Surgical treatment of diplopia in Graves' Orbitopathy patients
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COMPARISON OF CYCLODEVIATION AND DUCTION MEASUREMENT IN GRAVES’ ORBITOPATHY PATIENTS USING DIFFERENT DEVICES

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**ABSTRACT**

**Purpose:** To compare measurement outcomes of different devices measuring cyclodeviation and ductions in Graves’ Orbitopathy (GO) patients.

**Methods and materials:** Cyclodeviation in GO-patients was measured using the Harms tangent screen (HTS), the cycloforometer of Franceschetti and the synoptometer. Ductions were measured using the modified perimeter, the Goldmann perimeter and the Maddox tangent scale (MTS).

**Results:** In 13 patients, cyclodeviation in primary position, up- and downgaze was measured with the above mentioned devices. The mean differences ranged from 0.3° to 3.1° and were smallest between the HTS and the cycloforometer (89% of all measurements within 2° difference).

Measurement of abduction, adduction, elevation and depression using the modified perimeter, Goldmann perimeter and MTS were obtained in another 13 patients. The mean differences ranged from 1.2° to 12.9° and were smallest between the modified perimeter and the Goldmann perimeter (92% of all measurements ≤ 8°).

**Conclusions:** The HTS and cycloforometer produce interchangeable measurement outcomes. The modified perimeter and the Goldmann perimeter are interchangeable as well. However, the synoptometer and the MTS are not suitable for comparative analysis.
INTRODUCTION

Graves’ Orbitopathy (GO) is characterized by eyelid retraction, proptosis, double vision, restricted eye motility and reduced vision. Eventually, about 20% of GO-patients need surgery to correct diplopia (Sasim et al., 2008). Diplopia in GO is caused by the disease itself or develops or deteriorates after orbital decompression surgery. It can be horizontal, vertical or torsional. Thereby, restriction in eye movements, asymmetrical or symmetrical, severely reduces quality of life of GO patients (Ponto et al., 2009). In order to set up an optimal treatment plan for surgery, accurate measurements of the strabismus angle, fusion range, cyclodeviation, ductions and the field of binocular single vision are mandatory.

Various devices are used to measure these components of ocular motility. For instance, to measure cyclodeviation, the synoptophore (Boyce, 2000; Capdepon et al., 1994; Davidson & Clearly, 2000; Georgievski & Kowal, 1996; Klainguti et al., 1992), the synoptometer (Klainguti et al., 1992; Kolling, 1982), the Harms tangent screen (HTS) (Capdepon et al., 1994; Klainguti et al., 1992; Kolling, 1982), the Maddox Double Rod (MDR) test (Boyce, 2000; Capdepon et al., 1994; Garrity et al., 1992; Georgievski & Kowal, 1996; Klainguti et al., 1992;), the torsionometer (Boyce, 2000; Davidson & Clearly, 2000; Georgievski & Kowal, 1996), the Maddoxwing (Boyce, 2000; Georgievski & Kowal, 1996), the Awaya cyclotest (Boyce, 2000), Bagolini Striated glasses (Boyce, 2000; Johnson et al., 1987; Kraft et al., 1993) and the cycloforometer of Franceschetti (Gutter et al., 2010; Klainguti et al., 1992) are used. So far, few studies have been performed to assess whether these devices produce interchangeable results (Georgievski & Kowal, 1996; Klainguti et al., 1992; Kolling, 1982). This knowledge, however, is indispensable for research. Georgievski & Kowal found no significant difference in outcomes measuring cyclodeviation in primary position using the torsionometer, the MDR test, the synoptophore or the Maddox wing (Georgievski & Kowal, 1996).

However, measurement of cyclodeviation is not only required in the primary position, but also in up- and downgaze. The cycloforometer of Franceschetti, the HTS and the synoptometer allow such measurements and are therefore suitable to be used in GO-patients (Klainguti et al., 1992). These devices have not yet been studied in terms of their interchangeability.

Various devices are available to measure ductions in different directions in GO-patients: the cervical range of motion (CROM) (Kushner, 2000), the Maddox tangent scale (MTS)
The study was conducted according to the principles of the Declaration of Helsinki (seventh edition, October 2008, Seoul) and in accordance with the Medical Research Involving Human Subjects Act (WMO). Informed consent was given by each patient.

**Study A: Cyclodeviation**

We included consecutive GO-patients who visited the ophthalmology clinic in Mainz because of the availability of the HTS. Patients who accepted to participate in the study were asked about the presence of horizontal, vertical and/or torsional diplopia (no, yes). One orthoptist measured the cyclodeviation using the cycloforometer. Another orthoptist measured the cyclodeviation using the HTS or using the synoptometer. The measurements were performed in a random order.

Patients with intra-ocular pathology were excluded along with monocular patients, patients with uni- or bilateral vision < 1.0 LogMAR and patients with suppression. The tests were carried out binocularly without optical correction and with fixation of the right eye. Cyclodeviation in 25° up- and downgaze was only measured if the patient was able to fixate in those directions. In each device, each measurement was repeated four times, two times
Comparison of cyclodeviation and duction measurement

started from the excyclo direction and two times from the incyclo direction as suggested by Klainguti et al. (1992).

During the examination with the cycloforometer at 2½ meter in front of the HTS (Fig. 1), a headlamp was used to secure the head position of the patient. The cycloforometer was held with the horizontal slits for the right eye in such a way that the patient perceived an almost vertical red line. The cycloforometer was then rotated until the patient perceived the line exactly vertical. The procedure was carried out in primary position and in 25° up- and downgaze.

The cyclodeviation with the HTS and the headlamp was measured as described by Klainguti et al. (1992). Cyclodeviation with the HTS was measured by holding a Maddox glass in front of the right eye of the patient, who thereby perceived a red line. The patient was instructed to adjust the red line exactly horizontal with help of a handheld device. To measure the cyclodeviation using the synoptometer, a Maddox slide (foveal size) with a circle and a cross was presented in front of the right eye. The examiner rotated the slide from 20° excyclo position to 0° and asked the patient to warn as soon as the cross was perceived in perfect horizontal and vertical position.

![Figure 1. Cycloforometer of Franceschetti.](image1)

![Figure 2. Modified perimeter as described by Mourits et al. (1994).](image2)
Study B: Ductions

For this study, we included consecutive GO-patients who visited the ophthalmology clinic at the University of Amsterdam. Ductions were measured with the modified perimeter, the Goldmann perimeter and with the MTS at 0.75 m. Only the right eye was investigated. Each time, ductions were measured in 0°, 90°, 180° and 270° gaze directions. Patients with a vision < 1.0 LogMAR of the investigated eye were excluded.

Ductions were measured using the modified perimeter by instructing the patient to fixate a spotlight which moves on a rotatable rail (Fig. 2). The observer assesses the amount of duction by observing when the light reflex on the cornea moves out of the centre of the pupil (Mourits et al., 1994). In downgaze, the eyelid was held up by the investigator.

To measure ductions using the Goldmann perimeter we followed Gerling et al., except for the fact that the ductions were only measured once in each direction (1997). In downgaze, a small alteration had to be made because the eyelid could not be held open by the investigator due to the large bowl of the Goldmann perimeter. If the spotlight could not be seen because it was covered by the upper eyelid, the patient was asked to hold up the upper eyelid. The non-investigated eye was occluded and the strongest spotlight was used (relative intensity 4e (1.0), object V (64 mm²)).

To measure the ductions using the MTS, the MTS itself is used in combination with a headlamp. The patient fixates a fixation light in the center of the MTS, while the investigator turns the head of the patient in different directions and checks whether the corneal reflex of the light remains in the same place in the pupil. As soon as the reflex moves away from its place on the cornea, the duction can be read off on the tangent scale (the distance in degrees between the light on the wall and the reflex of the headlamp on the tangent scale). Normally, the patient is seated at a distance of 2½ meter in front of the tangent scale. But at that distance, the MTS is not big enough to record maximal duction (in which we are interested). In order to overcome this problem, we calculated a distance in which maximal recordable duction is possible. For this, we used the following formula: \( b = \frac{\tan(X_{b})}{\tan(X_{2.5})} \cdot 2.5 \), where \( X_{2.5} \) = degrees when measuring at 2½ m distance from Maddox tangent scale; \( X_{b} \) = degrees when measuring at \( b \) (in meters) distance from Maddox tangent scale and \( b \) = distance (in meters) between the patient and the MTS. We calculated a distance of 0.75 m. With conversion of this formula we were also able to adjust the measurement of the screen to the distance used.
Statistical analysis

We calculated the sample size for both studies with help of the Query Advisor (equivalence of means). A sample size of minimal 7 patients was necessary in the cyclodeviation group to detect a difference in outcome between the devices of > 2° with an alpha of 0.05 and a power of 80% by using the SD as found in the cyclodeviation study of Georgievski & Kowal (1996). The 2° difference was chosen because we found this to be a clinical difference in measurement outcome. For the duction group, minimal 8 patients had to be recruited to detect a difference of 5° with an alpha of 0.05 and a power of 80% by using the SD as found by Haggerty et al. (2005). Again, the chosen detectable difference was found to be clinical significant, as also argued by Mourits et al. (1994).

Software package SPSS 17.0 was used for the statistical analysis. Each variable was checked with the Kolmogorov-Smirnov test to find out whether it met the requirements for normal distribution. If so, parametric tests were used. If not, non-parametric tests were used. To assess agreement between devices, Bland-Altman analysis was carried out (Bland & Altman, 1986; Chan, 2003).

<table>
<thead>
<tr>
<th>Table 1. Measurement outcome differences between cyclodeviation devices</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>primary position</td>
</tr>
<tr>
<td>upgaze</td>
</tr>
<tr>
<td>downgaze</td>
</tr>
</tbody>
</table>

HTS = Harms tangent screen

<table>
<thead>
<tr>
<th>Table 2. “Tolerance table”; absolute differences for each direction of gaze between cyclo measurement devices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tolerance (degrees)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>≤ 1</td>
</tr>
<tr>
<td>&gt; 1 ≤ 2</td>
</tr>
<tr>
<td>&gt; 2 ≤ 3</td>
</tr>
<tr>
<td>&gt; 3</td>
</tr>
</tbody>
</table>

HTS = Harms tangent screen
RESULTS

Study A: Cyclodeviation

Thirteen GO-patients, 6 male and 7 female, participated in this part of the study. Ten patients experienced horizontal and/or vertical diplopia, of which one experienced torsional diplopia as well. We were able to measure cyclodeviation in primary position in all patients, elevation in 11 patients and depression in 12 patients. We found a normal distribution for all cyclodeviation measurements (Kolmogorov-Smirnov test).

Figure 3. Bland Altman plots for the comparison of the different cyclodeviation measurements (A1) HTS versus cycloforometer in primary position; (A1) HTS versus cycloforometer in upgaze; (A3) HTS versus cycloforometer in downgaze; (B1) HTS versus synoptometer in primary position; (B2) HTS versus synoptometer in upgaze; (B3) HTS versus synoptometer in downgaze; (C1) cycloforometer versus synoptometer in primary position; (B2) cycloforometer versus synoptometer in upgaze; (C3) cycloforometer versus synoptometer in downgaze.

HTS = Harms tangent screen; - - - = Mean; - = ± 1.96SD.
The mean differences between the devices are listed in Table 1 showing that the differences between the HTS and the cycloforometer were smaller than the differences between the other devices. The Bland Altman plots (Fig. 3) show, that the upper and lower limits of agreement were smallest between the HTS and the cycloforometer. However, confidence intervals (CI) for all plots were large. Finally, Table 2 shows that the differences between two measurements were smallest (70% < 1° in primary position) when comparing HTS and the cycloforometer.

**Study B: Ductions**

Thirteen patients, 1 male and 12 female, participated in this part of the study. The mean age of the patients was 55 years (range 37 – 73). The duction measurements of all three tests in all directions, showed a normal distribution (Kolmogorov-Smirnov test).

The mean differences between the devices are listed in Table 3, showing the smallest differences when ductions were measured using the modified perimeter and the Goldmann perimeter, except for measuring elevation. The Bland Altman plots (Fig. 4) show, that the upper and lower limits of agreement were smallest between the modified perimeter and the Goldmann perimeter. However, CI for all plots was large. In total, 4 (8%) duction measurements using the modified perimeter and Goldmann perimeter exceeded 8° of difference (Table 4).

<table>
<thead>
<tr>
<th>Tolerance (degrees)</th>
<th>Modified perimeter vs Goldmann degrees ± SD [95% CI]</th>
<th>Modified perimeter vs MTS degrees ± SD [95% CI]</th>
<th>Goldmann vs MTS degrees ± SD [95% CI]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abduction</td>
<td>3.1 ± 3.8 [-10.0 – 4.3]</td>
<td>4.5 ± 8.9 [-3.3 – 12.3]</td>
<td>7.6 ± 8.1 [0.0 – 15.2]</td>
</tr>
<tr>
<td>Adduction</td>
<td>1.2 ± 2.4 [-6.1 – 3.6]</td>
<td>7.0 ± 7.2 [-1.5 – 12.5]</td>
<td>8.2 ± 6.4 [2.6 – 13.8]</td>
</tr>
<tr>
<td>Elevation</td>
<td>3.8 ± 4.7 [-11.1 – 3.6]</td>
<td>2.2 ± 7.8 [-3.3 – 7.7]</td>
<td>6.0 ± 11.0 [-1.0 – 13.0]</td>
</tr>
<tr>
<td>Depression</td>
<td>3.4 ± 5.3 [-1.8 – 8.6]</td>
<td>12.9 ± 6.6 [5.0 – 20.1]</td>
<td>9.5 ± 8.8 [2.5 - 16.5]</td>
</tr>
</tbody>
</table>

MTS = Maddox tangent screen

Table 4. “Tolerance table”; absolute differences for each direction of gaze between duction measurement devices

<table>
<thead>
<tr>
<th>Tolerance (degrees)</th>
<th>Modified perimeter vs Goldmann perimeter n (%)</th>
<th>Modified perimeter vs MTS n (%)</th>
<th>Goldmann perimeter vs MTS n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>abd</td>
<td>add</td>
<td>elev</td>
</tr>
<tr>
<td>≤ 3</td>
<td>6 (46)</td>
<td>10 (77)</td>
<td>7 (54)</td>
</tr>
<tr>
<td>4 ≤ 5</td>
<td>3 (23)</td>
<td>2 (15)</td>
<td>2 (15)</td>
</tr>
<tr>
<td>6 ≤ 8</td>
<td>4 (31)</td>
<td>1 (8)</td>
<td>3 (23)</td>
</tr>
<tr>
<td>≥ 9</td>
<td>0</td>
<td>0</td>
<td>1 (8)</td>
</tr>
</tbody>
</table>

abcd = abduction; add = adduction; elev = elevation; depr = depression; MTS = Maddox tangent screen
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Figure 4. Bland Altman plots for the comparison of the different duction measurements (A) modified perimeter versus Goldmann perimeter; (A1) for abduction; (A2) for adduction; (A3) for elevation; (A4) for depression; (B) modified perimeter versus MTS; (B1) for abduction; (B2) for adduction; (B3) for elevation; (B4) for depression; (C) Goldmann perimeter versus MTS; (C1) for abduction; (C2) for adduction; (C3) for elevation; (C4) for depression.

MTS = Maddox tangent screen; - - - = Mean; = ± 1.9 SD.
DISCUSSION

This study shows that, whereas the differences of measurements of cyclodeviation between the HTS / synoptometer and the cycloforometer / synoptometer are significant, the differences between the HTS / cycloforometer are 'negligible. Regarding the ocular ductions, the modified perimeter and the Goldmann perimeter showed the best corresponding outcomes. Comparison of both devices with the MTS showed significant differences. We, therefore, conclude that the synoptometer and the MTS are not interchangeable within multicenter and unicenter trials.

We cannot exclude the possible bias caused by differences in head position in our two sub studies. Using the HTS, the cycloforometer and the MTS, head movement is necessary, whereas in the other devices, eye movements are required for the measurement outcomes. However, we used a headlamp to correct for the head movements. Another shortcoming of this study is that we did not measure the interobserver variations. The explanation for this is that we limited ourselves to the technique with which each of us was most experienced.

Table 5. Studies regarding cyclodeviation devices

<table>
<thead>
<tr>
<th>Study</th>
<th>Devices</th>
<th>Population (n)</th>
<th>Position of gaze</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown (1990)</td>
<td>Lees screen*</td>
<td>1 intermittent XT</td>
<td></td>
<td>less time consuming than synoptophore</td>
</tr>
<tr>
<td>Davinson and Cleary (2000)</td>
<td>torsionometer synoptometer</td>
<td>20 normal subjects</td>
<td>PS, ↑, ↓</td>
<td>no correlation (r &lt; 0.25)</td>
</tr>
<tr>
<td>Georgievsky and Kowal (1996)</td>
<td>torsionometer synoptometer MDR Maddox wing</td>
<td>33 torsional diplopia</td>
<td>PS and sometimes ↓</td>
<td>overall ICC 0.74 mean diff 2.4°±1.7°</td>
</tr>
<tr>
<td>Johnson and Harcourt (1987)</td>
<td>Lees screen* synoptometer MDR</td>
<td>1 large VD</td>
<td>PS</td>
<td>cyclo measurement only possible with Lees screen* because of large VD</td>
</tr>
<tr>
<td>Klainguti et al. (1992)</td>
<td>cycloforometer synoptometer MDR synoptometer HTS</td>
<td>30 normal subjects</td>
<td>PS</td>
<td>median all devices around 0°</td>
</tr>
<tr>
<td>Present study</td>
<td>cycloforometer synoptometer HTS</td>
<td>13 GO-patients</td>
<td>PS, ↑, ↓</td>
<td>min mean diff 0.3° ± 1.8° (HTS – cycloforometer) max mean diff 3.1° ± 3.4° (HTS – synoptometer)</td>
</tr>
</tbody>
</table>

MDR = Maddox Double Rod; HTS = Harms tangent screen; VD = vertical deviation; PS = primary position; diff = difference ↑ = elevation; ↓ = depression; * = with linear pointer; min = minimal; max = maximal; GO = Graves’ Orbitopathy; XT = exotropia
It is well-known, that the devices used for cyclodeviation measurements cause dissociative effects and therefore enhance measurement results. One may argue that these dissociative effects are different for each device and that the synoptometer for this reason causes the largest excyclodeviation measurements (Kolling, 1982). However, our findings do not support this hypothesis and are in line with the study of Georgievsky and Kowal, who concluded that dissociation differences between the devices did not influence the outcomes (1996).

Other devices for the measurement of cyclodeviation have been proposed (Table 5). Klainguti et al. suggested using the same tool when comparing pre- and postoperative cyclodeviation in clinical use, although they found a corresponding outcome when comparing different tests. They stated, that the Maddox double rod test (MDR) is suitable for clinical trials in GO-patients (1992). Georgievsky and Kowal compared the cyclodeviation in primary position with the torsionometer, the MDR, the synoptophore and the Maddox wing. The measurements with these tests showed a good correlation (1996). However, the accuracy of the MDR decreases when the vertical deviation is more than 20 PD (Bland & Altman, 1986; Johnson et al., 1987) and in other directions than primary position and is therefore not suitable for measuring cyclodeviations in GO-patients (Ansons & Davis, 2001; Bland & Altman, 1986; Brown, 1990; Capdepon et al., 1994; Johnson et al., 1987; Klainguti et al., 1992). Moreover, the Maddox wing and torsionometer are not suitable to measure the cyclodeviation in up- and downgaze and the Maddox wing has a small range for measuring cyclodeviation in relation to the clinically observed range of cyclodeviation.

Davidson and Cleary consider the synoptophore as the golden standard for the measurement of cyclodeviation (2000), but Brown found this tool time consuming, tending to overestimate the deviation and therefore inaccurate (Brown, 1990). The cyclodeviation measured with the synoptophore simulates infinity fixation due to the +6.50 lenses (Gutter et al., 2010). Because of the induced impression of convergence, the synoptophore is thought to produce an excyclodeviation in normal subjects (Kolling, 1982), but Klainguti et al., in contrast, found a tendency towards incyclodeviation (1992). In this study we also found a small tendency of incyclodeviation in the synoptometer group, but this tendency was not significant ($p = 0.142$). In the literature, few studies compared duction measurements using different devices (Table 6).
Hanif et al. compared the measurement of direct elevation using the Goldmann perimeter, the synoptophore and the Aimark (2009). The authors found a considerable variation among the three tests. They also stated that the synoptophore is limited in its use because of the ceiling-effect in upgaze (Hanif et al., 2009). We found that this ‘ceiling’-effect also occurs in depression. In our opinion this is one of the disadvantages of the synoptophore and therefore we do not favor this device for clinical use in GO-patients.

One could bring the accuracy of assessing the movement of the light reflex on the cornea up to discussion. However, this technique is used for all duction devices and our results show a low variance when comparing the modified perimeter with the Goldmann perimeter. Further research could be helpful to improve this technique.

Regarding the age of the patients, Haggerty et al. found no age-related decline in ductions when measuring ductions in 0°, 67°, 141°, 180°, 216° and 293°. In contrast, in a previous

<table>
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<th>Study</th>
<th>Devices</th>
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<th>Population (n)</th>
<th>Position of gaze</th>
<th>Results</th>
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<tbody>
<tr>
<td>Gerling et al. (1998)</td>
<td>Goldmann perimeter</td>
<td>objectively</td>
<td>100 normal subjects, 36 GO-patients</td>
<td>0°, 90°, 180°, 270°</td>
<td>GO population: Intra and inter mean CV 0,7% to 2,3%</td>
</tr>
<tr>
<td>Hanif et al. (2000)</td>
<td>Goldmann perimeter*, synoptophore, Aimark perimeter</td>
<td>subjectively</td>
<td>64 abnormal motility, 50 normal motility</td>
<td>90°</td>
<td>Mean bias from -10 ±10.43° (Goldmann – Aimark) to -26 ±11.71° (synoptophore – Aimark)</td>
</tr>
<tr>
<td>Haggerty et al. (2005)</td>
<td>Goldmann perimeter*</td>
<td>subjectively</td>
<td>35 normal subjects, 29 GO-patients</td>
<td>0°, 67°, 141°, 180°, 216°, 293°</td>
<td>Normal population: Intra OV within 4°, Inter OV within 7.9°, GO population: Inter OV within 7.8°</td>
</tr>
<tr>
<td>Mourits et al. (1994)</td>
<td>Perimeter*</td>
<td>objectively</td>
<td>40 normal subjects, 18 GO-patients</td>
<td>0°, 90°, 180°, 270°</td>
<td>GO population: Intra OV within 6.9°, Inter OV within 8.0°</td>
</tr>
<tr>
<td>Present study</td>
<td>Perimeter*, Goldmann perimeter MTS</td>
<td>objectively</td>
<td>13 GO-patients</td>
<td>0°, 90°, 180°, 270°</td>
<td>Mean difference from 1.2 ± 2.4° (180° perimeter* – Goldmann) to 12.9 ± 6.6° (270° perimeter* – MTS)</td>
</tr>
</tbody>
</table>

MTS = Maddox tangent screen; CV = coefficient of variation; OV = observer variation; diff = difference; * = modified; GO = Graves’ Orbitopathy
study we found an age related decline when measuring abduction, adduction, elevation and depression. In this study, the age ranged from 37 – 73 years, but the study population was too small to divide the subjects in different age groups. In this study, test equipment was limited so duction measurement were only performed in 0°, 180°, 270° and 360°.

Differences between subjective and objective duction measurements are described (Haggerty et al., 2005). Fatigue and discomfort during eye movement may influence the subjective measurement, particularly in GO-patients. Because of that fatigue component, we limited ourselves to objective duction measurement only.

The position of the upper eyelid in downgaze has been considered a disadvantage of objective measurement of duction in downgaze (Haggerty et al., 2005). We have tried to overcome this disadvantage by holding the upper lid digitally up. Nevertheless, relatively large differences were observed in downgaze comparing the modified perimeter with the Goldmann perimeter. This is in agreement with a prior publication, in which the largest intraobserver variation was found in downgaze (Mourits et al., 1994). Measurement in downgaze, therefore, remains an object of concern.

The measurement with the MTS could have been negatively influenced by the position of the patient in front of the MTS (height of the chair) and because of the head rotation and misalignment causing parallax errors. Nevertheless, we do not believe that, even when these shortcomings should have been corrected, the measurement outcomes between the modified perimeter / MTS and Goldmann perimeter / MTS will be interchangeable.

In conclusion, reproducible and objective measurements of cyclodeviation and duction are needed for proper patient care and for research. We recommend to, whenever possible, to use the same test to be utilized for follow-up. Thereby, we demonstrated that measurements of the HTS and the cycloforometer show least variations. The same holds true for duction measurements with the modified perimeter and the Goldmann perimeter. Although we measured the cyclodeviation and ductions in GO-patients, we believe that the outcomes of this study are also applicable to other patient groups.

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