A Novel Method for Evaluation of Ocular Torsion Angle by Optical Coherence Tomography

Katsuhide Yamadera, Hiroto Ishikawa, Ayame Imai, Mana Okamoto, Akiko Kimura, Osamu Mimura, and Fumi Gomi

Department of Ophthalmology, Hyogo College of Medicine, Nishinomiya, Hyogo, Japan

Purpose: The Glaucoma Module Premium Edition (GMPE) software for the SPECTRALIS optical coherence tomography (OCT) is able to automatically track the anatomic centers of both the fovea and the optic disc. We investigated the efficacy of the OCT in measuring the ocular torsion angle before and after strabismus surgery.

Methods: Between June 2017 and December 2018, 40 patients with cyclodeviation who had undergone strabismus surgery at Hyogo College of Medicine were enrolled. Ocular torsion angle measurements, including OCT and nonmydriatic fundus camera for objective measurements and synoptophore for subjective measurements, were performed before surgery and 1 day after surgery.

Results: The ocular torsion angles were measured as follows: synoptophore preoperative (–8.8° ± 4.1°) and postoperative (–3.1° ± 2.8°), fundus photography preoperative (–27.2° ± 6.4°) and postoperative (–18.6° ± 5.9°), and OCT preoperative (–25.9° ± 6.8°) and postoperative (–18.2° ± 5.8°). In all cases, symptoms related to cyclodeviation resolved postoperatively. All measurements were positively correlated before surgery. Postoperatively, changes in all measurements were also correlated. However, all synoptophore-related data were underestimated when compared with OCT and fundus photography.

Conclusions: For measuring the ocular torsion angle, the OCT-based technology GMPE appears to provide information regarding anatomic fundus torsion that is similar to that obtained using fundus photography.

Translational Relevance: This new objective measurement for the ocular torsion angle is helpful for treating cyclotropia.

Introduction

Cyclodeviation accompanies vertical strabismus in patients with trochlear nerve palsy, skew deviation, and Graves’ orbitopathy.1–7 Clinical assessment of subjective and anatomic torsion is an important adjunct for the diagnosis and treatment of cyclovertical strabismus. Commonly used methods for assessment of torsion include measurement of the ocular torsion angle for objective torsion8–10 and synoptophore assessment for measurement of subjective torsion.11–13 With fundus photography, the ocular torsion angle is determined by the angular displacement below the horizontal of a line connecting the center of the optic disc and the center of the fovea. The literature reported the normal ocular torsion angle was –5.6° ± 3.3°.14 Various methods for measuring subjective torsion have been developed, including the double Maddox rod test,15–17 the Bagolini lens test,17 and the Lancaster red–green test.4 Fundus cyclometry using a scanning laser ophthalmoscope has been developed for measuring objective torsion.18 Prior studies have compared the efficacy between subjective and objective measurements.18,19

Heidelberg Engineering (Heidelberg, Germany) developed the SPECTRALIS optical coherence tomography (OCT). The SPECTRALIS OCT, when equipped with the Glaucoma Module Premium Edition (GMPE) software and Anatomic Positioning System, is able to record position information of
the retina and optic disc by detecting the centers of the fovea and the optic disc. This in turn allows automated measurement of the ocular torsion angle.\textsuperscript{20}

In the present study, we aimed to develop a new objective measurement of the ocular torsion angle using GMPE technology and comparing it to existing means of measurement, such as fundus photography. We then assessed changes in the ocular torsion angle before and after strabismus surgery.

### Methods

#### Study Design and Eligibility

Between June 2017 and December 2018, a total of 40 patients with cyclodeviation who had undergone strabismus surgery at Hyogo College of Medicine were enrolled in this prospective interventional study. The current study was performed in accordance with the Declaration of Helsinki and with approval from the ethics committees of Hyogo College of Medicine (No. 2681). Prior to participating in the study, all enrolled patients provided written informed consent after a full explanation of the protocol in this study. The UMIN trial registration number is UMIN000027136.

#### Study Protocol

We extracted data from medical records including age, sex, and ocular torsion angle. Measurements of the ocular torsion angle, using a synoptophore for subjective and fundus photography and OCT for objective measurements, were taken before surgery and 1 day after surgery.

#### Measurements of the Ocular Torsion Angle

Methods for measurements using synoptophore\textsuperscript{8–10} and fundus photography\textsuperscript{11–13} were followed as described in the literature. Ocular torsion angle on synoptophore was measured with parafoveal slides A17/18, depicting a segmented circle and a cross. It took approximately 4 minutes for taking measurements of the ocular torsion angle using a synoptophore.

For fundus photography, we took the fundus photography using a nonmydriatic fundus camera, saving the image file to another computer. Imaging software was then used to calculate the angle from horizontal to a line linking the optic disc center to the fovea to obtain the ocular torsion angle. It took approximately 6 minutes to complete measurements of the ocular torsion angle using fundus photography.

For OCT, we used the SPECTRALIS OCT and GMPE. Briefly, the OCT scans the retina, the GMPE automatically detects the centers of the optic disc and fovea, and then the software calculates the ocular torsion angle on the same device (Fig. 1). Determining measurements of the ocular torsion angle using OCT took approximately 90 seconds.

#### Study Endpoints

The primary endpoint was similarity of OCT compared with fundus photography when comparing the ocular torsion angle. Comparison of OCT with synoptophore and comparison of changes in the ocular torsion angle between pre- and postoperative measurements were secondary endpoints. We also assessed the baseline characteristics of all patients.

#### Statistical Analyses

For continuous variables, the mean, median, and range were calculated. For discrete variables, the number of values in each category and the percentages in each category were calculated. Group differences were assessed using the Student’s \textit{t}-test or the Wilcoxon signed rank test for continuous variables, and the Fisher’s exact test or the Pearson \(\chi^2\) test for categorical variables. A Bland–Altman plot\textsuperscript{21} was used to compare the differences in the ocular torsion angle measurements between OCT and the synoptophore and between OCT and the fundus camera. Analyses were performed with JMP Pro version 14.0.0 (SAS Institute Inc., Cary, NC). For all analyses, \(P\) values were reported, as well as two-sided 95% confidence intervals for point estimates. Statistical significance was determined when \(P\) values were <0.05.

### Results

#### Baseline Characteristics

Forty patients with cyclodeviation who had undergone strabismus surgery were enrolled. Patients were predominantly male (\(N = 25, 62.5\%\)) with a mean age of 58.6 ± 14.3 years (range, 15–85). All patients complained of diplopia preoperatively and showed excyclotropia; symptoms were owing to acquired fourth cranial palsy (\(N = 14, 35.0\%\)), congenital superior oblique muscle palsy (\(N = 13, 32.5\%\)), thyroid-associated ophthalmopathy (\(N = 6, 15.0\%\)), sequelae of cerebral infarction (\(N = 2, 5.0\%\)), third cranial nerve palsy (\(N = 1, 2.5\%\)), double elevator palsy (\(N = 1, 2.5\%\)), ocular tilt reaction (\(N = 1, 2.5\%\)), sagging eye...
Figure 1. (a) OCT scans the retina, and GMPE automatically detects the centers of the optic disc and fovea, and then the software calculates the ocular torsion angle. (b) Magnification of the ocular torsion angle. The picture shows an ocular torsion angle of $-16.5^\circ$.

Table 1. Comparison of Measurements of Ocular Torsion Angle and Changes in Ocular Torsion Angle During Surgery

|                      | Preoperative (Lower confidence limit 95%; upper confidence limit 95%) | Postoperative (Lower confidence limit 95%; upper confidence limit 95%) |
|----------------------|---------------------------------------------------------------|---------------------------------------------------------------|
| Synoptophore         | $-8.8 \pm 4.1 (-10.13 \text{ to } -7.52)$                     | $-3.1 \pm 2.8 (-3.95 \text{ to } -2.15)$                      |
| Fundus camera        | $-27.2 \pm 6.4 (-29.21 \text{ to } -25.11)$                   | $-18.6 \pm 5.9 (-20.51 \text{ to } -16.72)$                   |
| OCT                  | $-25.9 \pm 6.8 (-28.05 \text{ to } -23.70)$                   | $-18.2 \pm 5.8 (-20.09 \text{ to } -16.38)$                   |

syndrome ($N = 1$, 2.5%), and myasthenia gravis ($N = 1$, 2.5%). In all cases, symptoms related to cyclodeivation resolved postoperatively.

**Measurements of the Ocular Torsion Angle**

Comparisons of measurements of the ocular torsion angle are shown in Table 1. Briefly, the objective measurements of the ocular torsion angle via OCT and fundus photography were similar. As expected, synoptophore measures of subjective torsion were smaller than the ocular torsion angle when measured using both fundus photography and OCT.

**Preoperative Correlation of the Ocular Torsion Angle as Measured by Synoptophore, Fundus Photography, and OCT**

Ocular torsion angle measurements taken by OCT were strongly correlated with fundus photography ($P < 0.0001$, $R^2 = 0.90$) and moderately correlated with synoptophore ($P = 0.0003$, $R^2 = 0.55$) (Fig. 2).

**Bland–Altman Plots**

Bland–Altman plots were constructed to verify the agreement of the pre- and postoperative ocular torsion angle measurements between OCT and the synoptophore and between OCT and the fundus camera (Table 2, Fig. 3). The mean differences between OCT and the synoptophore were preoperative ($-17.05^\circ$) and postoperative ($-15.18^\circ$). The mean differences between OCT and the fundus camera were preoperative ($1.29^\circ$) and postoperative ($0.39^\circ$). Comparisons made using the Bland–Altman plots showed good agreement between OCT and the fundus camera but not between OCT and the synoptophore.

**Discussion**

In the present study, we showed similarity of OCT compared with fundus photography as objective measurements of the ocular torsion angle. The ocular torsion angle results from OCT were strongly correlated with fundus photography both pre- and
Table 2. Comparisons Made Using the Bland–Altman plots

|                         | Preoperative | Postoperative |
|-------------------------|--------------|---------------|
|                         | (Lower confidence limit 95%; upper confidence limit 95%), P value, and R value | (Lower confidence limit 95%; upper confidence limit 95%), P value, and R value |
| OCT and synoptophore    | -18.88 to -15.22, \(P < 0.0001\), \(R = 0.55\) | -16.94 to -13.43, \(P = 0.009\), \(R = 0.90\) |
| OCT and fundus camera   | 0.34 to 2.23, \(P < 0.0001\), \(R = 0.35\) | -0.34 to 1.11, \(P = 0.29\), \(R = 0.93\) |

Bold italic indicates statistical significance \((P < 0.05)\).

postoperatively, and the pre- and postoperative values from both OCT and fundus photography were similar. In addition, OCT can measure the ocular torsion angle faster than fundus photography because it automatically detects anatomic position of the retina, and the computer analyzes it.

Fundus photography has been used as an objective measurement of the ocular torsion angle because of its high versatility. However, measuring ocular torsion angle is difficult in patients with small pupils or opacities of the optic media. The SPECTRALIS OCT uses high contrast infrared images to detect retinal information, therefore OCT makes it possible to measure the ocular torsion angle in patients difficult to measure using fundus photography. Furthermore, the anatomic positioning system of SPECTRALIS OCT can automatically detect the anatomic position of the centers of optic disc and fovea, allowing the ocular torsion angle to be calculated automatically and quickly.\(^{20}\) Therefore OCT appears to provide information about anatomic fundus torsion that is similar to that obtained using fundus photography.

Interestingly, the subjective measurements of the ocular torsion angle using the synoptophore were underestimated compared with objective measurements pre- and postoperatively. Patients’ torsional fusion is absent preoperatively, but symptoms related to cyclodeviation are resolved and torsional fusion is recovered postoperatively, demonstrating that the anatomic changes underestimate the ocular torsion angle compared with objective measurements. This suggests that individual differences in binocular fusion affect synoptophore measurements of the ocular torsion angle. When an objective measurement of the ocular torsion angle could detect misalignment and a subjective one could not, the patient did not feel cyclotropia. Dieterich and Brandt\(^{22}\) reported a range of objective physiological ocular torsion angle in normal subjects who did not feel cyclotropia. There have been no reports in the literature identifying the
Figure 3. Bland–Altman plots. (a) Comparisons between OCT and the synoptophore did not show good agreement. (b) Comparisons between OCT and the fundus camera showed good agreement.

association between fusion and the ocular torsion angle, therefore investigating the physiological ocular torsion angle using OCT in normal volunteers would be warranted.

There were several limitations in the present study. First, any head tilt present when OCT was performed could have affected the measurement of the ocular torsion angle. Therefore we could not eliminate all possibility of error. To address this, we recommend performing OCT three times and calculating the average to minimize any measurement error. We understand the difficulty in performing several tests repeatedly for the same patient on the same day. To address this, we performed preoperative tests in several days. However, postoperative tests are more difficult to perform, and the ocular torsion angle might differ depending on the day it is tested. Therefore we think OCT is better than fundus photography to record the ocular torsion angle for its convenience and speed. Second, we compared OCT to fundus photography, but not other methods for objective measurement of the ocular torsion angle. Future research should compare several objective measurements of the ocular torsion angle.

Conclusions

For measuring the ocular torsion angle, the OCT-based technology GMPE appears to provide information about anatomic fundus torsion that is similar to that obtained using fundus photography.
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