Combined with the magnification factor of ×1.4 of the fundus camera, the total magnification by the camera and ImageJ system was