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# A comparative review of methods to record ocular rotations

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**Abstract**

***Aim*: To review the methods reported for recording ocular rotations.**
***Methods*: A literature-based review from 1899 to 2008 was carried out to enable a comparative discussion on the methods available to record ocular rotations.**
***Results*: The recording of ocular rotations has changed and progressed over the years. Different methods are available that are essentially either kinetic or static. The important factors in evaluating the efficacy of methods for recording ocular rotations are: minimising patient discomfort; maintaining accuracy and minimising variability from head and chin movement; the speed and simplicity of the test, particularly for elderly patients; good repeatability and level of inter- and intra-observer reliability.**
***Conclusion*: No one method has been advocated in the literature as the gold standard. However, clinically the Goldmann perimeter for kinetic recording and the Lees screen for static recording are popular.**

**Key words:** Comparison, Kinetic, Ocular rotations, Static

## Introduction

The reproducible recording of ocular rotation is essential to the diagnosis and management of ocular motility disorders. It is of particular importance in neurogenic, myogenic and mechanical restrictions. Ocular motility is important for visual function, as accurate eye movements are essential to maintain the image of the object on the fovea thereby ensuring good visual acuity.[1]

In the clinical setting the assessment of ocular rotation is primarily performed qualitatively without spectacle correction, the examiner moving a torch from the primary position into the eight positions of gaze while the cover/uncover test is being performed.[2] Ductions are commonly graded using simple scales, such as −4 (i.e. underaction or restriction) to 0 to +4 (i.e. overaction).[3] Such methods are, however, prone to standardisation errors because of inter-observer variability, and are less suitable for accurate quantification. This is particularly true, for example, in Graves' orbitopathy, in which quantified motility change is an important outcome measure.[4]

There are numerous methods to assess ocular rotations, which may be kinetic or static. Kinetic methods, such as perimetry, require the patient to follow a moving target, while static methods, such as the Lees or Hess screen, involve measuring the patient's deviation at a given point.

For the purpose of this review, the assessment of ocular rotation will be discussed. The authors appreciate there are many eye movement recording methods, such as tracking methods that involve electro-oculograms, Purkinje image trackers, infra-red eye assessments, scleral search coils and video-based methods. However, these will not be considered here.

The aims of this review are to compare and evaluate the methods used for measuring ocular rotation, and to establish their validity in the clinical environment. The review was undertaken with the use of Medline (PubMed) and non-Medline (orthoptic journal and conference transactions) databases, followed by checking the reference sections of selected papers. The search terms used were 'ocular rotation methods', 'Goldmann perimeter', 'Aimark perimeter', 'synoptophore', and 'eye movement recording methods'. The time period was from 1899 to 2008.

## Methods of measurement of ocular rotation

There are reports of a variety of different methods for quantitatively assessing ocular rotation. These methods will be considered under the headings of kinetic and static methods.

### *Kinetic methods*

As defined in the literature, the term ductions is given to movements observed in one eye under monocular conditions as it moves from the primary position to one of the main positions of gaze.[4,5] Asher in 1899[6] reported one of the earliest studies on the range of uniocular field of fixation. He measured his own ocular rotations by positioning himself at one end of a corridor, 15 metres in length, at the other end of which was a light target. He had a bar in his mouth to which was attached a red target with a black marker; this formed a 16-point star on ocular rotations as he moved his head and fixated on the light target in the distance. There was a variation in the

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**Table 1.** Ocular rotation values for data reported by Asher (1899),[6] Yamishoro (1957)[8] and Mourits *et al*. (1994)[9]

| Position of eye | Right eye (degrees) | | | Left eye (degrees) | | |
|---|---|---|---|---|---|---|
| | Asher | Mourits Mean (SD) | Yamishoro Mean | Asher | Mourits Mean (SD) | Yamishoro Mean |
| Elevation | 43 | 34 (5.6) | 42 | 41 | 34 (5.6) | 42 |
| Depression | 45 | 58 (5.3) | 50 | 45 | 58 (5.3) | 49 |
| Abduction | 45 | 46 (4.0) | 53 | 39 | 46 (4.0) | 52 |
| Adduction | 44 | 48 (3.9) | 57 | 48 | 48 (3.9) | 58 |

**Table 2.** Ocular rotations data provided by Yamishoro (1957)[8]

| Position of eye | Right eye (degrees) | | | Left eye (degrees) | | |
|---|---|---|---|---|---|---|
| | Maximum | Minimum | Mean | Maximum | Minimum | Mean |
| Elevation | 55 | 31 | 42 | 56 | 33 | 42 |
| Depression | 62 | 31 | 50 | 60 | 33 | 49 |
| Abduction | 63 | 40 | 53 | 62 | 45 | 52 |
| Adduction | 68 | 47 | 57 | 66 | 50 | 58 |

results obtained for Asher's two eyes (Table 1), which may have been due to the coarse method of recording and the wearing of a myopic glasses correction, which probably caused distortion and a restricted view. In addition, there was no method of head stabilisation and standardisation was not maintained for the examiner's testing distance.

Mourits *et al.*[7] recently considered the range of monocular movement. This study used a calibrated modified Schweiger perimeter: a hand perimeter which consists of a support with a calibrated arch connected to it. The target is a light that can be moved through 180° and the head is supported. Forty healthy control subjects were evaluated. The results (mean values with standard deviation) of the study are shown in Table 1.

When comparing Asher and Mourits *et al.*'s data (Table 1), the greatest difference in rotation recorded between the two tests was for depression, with a mean difference of 13°, with Mourits reporting the greater range of 58° on depression. In contrast, Asher's values were higher for elevation. Whilst the difference in depression might be due to the spectacles in Asher's study obscuring the view of the target and thereby limiting the range of movement, it seems more likely that the differences were due to the coarseness of the test and the lack of head stabilisation.

Yamishoro[8] used a Wessley's keratometer to assess the amount of uniocular rotation of each eye. This measured the position of the limbus in four directions of gaze: abduction, adduction, elevation and depression. Measurements in these positions were taken for 100 patients with full eye movements. The maximum, minimum and mean angles reported for the 100 patients are shown in Table 2. There was a wide range of measurements for the right and left eye data, particularly for depression. The mean data show there was a greater extent of movement for adduction and abduction compared with elevation and depression.

The three techniques used by Asher, Mourits *et al*. and Yamishoro are coarse methods of assessing eye movements and have limited use due to the high degree of variation in measurements reported (Table 1). A variation of less than 5° is considered to be accurate and therefore more reliable.[2,3] Nevertheless, in a situation which involves a quick assessment in individuals with other general disabilities, these three tests can be useful in estimating ocular movement. However, these methods are no longer employed in clinical practice because of improvements in methods of assessment.

Kestenbaum[9] measured the limitation of eye movement in millimetres with a transparent ruler held in front of the cornea to note the limbus position in primary position compared with the gaze (new) position. This test was intended for the quick investigation of patients with muscle paresis. One hundred patients with normal eye movements were assessed. There was good inter-observer agreement between the measurements with a mean value of 9–10 mm in abduction, adduction and depression and a mean value of 7 mm in elevation. No standard deviation values were reported. This technique was used recently to assess ocular rotation measurements in patients undergoing macular translocation.[10] The authors found that although this technique was useful in evaluating the duction action of the eye into specific positions of gaze, inter-observer judgement influenced the repeatability of the results.

Urist[11] reported a similar test to Kestenbaum's. This was called the lateral version light reflex test. The examiner held a light at the patient's eye level while their head was held stationary by an assistant or a headrest. The patient was asked to make an extreme movement on lateral version; the examiner observed the extent of movement, and estimated the position of the light reflex on the sclera in millimetres. The test was repeated in 'mirror image' on the opposite side. The estimated positions of the light reflections were converted using the Hirschberg scale of values: each millimetre of displacement from the centre was approximately 7° with the pupillary margin of the iris arbitrarily taken as 20° and the midpoint between the pupillary margin and limbus as 45°. This test was limited in accuracy as it relied on the examiner's estimation of central corneal position and variation in pupil size may affect the measurement. Kestenbaum's test does not rely on such estimations and consequently there is less inherent variability. However, Clarke and Isenberg[12] used Urist's test to assess age-related changes in ocular movements and found it to be quick and easy with a good level of repeatability.

Another method for recording ocular rotations is the synoptophore, derived initially from a haploscopic device. The use of the synoptophore in the literature for recording ocular rotations is limited. It has been reported to assess the horizontal rotation in patients with Duane's syndrome[13] and other ocular motility problems[14] and the decrease of eye movements in elevation with age.[15] However its use is limited, as ocular rotations can only be assessed up to 30° on a vertical scale.

There are techniques that do not have this limitation and they involve the use of a perimeter.[16–18] The duction is measured on a calibrated arc perimeter when a light reflex is displaced from the centre of the cornea and is recorded on a chart objectively and/or subjectively. This method is well known and widely used by orthoptists in the United Kingdom. Arens[19] adapted this method and used a target letter E in place of the light and the reduction of visual acuity as an indicator for the loss of foveal fixation. However, the letter was not as easy to visualise as the light source, and patients required corresponding near visual acuity.

Owens[20] designed a deviometer, which consisted of a vertical stand around which a moveable horizontal arm could be pivoted. The end of the arm provided a fixation light that the patient followed. This test was very basic and measured only four axes, which although quick and easy, limited the assessment of the individual vertical muscles such as the inferior rectus muscle. Six positions are a more appropriate number of axes to assess.[3]

The value of the Goldmann perimeter to record ocular rotations in four to six positions of gaze in patients with Graves' orbitopathy has been reported.[21,22] Haggerty *et al.*[3] found the assessment to be of short duration and hence not tiring for the patient. However, the end point of movement is dependent upon the patient's voluntary effort, which maybe impaired by discomfort.[23] Estimating the patient's end point requires some experience on the examiner's part. Measurement of all meridians can be time-consuming,[3] but limiting assessments to four positions of gaze (abduction, adduction, elevation and depression)[20] does not allow interpretation of which muscles are primarily affected in vertical restrictions. In particular, small but significant changes in the inferior rectus restriction, commonly seen in patients with Graves' orbitopathy, may be less apparent if up-gaze in abduction is not assessed. A compromise has been found in which six positions, which reflect the primary field of action of each extraocular muscle, are assessed; this is the modified Goldmann technique.[3] For the right eye, the lateral rectus corresponds to 0, superior rectus to 67, inferior oblique to 141, medial rectus to 180, superior oblique to 216 and the inferior rectus to 293. The left eye mirrors the right eye.

High inter-observer variability has been reported with the modified Goldmann technique, with values of 8 degrees variation.[3] In contrast, other studies have reported good inter- and intra-observer reliability.[7,21] This is an important clinical consideration as to what constitutes a clinically significant change.

The Octopus machine can be used to assess ocular rotations in a similar way to the Goldmann, but in a computerised format. To date there is no published evidence base for this technique, but it is being evaluated in clinical trials for validity and reliability of the measurements.

### *Static methods*

While kinetic methods are ideal for identifying uniocular limitations and restrictions, the assessment of eye position at a fixed point and viewed binocularly, provides additional information. Repeated testing can be used to monitor the progression of many conditions such as cranial nerve palsies.

The recording of static eye position on a chart was first described by Hess in 1916.[24] The Hess screen test provides a concise description of the two-dimensional (vertical and horizontal) position of both eyes in the absence of fusional constraints. The Hess screen consists of a red grid printed onto a grey tangent screen; a red filter is placed in front of one eye and a green filter placed over the other eye, and the patient has to locate a green light with each eye in turn. The Hess screen was later adapted to form the Lees screen,[25] which uses a mirror in place of the filters to dissociate the eyes and has been found to be less time-consuming and easier for the patient to use. The Lees screen is widely used by orthoptists in the United Kingdom. The Hess/Lees screen is useful in recording any eye movement problems, particularly orbital floor fractures.[26–28]

The Harms wall test[29,30] and the Lancaster screen test are screen tests.[31] The Harms wall tangent screen dissociates the eyes using a red filter and can measure horizontal, vertical and torsional deviations; it also monitors head position to ensure accuracy when measuring the eye movements.[29] The Harms test can assess reliable and repeatable monocular movements as well as recording the field of binocular single vision, by moving the patient's head until diplopia occurs. It can also record and measure head postures and torsion, but cannot simultaneously measure torsion like the Lancaster screen. The disadvantages of the Harms test are the initial high cost and the space-consuming screen.

In contrast, the Lancaster screen is considerably smaller with horizontal and vertical lines that are at a distance of 1 metre from the patient. The test is used in a darkened room. It involves the use of two different coloured projectors (red and green), one for the patient and one for the examiner. The patient wears red/green goggles and is asked to locate the examiner's light.[31] This test is easier to perform than the Harms test as it takes less time. However, both tests require normal retinal correspondence and thus have limitations in their use for patients with abnormal retinal correspondence and suppression.

Thomson and Desai[32] have created a computerised Hess screen. Thirty-eight patients were assessed on the computerised version. The mean duration of the test was

7 minutes. The standard deviation (SD) for each point was calculated and combined to give a mean standard deviation. The combined standard deviations were 1.08° for horizontal deviations and 1.03° for vertical deviations. The combined SD was not significantly different from the individual SD. The data collected can be quantified, analysed and displayed in a variety of formats, plotted onto paper or saved onto disc. The authors report the computerised method offers minimal examiner supervision, the use of a joystick enables better control of the target (particularly in patients with poor motor coordination) and errors in recording the relative position of the target and stimulus are completely eliminated.[32]

Kushner[33] proposed an instrument called the Cervical Range of Motion Device (CROM) for recording ocular rotations. This was initially designed to assess the range of motion of the spine but was adapted to assess ocular rotations, abnormal head posture, and the field of binocular single vision. It consists of a spectacle frame worn by the subject with three magnetic dials that assess head position. Two separate examiners undertook measurements for 12 patients with limited ocular rotations.[33] There was a high degree of reliability between the results from the two examiners (mean difference $1.1° \pm 2.6°$, range 0–5°), which was not statistically significant ($p = 0.17$). The authors felt that the CROM device was easy to use, quick (the test takes only a few minutes to perform) and could be stored in an examination room. However, the test was not considered suitable for small children.

Holmes *et al*. described a photographic method for the assessment of restrictions of abduction in patients with sixth nerve palsies.[34] Photographs were taken when the patient looked to right and left gaze positions. Using a ruler the examiner measured the deficit of abduction in millimetres. The repeatability of the method was evaluated using a standard grading system for documenting and grading abduction deficit.[35–37] The technique was reported to be simple and effective with a high degree of agreement between two examiners ($p = 0.86$). There was complete agreement in 19 of the 26 cases (73%). In the 7 cases where there was not complete agreement, the grade differed only by one unit.

## Summary

This review has described kinetic and static methods that have been used to measure ocular rotations. The important factors in evaluating the efficacy of methods of recording ocular rotations are: minimising patient discomfort; maintaining accuracy and minimising variability from head and chin movement; the speed and simplicity of the test, particularly for elderly patients; good repeatability and level of inter- and intra-observer reliability.

Accuracy and repeatability of measurements are essential to clinical practice and research. No one method has been advocated in the literature as the gold standard. However, clinically the Goldmann perimeter for kinetic recording and the Lees screen for static recording are widely used in the United Kingdom. Many of the traditional clinical methods are no longer being manufactured, for example the Aimark/Lister perimeter and the Goldmann perimeter. These methods will need to be replaced by other methods in the future. The value of the computerised versions requires further investigation for clinical use.

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