Population Prevalence of Tilted and Torted Optic Discs Among an Adult Chinese Population in Singapore

The Tanjong Pagar Study

Alicia C. S. How, FRCS; Gavin S. W. Tan, MRCS; Yiong-Huak Chan, PhD; Tina T. L. Wong, MD, PhD; Steve K. Seah, FRCS; Paul J. Foster, FRCS, PhD; Tin Aung, MBBS, PhD, FRCS(Edin)

Objective: To determine the prevalence of tilted and torted optic discs and associated risk factors among Chinese adults in Singapore.

Methods: As part of a population-based survey, optic disc stereophotographs of both eyes were obtained, and left eyes were analyzed using imaging software. A tilted optic disc was defined as an index of tilt (ratio of minimum to maximum optic disc diameter) less than 0.75. The angle of tilt was defined as the angle between the maximum and vertical optic disc diameter, and optic discs were graded as torted if the angle of tilt exceeded 15°.

Results: Twenty-six of 739 subjects (3.5%) had tilted optic discs, and 478 (64.7%) had torted optic discs. Myopia was present in 23 of 26 eyes (88.5% [95% confidence interval, 69.9%-97.6%]) with tilted optic discs and in 211 of 661 eyes (31.9% [28.4%-35.6%]) without tilted optic discs (P < .001). On multivariate analysis, myopia (spherical equivalent) was a significant risk factor for tilted optic discs (P < .001). Index of tilt was not associated with corneal astigmatism or with cylindrical refractive error. Seventeen eyes (65.4%) with tilted optic discs had an optic disc morphologic abnormality, but none were glaucomatous.

Conclusions: The prevalence of tilted optic discs among this Chinese population was 3.5%. Tilted optic discs were associated with myopia but not with glaucoma.

Arch Ophthalmol. 2009;127(7):894-899

Myopia is fast becoming a growing public health concern. Over the past few decades, there has been a notable increase in the prevalence of myopia, particularly among Asian populations. Singapore has one of the highest prevalence rates of myopia worldwide.1 Optic disc morphologic function has been shown to be markedly different in myopic eyes compared with emmetropic eyes.2 Morphologic differences include shallow and concentric optic disc cupping, large optic discs, peripapillary atrophy (PPA), and elongated vertical optic disc diameter.2-7 Tilted and torted optic discs have also been reported as a morphologic feature associated with myopia.8 The prevalence of tilted optic discs among various populations has been found to range from 1.6% to 1.7%.5,8,9 Torted optic discs have also been shown to correlate with the axis of corneal astigmatism.10 Studies11,12 have shown a relationship between glaucomatous optic nerve damage and myopia. With the increasing aging populations in Asia, the diagnosis of glaucoma in myopes remains a challenge. To our knowledge, there are no population-based data on the prevalence of tilted or torted optic discs among Asians. In this study, we report the population prevalence of tilted or torted optic discs and its relationship with refractive error and axial length among an adult Chinese population 40 years and older in Singapore.

Author Affiliations: Glaucoma Department, Singapore National Eye Centre and Singapore Eye Research Institute (Drs How, Tan, Wong, Seah, and Aung) and Biostatistics Unit (Dr Chan), Yong Loo Lin School of Medicine, National University of Singapore, Singapore; and Moorfields Eye Hospital and Institute of Ophthalmology, London, England (Dr Foster).

The Tanjong Pagar Study was a population-based cross-sectional survey of the prevalence and risk factors of ocular diseases performed between October 1, 1997, and August 31, 1998, in a single district of Singapore. The study was performed in accord with the World Medical Association’s Declaration of Helsinki and was approved by the Ethics Committee of
the Singapore Eye Research Institute. Detailed methods of the study have been published elsewhere; a summary is presented herein.

Two thousand subjects (approximately 13% of 15,081) with Chinese names who were aged 40 to 79 years were selected from the 1996 electoral register using a stratified clustered sampling procedure. The population was divided into the following 4 age strata: 40 to 49, 50 to 59, 60 to 69, and 70 to 79 years. Five hundred subjects from each age stratum were randomly selected. The primary sampling unit was the street of residence. Electoral registration is a legal requirement in Singapore, and it provides a complete record of all residents 21 years and older in the country. The demographic and socioeconomic characteristics of this region are similar to those of Singapore as a whole. All subjects received a postal invitation for an eye examination in a research clinic, together with a pamphlet about glaucoma. All nonresponders were sent 2 further postal invitations and received a telephone call. Subsequently, a field-worker visited the address of persistent nonresponders twice to facilitate visits.

**EYE EXAMINATION**

The hospital clinic–based eye examination consisted of gonioscopy, visual field testing, applanation tonometry, visual acuity and refraction, dilated optic disc examination, slit-lamp examination of the anterior segment, and optical pachymetry measurement of central corneal thickness. Axial ocular dimensions (axial length, anterior chamber depth, and vitreous chamber depth) were measured using a 10-MHz A-mode ultrasonographic device (Compuscan; Storz, St Louis, Missouri). Noncycloplegic refraction was measured using a handheld autorefractor (Retinomax K-plus; Nikon, Tokyo, Japan) and was further refined subjectively by an optometrist with the aid of a phoropter. Noncycloplegic refraction data were converted to spherical equivalents, which were calculated using the spherical diopter (D) plus one-half the cylindrical dioptic power. Cylindrical refractive errors were recorded in the negative form.

Optic disc color stereophotographs were obtained. They were taken with a mydriatic fundus camera (Topcon, Paramus, New Jersey) and were digitalized.

All ocular examination and measurements were performed in both eyes, but the measurements and photographs used for analyses were from left eyes only (chosen randomly). From optic disc digital photographs viewed on a computer screen, the maximum, minimum, vertical, and horizontal optic disc diameters and the optic disc angle of tilt of patients’ left eyes were measured by a glaucoma fellowship–trained investigator (A.C.S.H.). Optic disc stereophotograph pairs were viewed using a stereoviewer, and the optic disc margins were identified. The measurements were obtained from the optic disc margins, defined as the inner border of the peripapillary scleral ring. All optic disc photograph measurements were obtained on digital images using the caliper function of commercially available software (Bersoft Image Measurement, version 5.0; Bersoft.com, Buenos Aires, Argentina).

**DEFINITIONS**

Myopia was defined as a spherical equivalent less than −0.5 D. Low myopia was defined as a spherical equivalent of −3 to −0.5 D, moderate myopia as −5 to −3 D, and high myopia as not exceeding −6 D. Astigmatism was defined as less than −0.5 D of cylinder.

Optic disc photographs were defined as readable if the optic disc margins could be clearly identified. Optic disc ovality was assessed using the ratio of minimum to maximum optic disc diameter (index of tilt). A tilted optic disc was defined as an optic disc with an index of tilt less than 0.75, as in previous studies. The angle of tilt was defined as the angle between the maximum optic disc diameter and the vertical meridian. The optic disc was graded as torted when the axis of maximum optic disc diameter was rotated more than 15° outside the vertical meridian, the same definition as that adopted in the Blue Mountains Eye Study. Examples of tilted and torted optic discs are shown in the Figure.

The diagnosis of glaucoma was based on characteristic structural and functional evidence of glaucomatous optic neuropathy and has been previously described. If visual field testing could not be performed because of severe visual impairment, glaucoma diagnosis was made based on evidence of severe structural optic disc damage. Optic disc morphologic abnormality was defined as a cup-disc ratio of at least 0.71, cup-disc ratio asymmetry of at least 0.21, or narrower neuroretinal rim less than 0.1 of the cup-disc ratio.

**ANALYSIS**

Biometric components and refractive data were analyzed as continuous variables from the left eye only because the correlation between eyes was high. A univariate linear regression model was used to assess the association of biometric, refractive, and other variables with index of tilt. Multiple logistic regression models were used to determine the effects of biometric, refractive, and other variables on the odds of having tilted or torted optic discs, adjusted for age and sex.
RESULTS

To confirm that the tilted optic discs ascertained based on index of tilt less than 0.75 were stereoscopically tilted, we re-examined 136 randomly selected eyes in a double-masked fashion. The optic disc stereophotograph pairs were graded using a handheld stereoviewer and were classified as tilted if one edge of the optic disc appeared more anteriorly located than its edge 180° away.

Classification of a tilted optic disc using the index of tilt was compared with stereoscopic assessment of the tilted optic disc as the reference standard. Receiver operating characteristic curve was used to measure agreement between the 2 methods of assessment.

Data were analyzed using commercially available software (Statistical Package for Social Sciences, version 11.5; SPSS Inc, Chicago, Illinois). Statistical significance was assumed at P<.05.

Of 2000 names selected from the sampling frame, 1717 subjects were eligible for the survey because 46 subjects had died, 235 had moved out of the district, and 2 were unfit for examination. The total number of participants was 1232 (71.8%). One thousand ninety subjects (63.5%) were examined in the research clinic and were considered eligible for the study because 142 subjects examined at home did not undergo optic disc photography or biometric examination. Of 1090 subjects, readable optic disc photographs for measurements of the clinical variables were obtained in 739 (67.8%). Subjects who did not have readable optic disc photographs were significantly older than those whose optic disc photographs were analyzed (mean age, 60.59 years vs 58.67 years; P=.008). Other characteristics such as myopia, spherical equivalent, and axial length were similar between the 2 groups (Table 1).

The mean (SD) age of study subjects was 58.7 (11.1) years. Twenty-six of 739 subjects (3.5%) had tilted optic discs, and 478 (64.7%) had torted optic discs. Table 2 summarizes the characteristics of subjects with tilted and torted optic discs. Eighteen subjects (2.4%) had both tilted and torted optic discs. There was no significant association between age and the presence of a tilted optic disc (Table 3). However, more women than men were found to have a low index of tilt (regression coefficient, −0.016; 95% confidence interval [CI], −0.025 to −0.007; P<.001). When adjusted for age, there was no association between sex and the presence of tilted optic discs (P=.14). When adjusted for age and sex, increasing axial length (odds ratio [OR], 3.68; 95% CI, 2.53-5.36; P<.001), decreasing spherical refractive error (0.63; 0.55-0.71; P<.001), and decreasing cylindrical refraction (0.58; 0.37-0.92; P=.02) were significant risk factors for the presence of tilted optic discs (Table 4).

Myopia was associated with tilted optic discs (OR, 16.08; 95% CI, 4.76-54.36; P<.001), but when subcategorized into low, moderate, and high myopia, only moderate and high myopes were associated with the combination of both tilted and torted optic discs compared with nonmyopes (Tables 3 and 4). On multivariate analysis (Table 5), spherical equivalent remained a significant risk factor for tilted optic discs (P<.001). Refraction data were available for 687 subjects. Myopia was present in 23 of 26 eyes (OR, 88.5% [95% CI, 69.9%-97.6%]) with associated tilted optic discs and in 211 of 661 eyes (31.9% [28.4%-35.6%]) without tilted optic discs (P<.001). Tilted optic discs were present in 23 of 234 eyes with myopia (OR, 9.8% [95% CI, 6.3%-14.4%]) compared with 3 of 453 eyes without myopia (0.7% [0.1%-1.9%]) (P<.001).

We found no significant relationship between the index of tilt or tilted optic discs with corneal astigmatism. Similarly, no significant relationship was found with cylindrical refractive error.

Seventeen of 26 patients (65.4%) with tilted optic discs had optic disc morphologic abnormality compared with 3 of 713 patients (0.4%) without tilted optic discs (P<.001). Despite abnormal optic disc findings, none
of the patients met defined criteria for glaucoma in either eye. A comparison of 3 subgroups (myopes with tilted optic discs, myopes without tilted optic discs, and non-myopes) is given in Table 5. Myopes with tilted optic discs were younger, were more myopic, had a lower cup-disc ratio, and had a higher prevalence of optic disc morphologic abnormality compared with the other 2 subgroups.

To confirm that the tilted optic discs ascertained based on index of tilt less than 0.75 were stereoscopically tilted, we reexamined 136 randomly selected eyes. Thirty of these eyes had clinically tilted optic discs, and 106 had non-tilted optic discs. Compared with stereoscopic assessment of tilted optic disc as the reference standard, the use of index of tilt less than 0.75 resulted in 0.755 area under the curve (P < .001), 56.7% sensitivity, 94.0% specificity, 88.5% negative predictive value, and 73.9% positive predictive value (Table 6).

Table 4. Age- and Sex-Adjusted Logistic Regression Analysis of Risk Factors Associated With Tilted and Torted Optic Discs

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Odds Ratio (95% Confidence Interval)</th>
<th>P Value</th>
<th>Odds Ratio (95% Confidence Interval)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spherical refraction, per D</td>
<td>0.63 (0.55-0.71)</td>
<td>&lt;.001</td>
<td>0.99 (0.93-1.05)</td>
<td>.62</td>
</tr>
<tr>
<td>Cylindrical refraction, per D</td>
<td>0.58 (0.37-0.92)</td>
<td>.02</td>
<td>0.94 (0.75-1.19)</td>
<td>.63</td>
</tr>
<tr>
<td>Spherical equivalent, per D</td>
<td>0.64 (0.56-0.72)</td>
<td>&lt;.001</td>
<td>0.98 (0.93-1.10)</td>
<td>.57</td>
</tr>
<tr>
<td>Anterior chamber depth, per mm</td>
<td>8.81 (2.42-32.06)</td>
<td>.001</td>
<td>0.98 (0.59-1.61)</td>
<td>.92</td>
</tr>
<tr>
<td>Axial length, per mm</td>
<td>3.68 (2.53-5.36)</td>
<td>&lt;.001</td>
<td>1.10 (0.97-1.26)</td>
<td>.14</td>
</tr>
<tr>
<td>Vitreous chamber depth, per mm</td>
<td>4.02 (2.69-6.02)</td>
<td>&lt;.001</td>
<td>1.17 (1.01-1.35)</td>
<td>.04</td>
</tr>
<tr>
<td>Glaucoma</td>
<td>0.00 (0.00-0.00)</td>
<td>&gt;.99</td>
<td>1.09 (0.27-4.42)</td>
<td>.91</td>
</tr>
<tr>
<td>Myopia</td>
<td>16.08 (4.76-54.36)</td>
<td>&lt;.001</td>
<td>1.11 (0.80-1.54)</td>
<td>.55</td>
</tr>
</tbody>
</table>

a Not all risk factors studied are shown.

Table 5. Comparison of 3 Subgroups

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value (95% Confidence Interval)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean, y</td>
<td>54.09 (49.74 to 58.44)</td>
</tr>
<tr>
<td>Female sex, %</td>
<td>69.6 (47.1 to 86.8)</td>
</tr>
<tr>
<td>Cup-disc ratio, mean</td>
<td>0.41 (0.35 to 0.46)</td>
</tr>
<tr>
<td>Glaucoma, %</td>
<td>0.0 (0.0 to 14.8)</td>
</tr>
<tr>
<td>Intraocular pressure, mm Hg</td>
<td>14.70 (13.40 to 16.00)</td>
</tr>
<tr>
<td>Prevalence of optic disc morphologic abnormality, %</td>
<td>69.6 (47.1 to 86.8)</td>
</tr>
<tr>
<td>Spherical equivalent, mean, D</td>
<td>-8.64 (-8.36 to -4.92)</td>
</tr>
</tbody>
</table>

a P values were derived using 1-way analysis of variance for quantitative variables and using χ² test for qualitative variables.

b Qualitative variables.

Table 6. Stereoscopic Assessment of Tilted Optic Disc vs Assessment Based on the Index of Tilt in 136 Randomly Selected Subjects

<table>
<thead>
<tr>
<th>Stereoscopic Assessment</th>
<th>Assessment Based on Index of Tilt</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥0.75</td>
<td>&lt;0.75</td>
</tr>
<tr>
<td>Not tilted</td>
<td>100 (88.5)</td>
</tr>
<tr>
<td>Tilted</td>
<td>13 (11.5)</td>
</tr>
<tr>
<td>Total</td>
<td>113 (100.0)</td>
</tr>
</tbody>
</table>

a A tilted optic disc was defined as an optic disc with an index of tilt less than 0.75.

East Asian adults. Because myopia is a growing public health concern in Singapore and in other parts of East Asia,20 its association with tilted optic discs4-6 and with glaucoma21 may prove to be a challenge for clinicians in diagnosing myopes with glaucoma as the population ages and as more individuals develop glaucoma.

The prevalence of tilted optic discs (based on index of ovality) among this adult Chinese population was 3.5%. If the definition of tilted optic discs includes tort (defined as an angle of tilt >15°), the prevalence was 2.4%. Both prevalence rates are higher than the 1.6% and 1.7% that

COMMENT

Few population-based investigations of optic disc tilt and its associated risk factors have been conducted, and this study (to our knowledge) is the first to provide population-based data on the prevalence of tilted optic discs among
have been reported among Australian and Italian populations.5,9 This variation may be partly explained by the fact that studies have adopted various definitions of tilted and torted optic discs, different inclusion criteria, and varying research methods. In the aforementioned studies,5,9 tilted optic discs were defined based on a qualitative assessment rather than a quantitative one measuring optic disc variables. Another possible explanation could be a difference between ethnic groups, as the other studies were conducted among populations of white race/ethnicity. In this study, 136 optic disc stereophotographs were reexamined to confirm that the tilted optic discs ascertained based on index of tilt less than 0.75 were stereoscopically tilted. Although this method of stereoscopic assessment is subjective and is dependent on focus of the camera and on camera angle, we found moderate agreement between the 2 methods. We found no difference in the prevalence of tort among eyes whether they were identified as tilted or not. This is in contrast to results of the Blue Mountains Eye Study1 in Australia, which found that the presence of a torted optic disc appearance was more common in patients with tilted optic discs (87.0%) vs in patients without tilted optic discs (26.8%).

The results of our study agree with evidence that most individuals (88.5%) who have tilted optic discs are also myopic.5,11-24 In contrast to previous findings, the prevalence of astigmatism (≥0.5 D) was not significantly different between eyes with tilted optic discs (85.0%) vs eyes without tilted optic discs (85.7%).5 The presence of oval tilted discs had no effect on the overall astigmatism of Chinese adult eyes vs eyes of white subjects. This may suggest a fundamental difference in pathogenesis of the posterior segment or some as yet unidentified developmental mechanism that gives rise to tilted optic discs in different racial/ethnic populations.

Optic nerve head analysis is crucial in aiding the clinician to diagnose glaucoma. Intrapapillary and pararpapillary morphologic structures help to differentiate normal eyes from those with early glaucomatous optic nerve damage. In a myope with a tilted optic disc, there may be underdiagnosis of glaucoma because of difficulties in assessing the neuroretinal rim and cup-disc ratio. However, glaucoma may be overdiagnosed in eyes that have nonglaucomatous visual field defects arising from tilted optic discs, myopia, and PPA.25,26 Static visual field defects were recently described in a cohort of young Chinese male patients by Doshi et al.27 These patients were treated as for glaucoma, which the authors suggest may have been unnecessary. They postulated that tilting of the optic nerve head and PPA may have increased the strain of intraocular pressure placed on certain axons, mimicking glaucomatous axonal damage and giving rise to visual field defects, which were nonprogressive in these patients. The difficult assessment of tilted optic discs, especially those resembling glaucomatous optic neuropathy, may mean that screening in the community will be ineffective among certain populations. This may ultimately place a large economic burden on hospitals, which will have a significant number of such patients who cannot be discharged and who will require long-term observation (probably indefinitely).

Limitations of this study were that the measurements were obtained by a single observer (A.C.S.H.) and that the reproducibility of measurements was not examined. However, the use of uniform methods of measurement and a large sample size may compensate for bias introduced by the single observer. Furthermore, that our definitions were based solely on qualitative measurements may facilitate comparisons with future studies among other populations or racial/ethnic groups. Additional myopic changes of optic discs such as PPA or visual field defects were not examined in this study. The association between PPA and tilted or torted optic discs should be further investigated to ascertain whether the presence of tilt or tort of the optic disc has any effect on the presence or extent of PPA. It would also be informative to know whether these subjects with tilted or torted optic discs have any accompanying visual field defects. In this study, visual field screening was performed on all subjects using the Henson field screen or using the frequency-doubling technology test. Eyes only underwent formal visual field testing with the Humphrey system if they were suspicious for glaucoma. The few subjects with tilted or torted optic discs make it difficult to draw definitive conclusions about associated risk factors.

In conclusion, our study provides the first epidemiologic data (to our knowledge) on the prevalence of tilted and torted optic discs among an adult Chinese population. We found that the prevalence of optic disc tilt was almost twice that among populations of white race/ethnicity. The presence of optic disc tilt was strongly associated with refractive myopia of at least −3 D and with increased axial length. Moderate to severe myopia is a significant risk factor for associated tilted optic discs in the Chinese population.

Submitted for Publication: January 6, 2008; final revision received September 17, 2008; accepted November 23, 2008.

Correspondence: Tin Aung, MBBS, PhD, FRCOphth, Glaucoma Department, Singapore National Eye Centre, 11 Third Hospital Ave, Singapore 168751 (tin11@pacific.net.sg).

Financial Disclosure: None reported.

Funding/Support: This study was supported by the National Medical Research Council (Singapore) through a grant to the Singapore Eye Research Institute by the International Glaucoma Association (London), the British Council for the Prevention of Blindness (London), and Special Trustees of Moorfields Eye Hospital.

Additional Contributions: Rupert Bourne, FRCOphth, helped with digitalization of optic disc photographs.

Additional Information: Drs Foster and Aung are joint last authors.

REFERENCES


From the Archives of the Archives

140 Years Ago . . .

The number of published observations on the formation of cysts in the iris, is already so considerable, that it is hardly worth while to add to them a new case, but that it will give us an opportunity to describe the manner in which these tumors are formed.

It will appear strange to every one who has seriously studied the pathological anatomy of the eye, that the iris, which is in such intimate relation with the choroid, should have the exclusive privilege of being the seat of cysts, which are hardly ever met with in the remaining parts of the uveal tract.


Louis de Wecker (1832-1906), German by birth and medical education, practiced ophthalmology in Paris, France, beginning in 1862. He invented many instruments and devised several surgical techniques.