Comparison of measurements between manual and automated eyetracking systems in patients with strabismus – A preliminary study

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Purpose: The main objective is to test the measurements made by an automated eye-tracking system in the presence of strabismus and to compare the data with manual measurements of deviation.

Methods: A prospective observational cross-sectional masked double-blinded study was conducted in a tertiary eye care center with 39 participants included in our study, aged 3–41 years. Initial screening of all participants was performed by an ophthalmologist. Ocular deviations were evaluated and compared between manual measurements and an automated eye-tracking system. The device is based on eye-tracking technology. The participants had either a congenital or acquired type of manifest or latent strabismus. Children less than 3 years of age, visual acuity <6/36, and abnormal configuration of the anterior segment were excluded from the study. Results: The prism alternate cover test (PACT) manual measurements and the automated alternate cover test for measuring horizontal deviation, the manual measurement, and the automated eye track system showed a highly positive correlation ($r = 0.932$, $P < 0.001$). The Bland Altman plot analysis shows good agreement between the two measurements, with the mean difference between the two measurements being 1.55 PD, and the 95% limit of agreement was ± 10 PD. Conclusion: The results obtained with an automated eye-tracking system correlate well with manual strabismus measurements with PACT in terms of diagnosis, precision, and accuracy, with an added benefit of lesser time consumption in performing the test in cooperative/motivated patients. Considering these aspects, patients above the age of 3 years could be assessed with the equipment.

Key words: Alternate cover test, automated eye tracking system, strabismus measurement

In normal binocular vision, both eyes are equally aligned on an object of regard, so images from an object fall on the fovea of each eye.[1] Strabismus, also termed as heterotropia, is a condition when the two eyes do not align in the same direction because of a lack of coordination among extra-ocular muscles or other reasons.[2] Strabismus, a relatively common ophthalmic disorder, is present in around 4% of the population.[2] The early accurate diagnosis and quantification is essential and aids in the management of the condition. The definitive goals of strabismus management/evaluation include quantification of squint, assessing the binocular status, establishing the diagnosis, and detecting amblyopia. A focused, goal-oriented evaluation helps prevent a laborious exhaustive examination that results in patient and examiner fatigue and the collection of spurious data.[1]

The different tests to detect ocular deviations can be classified into objective methods such as the cover–uncover tests (CUTs) and prism cover test and subjective methods such as the Maddox rod test. However, active cooperation from the patient is essential. The most commonly used method in clinical practice to quantify the deviation is the prism cover test. The main disadvantages, however, are the long duration of the test; the associated difficulty in performing the test in babies, toddlers, and young children; and that the measurements depend on the examiner’s attention and professional experience.[3] The results may not reliable and inconsistent between repeated measurements by the same examiner or between several different examiners.[4]

Methods

A prospective observational cross-sectional masked double-blinded study was conducted over 6 months from July 2020 to December 2020 in the Out-patient department of the Pediatric Ophthalmology Clinic at a tertiary eye care center. The study was approved by the Institutional Review Board of the hospital, and written informed consent was taken from each patient/parent of the patient. Patients above 3 years of age, with moderate degrees of horizontal strabismus, and with residual strabismus were included in the study. Children less than 3 years of age, visual acuity <6/36, and abnormal anterior segment configuration were excluded from the study.

All study subjects underwent complete ophthalmic assessment, manual orthoptic assessment, and automated testing. Both the automatic and manual estimation tests

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maintained a testing distance of 50 cm. The manual CUT and the prism alternate cover test (PACT) were performed on all subjects by an orthoptist. The examiner was masked to the results of the automated test result. The constant monitoring of automated testing distance was performed using two parallel and independent methods. The first method used the eye tracker’s ability to measure the distance of the eyes from the eye tracker camera positioned on the screen. The second method used full occlusion glasses that have designated marks on them, which are part of the testing system; this also enables to accurately measure their distance from the monitor. In addition, the operator’s screen indicated any change in the patient’s position.

Eye tracker

There are many commercially available eye trackers. The sampling rate and accuracy are high enough for tracking a subject’s eye movement precisely. An eye tracker is a portable device and is convenient for use in different clinical settings ([Fig. 1]). The infrared light that is reflected from the eye is sensed by a video camera and an optical sensor and is thus based on the principle of optical eye-tracking technology. The center of the pupil is taken as a reference point for the eye tracker, and infrared/near-infrared non-collimated light is used to create corneal reflections. The vector between the corneal light reflex and pupil center is used to compute the point of regard on a surface or gaze direction. The position of the eye and the point of gaze are estimated using algorithms for image processing and a physiological 3D model of the eye.

The deviation tests are performed using a pair of calibrated glasses via the eye-tracker software. It alternatively covers and uncovers each eye, similar to our traditional test. The subject is made to put on the glasses and follow an optically stimulating target projected on the screen. No language or verbal skills are required to perform the test. The components of the system included a Tablet PC that displays the user interface and displays targets to patients during tests, a portable eye tracker which records the eye position, an infrared emitter that controls lens shutters of the glasses, and infrared glasses.

The first step is to perform an automated CUT to assess the presence of a deviation and if present to determine the deviating eye and the amount of deviation. The second step is to perform an automated alternating cover test (ACT) to measure the amount of total deviation and its direction, which is similar to the traditional PACT but without the physical need of a prism. If tropia is detected using CUT, the deviating eye is reported (i.e., right, left, or alternating). If a deviation is detected using only ACT and not CUT, a phoria is reported, including the deviation direction (i.e., esophoria, exophoria, hyperphoria, or hypophoria). In addition, if ACT begins with no tropia, but a phoria develops during ACT, and by the end of ACT, under binocular viewing conditions, a tropia is measured, and an intermittent deviation is reported.

The results of the automated eye tracker were compared with the manual orthoptic examination. The characteristics of the study population such as age and gender were presented as mean (SD) and frequency (percentages).

An agreement was noted between the manual and automated tests and was represented using Bland–Altman plots and concordance correlation coefficients with scatter plots. A P value <0.05 was considered statistically significant. Statistical software STATA Version 14 was used for the analysis.

Results

A total of 39 patients were prospectively evaluated at Aravind Eye Hospital, Madurai, aged between 3 and 41 years (mean 13.64 ± 9.04). The study included 20 females (51.28%) and 19 males (48.71%). The patients had congenital or acquired forms of strabismus. As per our exclusion criteria, children less than 3 years, patients a visual acuity worse than 6/36, and patients with abnormal anterior segment configuration were excluded from our study. Twenty-seven patients had exodeviation, and 12 patients had esodeviation. A total of 26 had constant tropia, 11 had intermittent tropia, and two had phoria.

For measuring horizontal deviation, the mean deviation measurement by the manual method was 31.36 ± 13.79 and that by the automated method was 29.81 ± 13.10. For evaluation of horizontal deviation, the manual PACT measurement and automated eye track system show a highly significant positive correlation (r = 0.932, P < 0.001, Fig. 2).

The Bland–Altman plot analysis showing a significant agreement between the two measurements is represented. The mean difference between the two measurements was noted to be 1.55 PD, and the 95% limit of agreement was ±10 PD [Fig. 3].

Discussion

This prospective study compared the ocular deviation between automated systems for measuring ocular deviation which consisted of eye tracker infrared active shutter glasses and manual PACT. The type and direction of deviation in the cases of all 39 patients with horizontal deviation were identified correctly by the automated system just as in the manual method. The results showed good agreement between
both techniques for measuring deviation in horizontal strabismus.

The manual method of evaluation of deviation relies highly on the examiner’s skill and experience in observing small ocular movements during the testing period. The level of accuracy of strabismus diagnosis and measurement largely depends upon the examiner’s skill and expertise and also on the cooperation of the patient, which could not be dependable while examining small children. The significant inter-examiner variability even among experienced examiners ranging from 6.9 D to 12.5 D have been shown in studies. The range of variability between the two methods is 1–16.5 PD, and we have removed the outliers. The findings of the manual and automated systems matched exactly in four patients; 26 patients had variation in the range of 1–5 PD, eight patients had variation in the range of 6–10 PD, and one patient had a variation of 16.5 PD.

Several devices for automated measurements of ocular deviation have been described, including video-based infrared eye tracking, video goggles for Hess chart assessment, and binocular optical coherence tomography to evaluate strabismus in the primary position. In the study comparing the use of video goggles for strabismus evaluation to Hess screen test, there was a high agreement in all tested gaze positions, but it was unsuitable for patients under 6 years of age. The main advantage however was that it could be used in patients with visual suppression, who could not be tested with the Hess screen test.

The main advantage of the automated system is that it is non-invasive and takes up to a minute to complete the entire test, which is advantageous in children and patients with limited levels of cooperation. Moreover, it provides automatic results which do not require expert evaluation or interpretation and can be used in communities where strabismus specialists or orthoptists are unavailable; it can be used for telemedicine consultation. Measurements are likely to be repeatable. Also, an additional benefit of the automated system is that the full range of deviation can be measured in steps of 1D, whereas for manual evaluation of deviations above 20 PD, prisms are available in step differences of 5 PD. The results of the repeated manual evaluation can vary because of the fatigue of both the patient and examiner. Coming to the drawbacks, the automated eye tracker method is based on eye movement detection and hence not feasible for patients with paralytic strabismus, where there are restrictions of extra-ocular movements. The measurement is variable in cases with large-amplitude nystagmus; with a large amplitude of nystagmus, the values could be variable. The automated tracker tests deviation only in the primary position of gaze, and we cannot measure the deviations in nine directions of gaze which could be needed to diagnose an associated pattern deviation. The automated eye tracker detects deviation at 50 cm; hence, there is scope in the future to develop devices that detect distance deviation. The automated method described above cannot detect torsion. Although methods to measure ocular torsion were devised some years ago, it is not frequently used in a clinical setting.

The limitations of our study are our small sample size, non-inclusion of patients with vertical deviations, and that measurements were performed for near deviation alone.

Conclusion

In this study, we successfully validated good agreement of the automated eye-tracking system, with the manual method for estimation of ocular deviation in strabismus patients. The device is simple, fast, and accurate in measuring ocular deviations. It can be used in communities where strabismus specialists or orthoptists are unavailable. In summary, the eye tracker system can serve as a screening tool to help make a diagnosis in a high-volume setup, teleophthalmology units, and general out-patient departments. The above study shows preliminary results of a small sample size; further studies involving a larger group of patients are needed.

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Conflicts of interest

There are no conflicts of interest.

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