The Calibration of the Corneal Light Reflex to Estimate the Degree of an Angle of Deviation

Supaporn Tengtrisorn MD*,
Sitthi Tangkijwongpaisarn MD*, Somporn Burachokvivat BSc*

** Department of Ophthalmology, Faculty of Medicine, Prince of Songkla University, Hat Yai, Songkhla, Thailand*

Objective: *To measure the conversion factor for the size of an angle of deviation from the clinical photographs of the corneal light reflex.*
Material and Method: *In this cross-sectional study, 19 normal subjects with 20/20 visual acuity were photographed with a digital camera while staring at targets placed five prism diopters (PD) apart from one another on a screen. The subjects were tested at a distance of 1 meter (m) and 4 m from a screen. Measurement of the corneal light reflex displacement for each fixed target was obtained from the photographs. The calibration of the corneal light reflex displacement in millimeters (mm) against the angle of deviation in PD was then analyzed with repeated measure linear regression analysis.*
Results: *At 1 m, the values of 0.047 mm/PD and 0.058 mm/PD were obtained as the conversion factor from reflex displacement to deviated angle for the nasal side and temporal side respectively. At 4 m, the values were 0.050 mm/PD and 0.064 mm/PD for the nasal side and the temporal side respectively. There were significant differences between the values obtained at the different distances, regardless of nasal or temporal side.*
Conclusion: *Conversion factors were presented for estimating the strabismic angle at different distances and gazes. For clinical practice, the use of photographs to estimate the strabismic angle should use different values for different distances and strabismic types.*

Keywords: *Corneal light reflex, Hirschberg, Photograph, Angle deviation*

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The Krimsky and Hirschberg tests are used to assess ocular alignment. The prism cover test is usually used in a clinical setting while the Hirschberg test is the simplest method. However, accuracy depends on personal experience. The Hirschberg test consists of estimating the strabismic angle by comparing the position of the corneal light reflex. Generally, 1 millimeter (mm) decentration of the corneal light reflex corresponds to 15 prism diopters (PD), or about 7 degrees of deviation[1,2]. However, there is substantial variation among the values recommended for this coefficient, ranging from 8 to 14.11 degrees/mm[3-6]. The growing popularity of digital cameras and computers has led to the increasing use of photographs to screen for strabismus, especially to screen people who live in rural areas and cannot go to a hospital. The instrument, which combines the Hirschberg test with digital cameras and computers, should allow for simplicity and yield highly accurate strabismus measurements. Many researchers have developed techniques using photoscreening, such as special design and interpretation from photos[3-6] including MRT photoscreening, but the accuracy has varied among observers[7-9].

The standard method used to measure the size of the angle of deviation must be performed by well-trained medical personnel, for example, an orthoptist[10]. However, the paucity of medical personnel in general, and orthoptists in particular, is one of the big problems of the public health system. In view of this problem, the present research aimed to provide the data obtained from a digital camera that could be applied using a simple method and performed by non-medical personnel, by primarily estimating the deviation of the angle using corneal light reflex parameters from photographs. The present study also aimed to determine the calibration between the corneal light reflex displacement from a digital photograph and the magnitude of deviation. The simple photographic method was expected to decrease the workload of orthoptists, and shorten the time spent for conventional orthoptic testing both at preoperative evaluations and at the follow-ups of strabismic patients.

Correspondence to:
Tengtrisorn S, Department of Ophthalmology, Faculty of Medicine, Prince of Songkla University, Hat Yai, Songkhla 90112, Thailand.
Phone: +66-74-451381, Fax: +66-74-429619
E-mail: tsupapor@medicine.psu.ac.th

Material and Method

The study followed the tenets of the Declaration of Helsinki and was approved by the Ethics Committee of the Faculty of Medicine, Prince of Songkla University. The investigation enrolled 19 subjects. All subjects were older than 16 years with normal eye function and volunteered to participate in the study. Fourteen females and five males were included in the study with age ranging from 18 to 40 years. The data were collected from June to August 2012.

Corneal light reflex photographs were recorded by a Nikon D5100 digital camera. The photograph resolution was 3,696 x 2,448 pixels. The camera was placed on a tripod with its lens at the same level as the target on the screen and the subject's eye. Remote-control shutter in every single shot stabilized the camera throughout the series of photographs taken. On the 1m screen, each target was placed 5 cm away from the adjacent one. On the 4 m screen, the targets were spaced 20 cm from each other. Those yielded a visual angle of five PD separations between the targets at both distances (Fig. 1).

Subjects were seated 1m in front of the digital camera. A ruler was held over the subject's forehead. Each eye was tested separately using a sticky tape occluder in order to occlude one eye while the other was tested. With the other eye, the subject fixed on a target from the temporal side and then moved to a target at the nasal side (26 and 23 fixed targets at the 1 m and 4 m screen respectively), as shown in Fig. 2 Every single fixation was thereafter captured by the digital camera. After finishing the last target, this process was repeated on the other untested eye.

Digital images were transferred to a desktop computer and displayed using Adobe Photoshop version 5 at a magnification of 300%. The distance from the temporal limbus to the corneal light reflex was measured with a millimeter ruler cropped from each image. The position of the light reflex for each fixation was plotted as a function of the known direction of gaze.

Mixed effect random-intercept linear regression models of corneal light reflex displacement against PD, in which the subject was the random element and the PD was considered to have a fixed effect, were used for data analysis in order to determine the relationship between the corneal light reflex displacement and the angle of deviation, which in turn also gives the Hirschberg coefficient.

The research was registered with the Thai Clinical Trials Registry (TCTR), which was linked to the WHO International Clinical Trials Registry Platform (WHO-ICTRP). The study ID was TCTR20140106002.

Results

Nineteen subjects, 14 females and 5 males, fitting the inclusion criteria were enrolled. The mean age was 28.3 years with a range of 18 to 40 years. All subjects had a visual acuity of 20/20 or better and were orthophoria. The relationship between the corneal reflex position and the angle of deviation of the right and left eye at 1 m and 4 m were shown in Fig. 3-6. Measurement of corneal light reflex displacement in different targets showed a good correlation at 1 m and 4 m.

The slope of the regression line for the deviation from the central target at 1 m was 0.052 mm/PD (95% CI: 0.051, 0.053). This yielded a final value for the Hirschberg coefficient of 19.07 PD/mm (95% CI: 18.01, 19.47) for the strabismus.

For the subgroup analysis, the slope of the regression line for the deviation from the central target

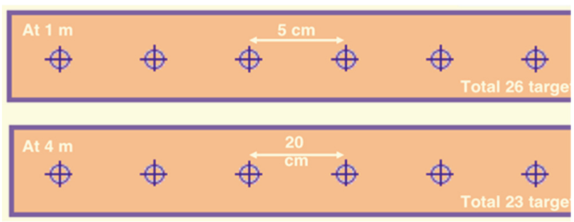

Fig. 1 Schematic illustration of the target screens at 1 m and 4 m. Targets were equally spaced 5 cm and 20 cm apart for 1 m and 4 m screens respectively.

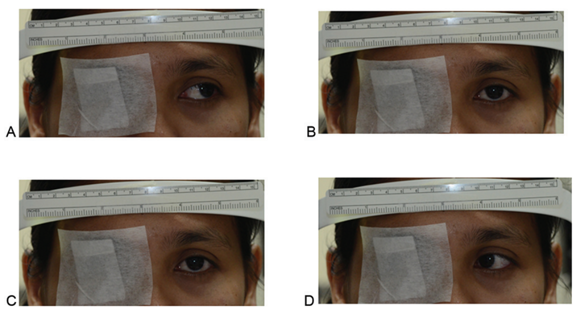

Fig. 2 Clinical photographs of a subject with left eye fixed on a target object the right eye occluded. A subject fixed to a target object at the temporal side (A) and moved to the central target (B). A subject fixed to a central target (C) and moved to the nasal side (D).

to the nasal side at 1 m was 0.047 mm/PD (95% CI: 0.046, 0.048) (Fig. 3). This yielded a final value for the Hirschberg coefficient of 21.31 PD/mm (95% CI: 20.92, 21.72) for the esotropia position. However, the slope of the regression line from the central target to the temporal side at 1 m was 0.058 mm/PD (95% CI: 0.057, 0.059) (Fig. 4). This yielded a final value for the Hirschberg coefficient of 17.27 PD/mm (95% CI: 16.96, 17.59) for the exotropia position. The regression slopes for the nasal and for the temporal movement at 1 m differed significantly ($p<0.001$).

The slope of the regression line for the deviation from the central target at 4 m was 0.057 mm/PD (95% CI: 0.055, 0.058). This yielded a final value for the Hirschberg coefficient of 17.61 PD/mm (95% CI: 17.17, 18.08) for the strabismus.

For the subgroup analysis, the slope of the regression line for the deviation from the central target to the nasal side at 4 m was 0.050 mm/PD (95% CI: 0.048, 0.051) (Fig. 5). This yielded a final value for the Hirschberg coefficient of 20.16 PD/mm (95% CI: 19.70, 20.65) for the esotropia position, whereas the slope of the regression line from the central target to the temporal side was 0.064 mm/PD (0.063, 0.065) (Fig. 6). This yielded a final value for the Hirschberg coefficient of 15.63 PD/mm (95% CI: 15.34, 15.94) for the exotropia position. The regression slopes for the nasal and for the temporal movement at 4 m differed significantly ($p<0.001$).

The regression slopes, both for the nasal and for the temporal movement, differed significantly between 1 and 4 m viewing distance ($p<0.001$).

Discussion

The Hirschberg test is one of the most frequently used tests for estimating the strabismic angle in clinical practice. However, due to the subjective nature of the test, in terms of landmarks furnished by the pupil, iris, and limbus, in combination with the persistent lack of agreement concerning the interpretation of the test estimates, the Hirschberg test can also give an inaccurate value. The Hirschberg

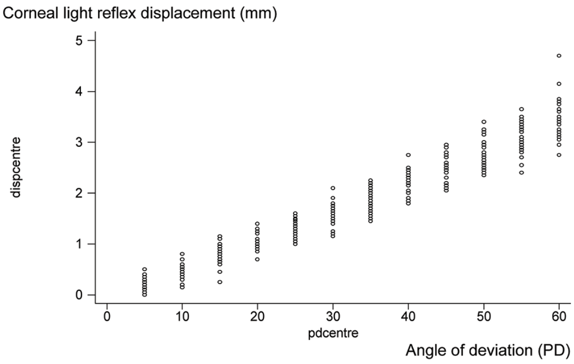

Fig. 3 Corneal light reflex displacement (mm) plotted as a function of fixation angle (PD) for both eyes to nasal side at 1 m.

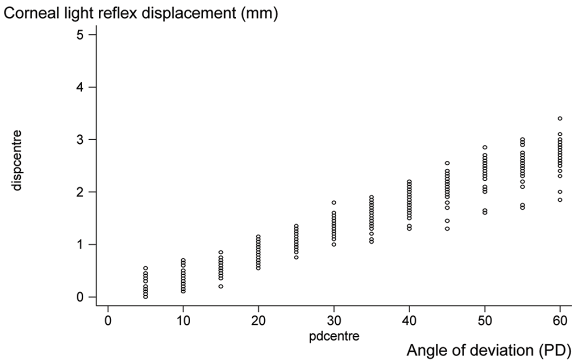

Fig. 4 Corneal light reflex displacement (mm) plotted as a function of fixation angle (PD) for both eyes to temporal side at 1 m.

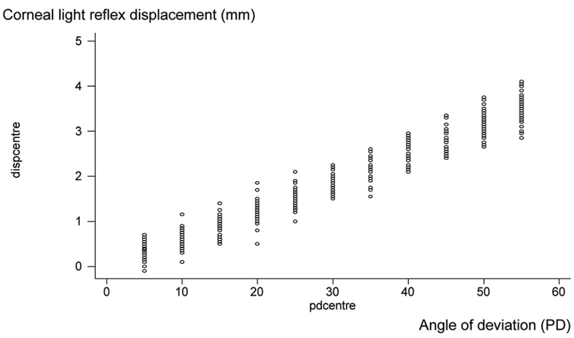

Fig. 5 Corneal light reflex displacement (mm) plotted as a function of fixation angle (PD) for both eyes to nasal side at 4 m.

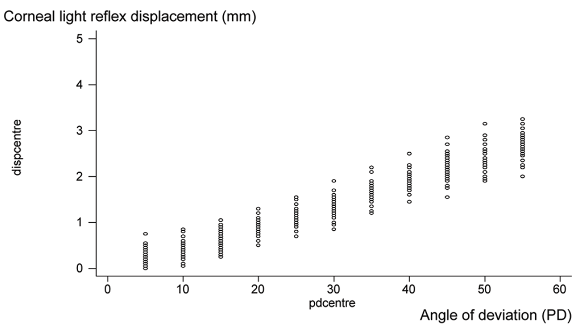

Fig. 6 Corneal light reflex displacement (mm) plotted as a function of fixation angle (PD) for both eyes to temporal side at 4 m.

ratio has been greatly clarified in the past between 7 degrees/mm and 13.6 degrees/mm[3-6,11,12].

The discrepancy of the Hirschberg ratio is substantially large, ranging from 14 to 21 PD/mm[3-6,11]. DeRespinis et al[5] introduced a Hirschberg coefficient obtained from the measurement of the corneal light reflex displacement from photographs compared with standard prism cover results in strabismic patients with the value of 20.89 PD/mm. Brodie[6] recommended a coefficient of 21 PD/mm on the basis of photographic calibration studies on normal subjects and calculations based on the Gullstrand model eye. More recent studies have shown relatively constant values. Miller et al[13] showed a linear correlation of the Hirschberg horizontal reflex deviation with asymmetric fixation in normal subjects; they suggested that the image processing method might be appropriate for a screening instrument. In the present study we, showed the linear relationship of corneal light reflex deviation with the degree of an angle of deviation but a difference in Hirschberg coefficients among different distances and gazes.

The current study provided the Hirschberg coefficient at both near (1 m) and far (4 m) gaze, 19.07 and 17.61 PD/mm respectively. As the researchers had anticipated, these two values were significantly different from each other. The accommodation reflex normally occurred in response to focusing on a near object, comprising coordinated change in convergence, lens shape, and pupil size. Convergence, that is, the simultaneous inward movement of the eyes toward each other, influenced the ocular alignment, which also affected the corneal position. This could be the reason why the Hirschberg coefficient at near gaze was different from at far gaze.

The Hirschberg coefficient for nasal movement, representing esotropia, and temporal movement, representing exotropia, at 1 m were 21.31 and 17.27 PD/mm respectively, whereas the Hirschberg coefficient for nasal movement, representing esotropia, and temporal movement, representing exotropia, at 4 m were 20.16 and 15.63 PD/mm respectively. The values from different gazes were significantly different. This might be the effect of the difference in muscle position, length of muscle, arc of contact, and angle kappa. Basmak et al[14] showed a higher angle kappa value in exotropic patients compared to esotropic patients. Thus, we suggest using a different Hirschberg coefficient for near gaze, distant gaze, nasal movement, and temporal movement. The Hirschberg coefficient is independent of age because the overall size of the eye from infancy to adulthood changes by only a small percentage[9]. However, there is a difference in corneal curvature below and above 46 diopters (D)[15].

In clinical practice, the use of photographs to estimate the strabismic angle helps reduce the interobserver uncertainty that frustrates the Hirschberg test. Moreover, with the widespread availability of an uncomplicated digital camera, the outcome of the study could simplify the measurement of the strabismic angle for anyone who can use a digital camera. It seems to be a very useful solution to the big problem of a lack of medical personnel, including orthoptists, in many areas of Thailand. However, the clinical relevance needs to be established in further studies. The Hirschberg coefficients obtained from the present study should be compared with the standard orthoptic measurements.

In conclusion, the Hirschberg coefficients from the study (19.07 PD/mm at 1 m and 17.61 PD/mm at 4 m) were useful for estimating the strabismic angle for pre and postoperative evaluation, and when following up strabismic patients using only an uncomplicated digital camera.

What is already known on this topic?

The Hirschberg test consists of estimating the strabismic angle by comparing the position of the corneal light reflex. There is substantial variation among the values recommended for this coefficient, ranging from 7 to 14.11 degrees/mm.

What this study adds?

The Hirschberg coefficients from the present study (19.07 PD/mm at 1 m and 17.61 PD/mm at 4 m) are different from previous study. There was a significant difference between the values obtained at the different distances, regardless of nasal or temporal side.

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Potential conflicts of interest

None.

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ค่าเทียบทาบการวัดการสะท้อนของกระจกตาเพื่อประเมินมุมเข

สุภาภรณ์ เต็งไตรสรณ์, สิทธิ ตั้งกิจวงศ์ไพศาล, สมพร บูรโชควิวัฒน์

วัตถุประสงค์: *เพื่อวัดปัจจัยแปลงผันสำหรับขนาดมุมเบี่ยงเบนจากภาพถ่ายคลินิกของการสะท้อนกลับของกระจกตา*
วัสดุและวิธีการ: *การศึกษาแบบตัดขวางนี้ ถ่ายภาพคนปกติ 19 คน ผู้ซึ่งมีระดับสายตา 20/20 ถ่ายภาพด้วยกล้องดิจิทัลขณะจ้องเป้าหมายวางห่างกัน 5 ปริซึมไดอ๊อพเตอร์ (prism diopters, PD) ผู้รับการทดลองถูกทดสอบ ที่ระยะ 1 เมตร และ 4 เมตร วัดการเคลื่อนออกการสะท้อนกลับของกระจกตาสำหรับแต่ละเป้าหมายติดตรึงจากรูปถ่าย ปรับการเคลื่อนออกการสะท้อนกลับของกระจกตาเป็นมิลลิเมตร (มม.) เทียบทาบกับการเบี่ยงเบนเป็น PD และวิเคราะห์ด้วยการวิเคราะห์ถดถอยเป็นเส้นตรง (linear regression analysis)*
ผลการศึกษา: *ที่ 1 เมตร ค่าปัจจัยแปลงผันเท่ากับ 0.047 มม. ต่อ PD และ 0.058 มม. ต่อ PD สำหรับด้านจมูกและด้านขมับตามลำดับ ที่ 4 เมตร ค่าปัจจัยแปลงผันเท่ากับ 0.050 มม. ต่อ PD และ 0.064 มม. ต่อ PD สำหรับด้านจมูกและด้านขมับตามลำดับ มีค่าความแตกต่างอย่างมีนัยสำคัญทางสถิติในระยะทางที่แตกต่าง รวมทั้งตำแหน่งด้านจมูกและด้านขมับ*
สรุป: *นำเสนอปัจจัยแปลงผันสำหรับการประเมินค่ามุมตาเขที่ระยะทางและการเพ่งมองแตกต่างกัน ในทางคลินิกการใช้ภาพถ่ายเพื่อประเมินค่ามุมตาเข ควรใช้ค่าที่แตกต่างกันตามระยะทาง และชนิดของตาเข*