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Comparison of Harms tangent screen and search coil recordings in patients with trochlear nerve palsy

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Abstract

Harms tangent screen, a subjective measurement method of three-dimensional binocular alignment, was compared with search coil recording. Twenty-three patients with unilateral trochlear nerve palsy were measured in nine gaze positions. The two methods correlated best for the horizontal gaze deviation, the vertical gaze deviation, and the vertical incomitance, but there was no correlation for the results of torsional incomitance. Using Harms tangent screen, torsional deviation underestimated the torsional incomitance measured by the search coils. Therefore, central torsional fusional mechanisms or alignment error in the Harms tangent screen are assumed.

Keywords: Strabismus; Search coils; Harms tangent screen; Three-dimensional; Incomitance

1. Introduction

The Harms tangent screen (Harms, 1941) is clinically often used and serves to quantify the horizontal, vertical and torsional components of eye misalignment in nine different gaze positions. In patients with trochlear nerve palsy, this test helps to verify the source of ocular misalignment and to decide on the type of surgical management. The Harms tangent screen method is subjective. To achieve data of the eight eccentric gaze positions, the head of the subject is turned to the opposite horizontal/vertical direction. When suppression occurs, ocular misalignment cannot be measured in all gaze positions.

The recently introduced three dimensional Hess screen test uses binocular dual search coils (Bergamin, Zee, & Roberts, 2001; Collewijn, van der, & Jansen, 1975) for measuring all three components of ocular positions. It relies much less on patient's compliance. During recording the head is fixed with a bite bar. Suppression does not interfere with performance, as the patient only fixates with one eye while the fellow eye is covered.

The goal of the study was to compare the two methods. In patients with unilateral trochlear nerve palsy, a disorder in which torsional deviations are expected, we used both types of recordings before surgical treatment of the eye misalignment.

2. Methods

2.1. Subjects

Between May 1997 and July 2003 all patients with unilateral trochlear nerve palsy (TNP) were recruited for the study. Twenty-nine patients with trochlear nerve palsies (21 males and 8 females, all Caucasians, aged from 18 to 78 years; mean age 41.7 ± 17.5 years) were tested using identical technical equipment. In 13 patients, TNP was classified as congenital, in 8 as ac-

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quired, and in 8 patients the origin was uncertain. The experimental protocol adhered to the Declaration of Helsinki for research involving human subjects (adopted by the 18th World Medical Assembly, Helsinki, Finland, 1964, and as revised last in Hong Kong in 1989). Local Ethical committee approval was obtained for the search coil method. Patients gave written and informed consent to participate in the study.

2.2. Harms tangent screen recordings

Patients were seated at 2-m distance from the screen with the center of the interpupillary line opposite to the center of the Harms tangent screen. A helmet that projected a white light cross on to the Harms tangent screen was comfortably mounted on the patient's head. The light cross was adjusted to meet the center of the Harms tangent screen with its horizontal and vertical branches aligned to the thin black rectangular lines on the screen when the patient held his head straight. The patients saw a permanently shining white spotlight in the center of the screen. When a red filter was positioned in front of one eye, this eye saw only a red light. The patient then guided a laser pointer that projected a green light circle with his dominant hand. His task was to catch the red light with the green circle. The investigator then moved the patient's head (with his firmly fixed helmet and the light cross on it) to the eight eccentric 25° positions using the grid of the Harms tangent screen. For every fixation target, the head was shortly held in position by the investigator. The horizontal and vertical eye misalignment was characterized by the distance of the pointed green circle to the white spotlight in the center of the Harms tangent screen. The investigator wrote down the misalignment in degrees for all nine diagnostic gaze positions.

To get the torsional ocular misalignment data, the patient's head direction was again moved step by step to the nine positions. This time, the patient observed a white light bar that was switched on in the same center of the Harms tangent screen. The bar position was primarily horizontal and could be rotated with a remote control. With the red filter in front of one eye, the patient had to align the red light bar parallel to the thin horizontal grid on the Harms tangent screen. This was also done for all gaze positions.

The resolution of the Harms tangent screen is at best one degree in all three components of eye misalignment. In contrast to the search coil data, gaze straight ahead provides an absolute value of cyclodeviation. In order to make the Harms tangent screen data more easily comparable to the search coil data, the absolute value of cylcodeviation in gaze straight ahead was set to zero and the eight eccentric values were adapted respectively.

2.3. Search coil recordings leading to the three dimensional Hess screen test

The calibration procedure for the search coil recordings is described elsewhere (Bergamin et al., 2001). The patient was seated in the center of an orthogonal three-dimensional magnetic field which is built in a cubic metallic frame of 1.4 m side lengths and which produces frequencies of 55.5, 83.3 and 41.6 kHz and intensities of 0.088 Gauss (Robinson, 1963). The ocular surface of both eyes was anaesthetized with 0.2% Oxybuprocaine-HCl eye drops before mounting the search coil annuli. To prevent head movement, a soft bite bar was used. During measurements, subjects monocularly fixed a computer-animated laser point projection on a tangent screen at a distance of 1.24 m at its center, while the other eye was covered. The red laser dot was first located straight-ahead and then slowly moved to the eight eccentric positions where it rested for a second (horizontal and vertical coordinates in degrees: [0, 20]; [20, 20]; [20, 0]; [20, −20]; [0, −20]; [−20, −20]; [−20, 0]; [−20, 20]). These simultaneous binocular recordings were repeated once with straight head position and the results were averaged. Patients examined between 1997 and 1999 followed monocularly the movements of the tip of a stick guided by the investigator. The targets were located straight ahead and at eight radially 20° eccentric positions on a tangent screen. These measurements were included to increase the number of patients for this study. The different areas of recording depending on the type of method are shown in Fig. 1. The entire set of recordings lasted about 20 minutes for each session.

The binocular gaze positions (horizontal-, vertical- and torsional data) were calculated using Matlab version 6.1.0.450 (Release 12.1, The MathWorks, Inc., 3 Apple Hill Drive, Natick, MA 01760-2098, United States). The data acquired from each of the nine gaze positions was then selected with an interactive computer program and averaged (Bergamin et al., 2001).

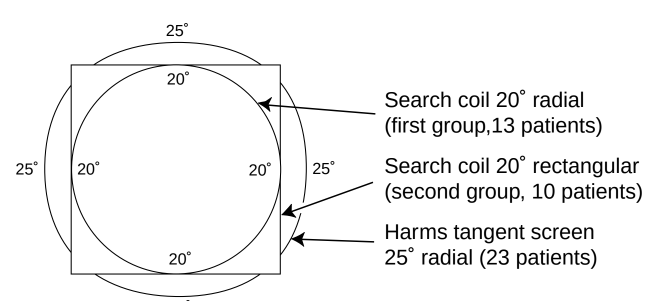

Fig. 1. Eccentricity of the gaze positions presented to the two patient groups. The first group was measured radially from the gaze straight ahead, the second group was measured within a 20° horizontal- and vertical gaze field. All Harms tangent screen recordings were done within a 25° field radially from gaze straight ahead.

Using 3 D Hess analysis, absolute cyclodeviation in the straight ahead position cannot be determined. Therefore, this value was set to zero and relative cyclodeviation values were measured and compared to the eight eccentric gaze positions. With both methods the data used for further calculations were those recorded with the non-paretic eye viewing (primary deviations).

3. Results

Fig. 2 shows a representative example (patient GH: acquired left TNP) of a Harms tangent screen measurement (2A) with the corresponding search coil measurement below (2B: numerical, 2C: graphical). Vertical deviation was greatest at downward and down-rightward gaze. The gradient of excyclodeviation was greater at

A Harms tangent screen

Eso 3.0° L/R 3.0° Excyc 1.0°	Eso 4.0° L/R 3.5° Incyc 1.0°	Eso 3.0° L/R 4.0° Excyc 0.0°
Eso 4.0° L/R 4.0° Excyc 2.0°	Eso 5.0° L/R 5.0° Excyc 0.0°	Eso 4.0° L/R 5.0° Excyc 1.0°
Eso 8.0° L/R 6.0° Excyc 10.0°	Eso 9.0° L/R 8.0° Excyc 8.0°	Eso 8.0° L/R 7.0° Excyc 3.0°

B Search coil measurements

Eso 1.3° L/R 4.6° Incyc 7.8°	Eso 3.5° L/R 5.5° Incyc 8.2°	Eso 3.5° L/R 6.9° Incyc 6.4°
Eso 3.8° L/R 7.1° Excyc 1.5°	Eso 7.4° L/R 10.5° Excyc 0.0°	Eso 5.5° L/R 12.2° Excyc 0.1°
Eso 5.5° L/R 7.7° Excyc 10.8°	Eso 10.4° L/R 14.9° Excyc 8.5°	Eso 7.3° L/R 15.9° Excyc 5.8°

C

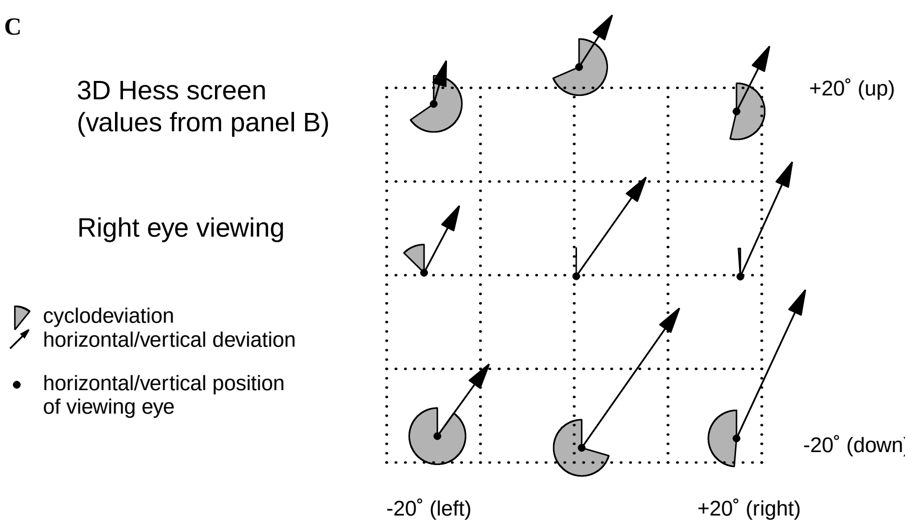

Fig. 2. Patient with acquired left trochlear nerve palsy. (A) Numerical scheme of vergence using the Harms tangent screen data. Horizontal ('Exo' = exodeviation), vertical ('L/R' = left hypertropia), and torsional ('Excyc' = excyclodeviation or 'Incyc' = incyclodeviation) deviation. Directions are from the subject's view. Similar as in the search coil measurement, cyclodeviation in the Harms tangent screen measurement was set to zero in gaze straight ahead and relative eccentric values were noted down. (B) Numerical scheme of vergence using the search coil technique. (C) Three-dimensional Hess screen test (same patient, values from panel B): Small dots: median horizontal and vertical directions of the line-of-sight of the fixating eye. Arrows: two-dimensional vectors of horizontal and vertical deviation between the two eyes. Unit of sectors: 1 h corresponds to one degree of torsional deviation, with zero torsion at 12 o'clock. Vertical and torsional gradient is smaller in the Harms tangent screen than in the search coil recordings.

down-leftward gaze. This pattern of eye position is typical for acquired TNP. The search coil measurement indicated a greater vertical deviation and a greater torsional gradient than the Harms tangent screen measurement.

Five of the 29 patients (17%) were not able to completely perform the Harms tangent screen test due to suppression. These patients were excluded from more detailed calculations, because one or more eye position components were missing in one or more of the 9 gaze positions. Except in one patient, all presented with suppression in the torsional axis only (on average 4.6 out of the 9 gaze positions were suppressed; standard deviation = 2.88). When suppression occurred during Harms tangent screen, torsional deviation measured with the search coils was 3.51° (standard deviation = 3.43°) averaged for the five patients. This was not significantly greater in comparison to gaze positions where no suppression was present (mean = 2.22°, standard deviation = 1.95°; $p > 0.05$, paired *t*-test). One other patient was excluded because the pattern of eye misalignment obtained by the search coils and the Harms tangent screen did not confirm the Hess screen test and the clinical assumption of a trochlear nerve palsy.

In the remaining 23 patients we compared the average angle of deviation acquired from the nine gaze positions using the Harms tangent screen with the respective values obtained with the search coil recordings. Average horizontal gaze deviation measured with search coils ranged from 8.1° esodeviation to 7.3° exodeviation and correlated very well with Harms tangent screen which ranged from 6.6° esodeviation to 5.8 exodeviation ($R^2 = 0.81$, $p > 0.01$). The average vertical gaze deviation resulting from the search coils (2.2–15.0°) correlated also well with the average vertical angle obtained by the Harms tangent screen (2.2–15.6°, $R^2 = 0.58$, $p > 0.01$). Both panels of Fig. 3 show the slope of linear regression to be lower than 1 with the Harms tangent screen (horizontal: 0.82, vertical: 0.88). Sub-analysis of the two groups measured at different time periods (Fig. 1) did not show different results in the two patient groups tested. Patients with congenital trochlear nerve palsy (full circles) presented with about the same vertical and horizontal deviation, as did patients with acquired trochlear nerve palsy (full triangles). Since search coils are not able to evaluate absolute torsional deviation of eye position, the two methods cannot be compared using absolute torsion.

The mean of the measured deviations in nine gaze directions provides the average ocular deviation in the examined gaze field, while the standard deviation of the measured deviations in nine gaze positions provides the degree of incomitance for the horizontal, vertical and torsional deviation component separately. There was no correlation in the amount of horizontal incomitance comparing both methods (Fig. 4A), but the amount of vertical incomitance (Fig. 4B) did correlate ($R^2 = 0.29$, $p < 0.01$). The slope of the linear regression line was close to 1 and the intercept was close to 0, which means, that the Harms tangent screen and the search coil test measured a comparable vertical degree of incomitance for the 23 patients. Congenital trochlear nerve palsy was more comitant than acquired trochlear nerve palsy for torsional (see Fig. 4C: 2.8° vs. 5.2°: the full circles were more located to the left than the full triangles; $p = 0.047$, analysis of variance) but not for vertical eye alignment (Fig. 4B: 3.8° vs. 3.5°), measured with

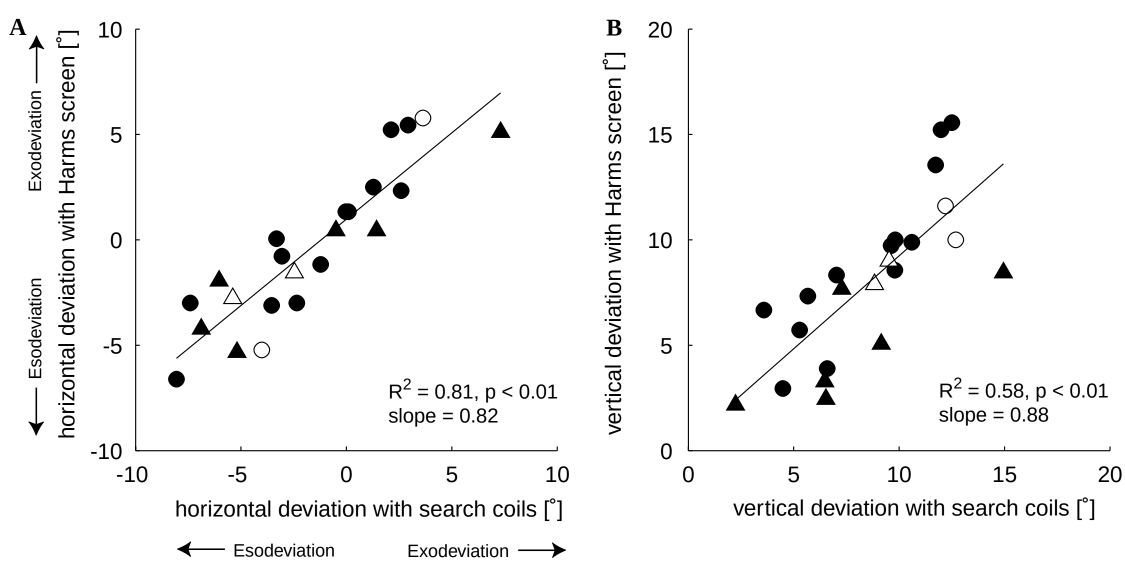

Fig. 3. Average angle of deviation in nine gaze positions. Correlation between the search coil data (*x*-axis) and the Harms tangent screen data (*y*-axis) of the 23 patients with trochlear nerve palsy (TNP). (A) Average horizontal angle and (B) average vertical angle of ocular misalignment. Patients with left hypertropia were mirrored to patients with right hypertropia. Full circles: congenital TNP; empty circles: presumed congenital TNP; empty triangles: presumed acquired TNP; full triangles: acquired TNP.

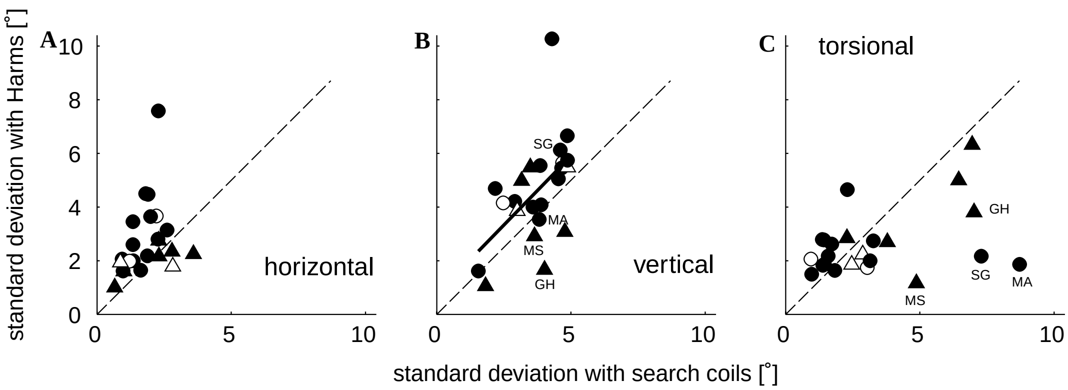

Fig. 4. Degree of incomitance. Correlation between the search coil data (x-axis) and the Harms tangent screen data (y-axis) of the 23 patients with trochlear nerve palsy (TNP). (A) Amount of horizontal incomitance, (B) vertical incomitance, and (C) torsional incomitance. Symbols are according to Fig. 3.

search coils. There was no correlation for torsional incomitance comparing both methods. However, torsional incomitance was less pronounced with Harms tangent screen compared to search coils, especially when the torsional incomitance measured with search coils was large (see full circles and triangles marked with initials).

The four patients (GH, SG, MS, MA labeled in Figs. 4B and C) with the greatest difference of torsional incomitance between the Harms tangent screen and the search coil method were analyzed in more detail: three of these four patients (Figs. 5A–C) showed a significant correlation when the changes of torsional eye position are determined with each technique between straight ahead gaze and the other 8 gaze positions. Therefore, in these patients, the search coil measurement did not show any artificial big cyclodeviation due to the exiting wire or the lid touching the search coil. Panel E summarizes the regression lines (solid when the fitting procedure showed a significant correlation, dotted when not) between the two methods for all 23 patients. Ten correlations were significant. The average slope of these regression lines was 0.77 with the search coil data on the abszissa (standard deviation = 0.49). This differed not significantly from 1 ($p = 0.16$; t-test for independent samples). When the axis were reversed (with the Harms tangent screen data on the abszissa), the average slope of the ten regression lines with significant correlation was 1.32 (standard deviation = 0.87), again with a non significant deviation from 1 ($p = 0.27$).

The correlation for all 23 patients individually using the 9 gaze positions was analyzed for the other two rotation axes in a similar way as it was done for

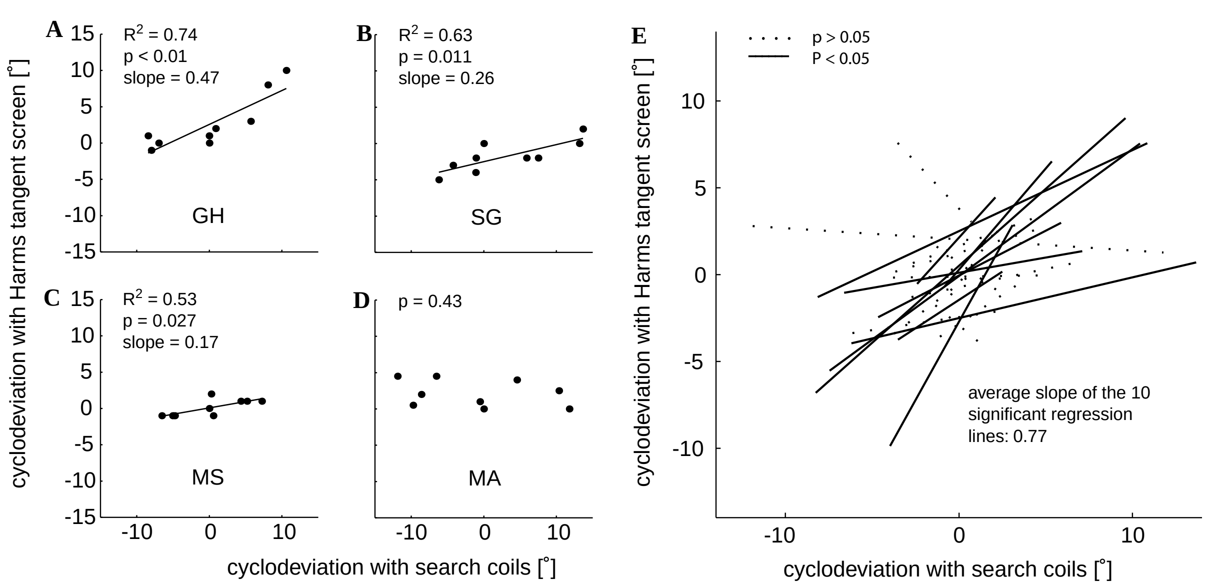

Fig. 5. Detailed analysis of patients who are outliers and labeled with their initials in Fig. 4C. (A–C) Patients GH, SG and MS presented with a significant correlation of the two methods. (D) Patient MA showed no correlation. Every dot represents one gaze position. Positive numbers are excyclovalues, negative numbers are incylcovalues. Similar as in the search coil measurement, cyclodeviation in the Harms tangent screen measurement was set to zero in gaze straight ahead and relative eccentric values were noted down. (E) Regression lines of all 23 patients (solid when significant, (10 patients), dotted when non-significant (13 patients) using p-level = 0.05).

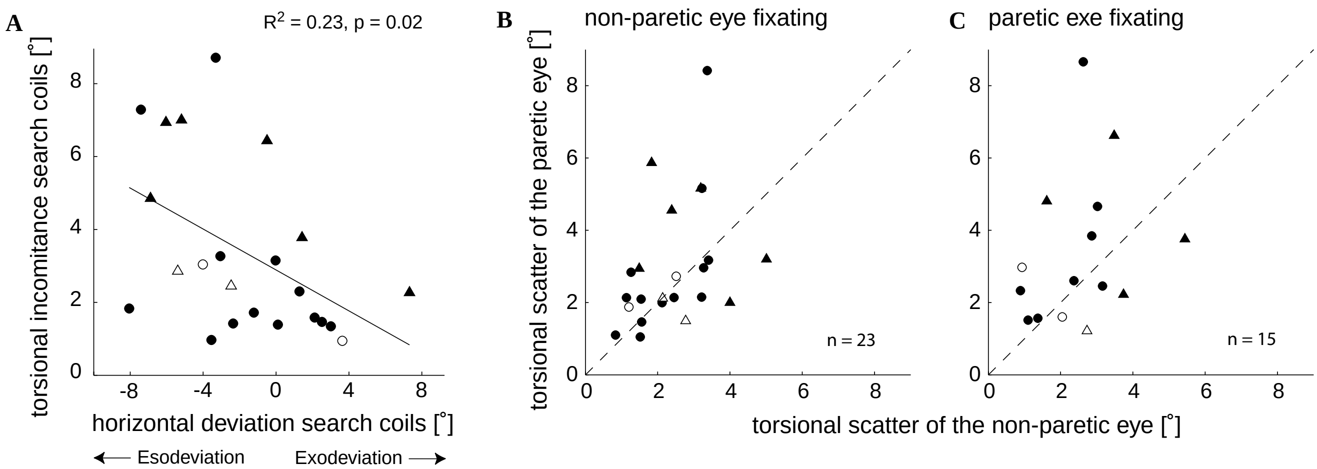

Fig. 6. (A) Correlation between the mean horizontal angle of gaze deviation compared with the incomitance of torsional gaze deviation. (B) Non-paretic eye fixating: torsional scatter (= standard deviation of the non-paretic eye (*x*-axis) vs. torsional scatter of the paretic eye (*y*-axis)). (C) Same setup but with the paretic eye fixating. Symbols are according to Fig. 3. The torsional scatter was greater in the paretic eye and not in the adducted eye, thus making a coil artifact highly unlikely.

cyclodeviation. Comparing the search coil data with the Harms tangent screen data vertical misalignment was significant in 18 patients. Comparing both methods using the horizontal misalignment was significant in 11 patients. The individual regression slopes determined with each technique between straight ahead gaze and the other 8 gaze positions of all 23 patients did not deviate significantly from 1 for the vertical and the horizontal axes (*t*-test for independent samples).

Fig. 6 shows a statistically significant correlation between the mean angle of horizontal deviation and the incomitance of the torsional deviation: patients with esodeviation presented with a greater torsional incomitance (Fig. 6A). When the non-paretic eye was fixating (Fig. 6B) the torsional scatter using the 9 diagnostic gaze positions of the paretic eye was bigger than the torsional scatter of the non-paretic eye (average torsional scatter for all patients of the paretic eye: 2.98° vs. average torsional scatter for all patients of the non-paretic eye: 2.41°; $p = 0.12$, paired *t*-test). When the paretic eye was fixating (Fig. 6C), the difference was even bigger but not statistically significant (3.39° vs. 2.49°; $p = 0.12$, paired *t*-test).

Younger patients showed a non-significant trend ($p = 0.065$; $R^2 = 0.15$) to have greater incomitance of cyclodeviation measured by the Harms tangent screen than older patients. There was equal distribution of acquired and congenital trochlear nerve palsy within age. Incomitance of cyclodeviation was independent of age using the search coil technique.

4. Discussion

The present study demonstrated that the Harms tangent screen and the search coil method provide comparable and therefore reliable results when the horizontal and vertical angle of ocular misalignment was obtained by averaging the ocular positions of gaze straight ahead with eight eccentric gaze positions. The two methods correlated best when the horizontal gaze deviation was measured (Fig. 3). This is explained by the great interpersonal variation of horizontal gaze deviations. Patients with trochlear nerve palsy did not predominantly present with esodeviation (Fig. 6) although the muscle that is weakened is the superior oblique muscle, whose tertiary action is abduction. Lack of fusion and the lateral configuration of the orbit may explain why some patients showed an exodeviation using both test strategies. For the vertical deviation, there was still a good but a slightly weaker correlation between the two methods, indicating that the two methods dissociated little more in the vertical compared to the horizontal component of eye misalignment. This greater dissociation can be assigned to the impaired superior oblique muscle, which pulls with a greater effect on the vertical than on the horizontal direction of gaze.

In this study, the amount of incomitance of gaze deviation was determined by the standard deviation of the nine gaze positions and obtained for the horizontal, vertical, and torsional component of eye misalignment (Fig. 4). As expected, the horizontal degree of incomitance was smaller than the vertical degree of incomitance because the horizontal pulling direction is a tertiary function of the superior oblique muscle. The incomitance of the vertical component of the eye misalignment correlated between the two testing methods indicating that both methods reveal the paretic superior oblique muscle. Summarizing all patients with trochlear nerve palsy, Harms tangent screen measurement revealed a smaller average incomitance in the torsional than in the vertical component of ocular misalignment.

As this difference could not be found using the search coil measurement, here the two methods showed disagreement. In general, these patients also present with a smaller average torsional angle than the vertical angle of deviation. Spread of comitance is accomplished by the secondary activation of the remaining cyclorotatory extraocular muscles and is the result of adaptive neural mechanisms that can also be shown by a shift of primary position defined by Helmholtz (Straumann, Steffen, & Landau, 2003; Wong, Sharpe, & Tweed, 2002). Surprisingly, four patients showed a great amount of torsional incomitance measured with search coils but less so with the Harms tangent screen (Figs. 5A–D). The lack of agreement was shown by a significant correlation with a slope considerably lower than 1 when the changes of torsional eye position were determined with each technique between straight ahead gaze and the other 8 gaze positions (Fig. 5E). The discrepancy of the two methods in the four patients was not explained by coil wire artifacts although there was a significant correlation between the mean horizontal angle of deviation and the torsional incomitance (Fig. 6A). Possible coil artifacts may be more pronounced in adduction (Bergamin, Ramat, Straumann, & Zee, 2004, Fig. 7). As the torsional incomitance measured in this study was greater in the paretic and not in the adducted eye (Figs. 6B and C), a coil wire artifact is unlikely. The significant correlation between horizontal deviation and the standard deviation of the torsional deviation may be interpreted as follows: since great torsional incomitance goes along with a strong paresis, compensatory innervation of the ipsilateral superior rectus and/or the contralateral inferior rectus muscle may initiate esodeviation.

The technique of determining torsional deviation with the Harms tangent screen is more likely to underestimate the actual deviation. During the alignment of the red light bar to the horizontal lines of the grid on the Harms tangent screen, central fusional mechanisms could be activated in cases where the two lines were close to parallel. This could happen during the alignment procedure determining all nine gaze positions, no matter if the torsional deviation between the red bar and the horizontal lines of the grid directed to a slightly excyclo- or incyclodeviation, the manually preset value remained subjectively close to parallel. This led to an artificially decreased amount of torsional incomitance in comparison to the objectively measured torsional incomitance (Fig. 5E). Still, intrapersonal comparison between the two methods showed a reliable correlation even in the group of outliers with the underestimated torsional deviation using the Harms tangent screen method (Figs. 5A–C). If the light bar were first offset in clockwise direction by the investigator and then readjusted by the patient, and this repeated also in counterclockwise direction, a more reliable amount of cyclodeviation would have been determined. Using a flashing bar, torsional deviation would be more accurately measured and not perturbed by the previous recording and additionally alleviate the problem of suppression. However, this type of testing would be much more time consuming than the original Harms tangent screen examination.

Other influences like otolith activation due to different head positions during the Harms tangent screen test in contrast to the fixed head during the three dimensional Hess screen test may also explain the different outcome between the two methods.

Since the Harms tangent screen method is not invasive and needs less technical support than the search coil technique, it is more convenient for clinical purposes. However, the considerable amount of missing values in different gaze positions in the presence of suppression may impair the clinical interpretation of this test. Although more time consuming, the search coil method has proven to be safe and reliable for recording eye misalignment.

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