Original Scientific Study with Case Reports

Evaluation of Binocular Vision Therapy Efficacy by 3D Video-Oculography Measurement of Binocular Alignment and Motility

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ABSTRACT: ***Objective:*** To evaluate two cases of intermittent exotropia (IX(T)) treated by vision therapy the efficacy of the treatment by complementing the clinical examination with a 3-D video-oculography to register and to evidence the potential applicability of this technology for such purpose.

Methods: We report the binocular alignment changes occurring after vision therapy in a woman of 36 years with an IX(T) of 25 prism diopters (Δ) at far and 18 Δ at near and a child of 10 years with 8 Δ of IX(T) in primary position associated to 6 Δ of left eye hypotropia. Both patients presented good visual acuity with correction in both eyes. Instability of ocular deviation was evident by VOG analysis, revealing also the presence of vertical and torsional components. Binocular vision therapy was prescribed and performed including different types of vergence, accommodation, and consciousness of diplopia training.

Results: After therapy, excellent ranges of fusional vergence and a "to-the-nose" near point of convergence were obtained. The 3-D VOG examination (Sensoro Motoric Instruments, Teltow, Germany) confirmed the compensation of the deviation with a high level of stability of binocular alignment. Significant improvement could be observed after therapy in the vertical and torsional components that were found to become more stable. Patients were very satisfied with the outcome obtained by vision therapy.

Conclusion: 3D-VOG is a useful technique for providing an objective register of the compensation of the ocular deviation and the stability of the binocular alignment achieved after vision therapy in cases of IX(T), providing a detailed analysis of vertical and torsional improvements.

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INTRODUCTION

Vision therapy encompasses a broad group of techniques aimed at correcting and improving binocular, oculomotor, visual processing, and perceptual disorders (1). Several studies have evaluated the efficacy of these techniques for some specific clinical conditions but always using subjective measurements based on patient or examiner's subjective perception (2-10) and/or quality-of-life questionnaires (11). However, no objective validation has been performed to this date of the efficacy of vision therapy. Only Alvarez et al (12) have demonstrated by means of magnetic resonance imaging that vision therapy was associated with clinical and cortical activity changes in cases of convergence insufficiency. Therefore, there is a need for studies validating the results of vision therapy but using objective methods.

The 3D-videoculography (3D-VOG) is a non-invasive method to evaluate and analyze objectively and with high precision the horizontal and vertical ocular movements as well as the torsional components (13). This technology allows the clinician to perform a 3-D register of the ocular movements (14-17) and to have an objective guidance for taking clinical decisions. The 3D-VOG has been found to have a great variety of clinical applications, such as the objective characterization of nystagmus (18), the precise analysis of effects of extraocular muscle paralysis or paresis in ocular dynamics (19), the objective analysis of saccadic eye movements (20), the evaluation of eye movement impairment in neurological diseases (21), and even the analysis of cyclotorsional changes in refractive surgery (22).

However, to this date, the 3D-VOG technology has not been used in the field of vision therapy as a tool for evaluating objectively the efficacy of exercises to restore the binocular functionality. In the current case report, we show the objective evaluation of two cases of intermittent exotropia IX(T) treated by vision therapy and evaluated with a 3D-VOG system pre and post-therapy in order to evidence the potential applicability of this technology in this field.

CASE 1

A woman of 36 years old attended to our clinic referring intermittent deviation of the left eye without diplopia, especially at the end of the day or when she is very tired. On examination, the patient presented an uncorrected distance visual acuity (UDVA) of 0.0 LogMAR in right eye (RE) and -0.10 LogMAR in left eye (LE). Manifest refraction was 0 in both eyes, whereas under cycloplegia it was of +0.50 sphere -0.50 x 10º cylinder in RE and +0.25 sphere in LE. Anterior segment analyzed by biomicroscopy, Goldmann intraocular pressure (IOP), and fundus analyzed by indirect ophthalmoscopy were found to be within the normality ranges.

The oculomotor study revealed the presence of an intermittent exotropia IX(T) of 25 prism diopters (Δ) at far distance (5 m) and 18 Δ of exophoria (X(P)) at near (40 cm) (cover test). The negative and positive fusional vergence amplitudes measured with a prism bar were acceptable and the near point of convergence was to the nose. Specifically, the negative fusional vergence (NFV) was 16/12 and 20/18 Δ (break/recovery) at far and near distances, respectively. Positive fusional vergence (PFV) was 25/20 and 40/35 Δ at far and near distances, respectively. A video-oculographic study was performed with the 3D video-oculography system 3D-VOG from Sensomotoric Instrument (SMI, Teltow, Germany) which is a noninvasive optical system with two infrared video cameras mounted in a non-invasive pair of goggle (VOG goggles). These cameras are adjusted to a mask that is placed on the head with two plastic rubs that allow the ocular movements at the different sight positions to be registered independently at the three axis of the space with each movement of the patient´s head. The spatial resolution of the 3D-VOG is 0.05˚/0.05˚/0.10˚ (horizontal/vertical/torsional) and the measurement range is ±25˚/±20˚/±18˚ (horizontal/vertical/torsional), with a measurement area for torsional eye movement measurement of ±20˚ around the primary gaze position. This video-oculographic study showed that there was a variable horizontal deviation component that increased spontaneously at distance during a period of time until reaching the values measured dissociating with the cover test (**Figure 1A**, **next page**). No significant changes were evidenced in the vertical and torsional components during the period of examination (**Figure 1A**).

A 2-month vision therapy programme was prescribed and performed including different type of exercises, such as Brock string, Hart charts, prism bar vergence training, consciousness of diplopia training, variable anaglyphs, accommodative facility training with flipper, or aperture rule. After therapy, the patient referred an absence of episodes of deviation that could be objectively confirmed with the video-oculographic examination (**Figure 1B, next page**). The patient was very satisfied with the outcome obtained.

CASE 2

A child of 10 years old attended to our clinic referring intermittent ocular deviation of the left eye without diplopia that had increased in the last year. On examination, the patient presented a corrected distance visual acuity (CDVA) of 0.0 LogMAR in both eyes, with -1.75 sphere and -0.50 x 120º cylinder in RE and -1.75 sphere and -1.00 x 40º cylinder in LE. The same refraction was obtained under cycloplegia. Anterior segment was analyzed by biomicroscopy, Goldmann intraocular pressure (IOP), and fundus analyzed by indirect ophthalmoscopy were found to be within the normality ranges.

The oculomotor study revealed the presence of 8 Δ of IX(T) in primary position associated to 6 Δ of RE hypertropia, and a X(P) and RE hyperphoria of the same magnitude at near. In addition, a grade 3 hyperfunction of the RE inferior oblique was observed, with excyclodeviation associated. Positive fusional vergence amplitudes were low (NFV: far 8/4, near 20/18; PFV: far 10/8, near 2/1) and the near point of convergence was of 8 cm.

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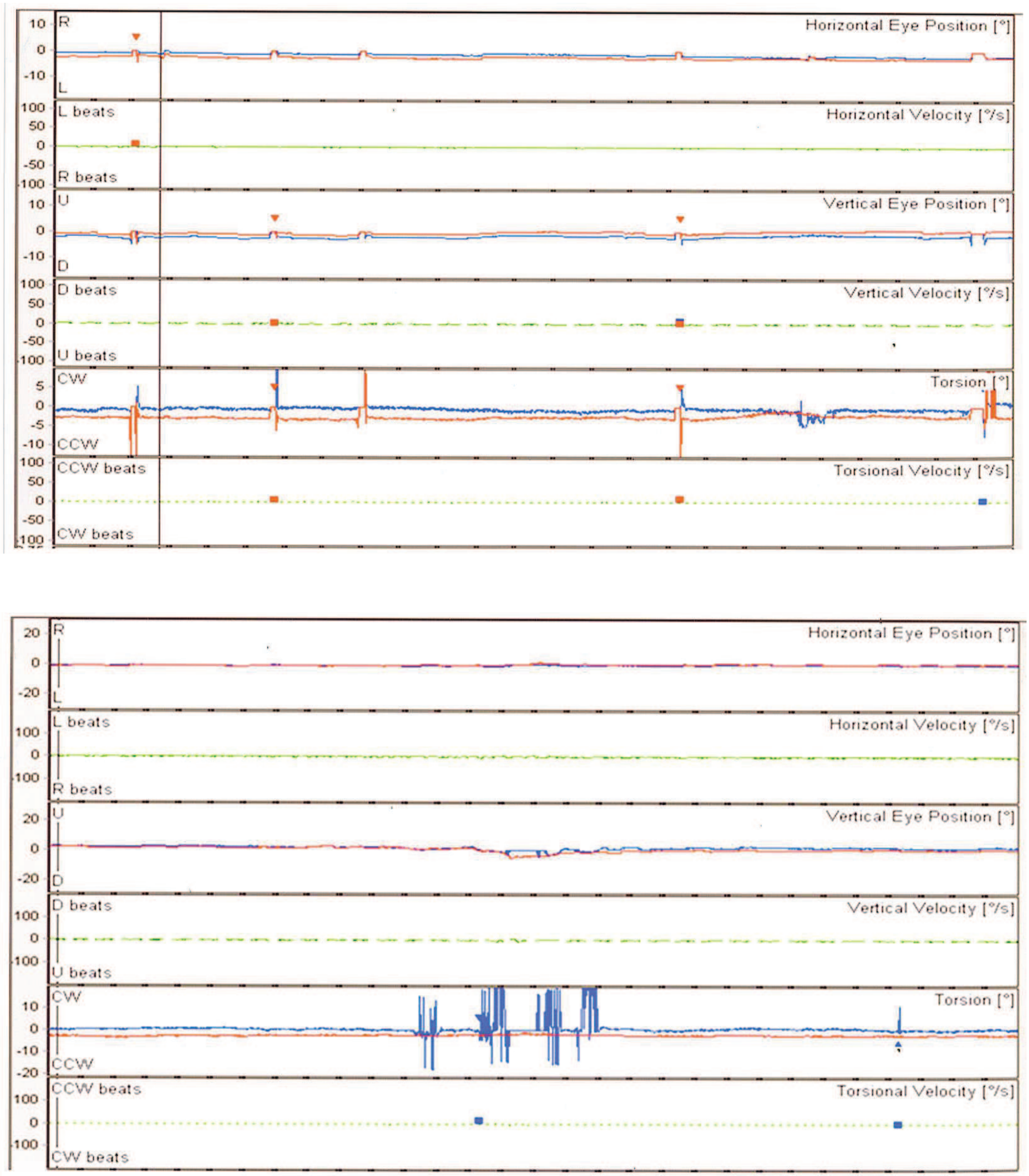
***Figure 1** (Laria & Piñero): Graphic display of the results of the video-oculographic analysis performed before **(A, Top)** and after **(B, Bottom)** a vision therapy programme in the first case reported simulating distance vision. In each display, changes in horizontal, vertical and torsional components during the period of time of the examination.*



CASE 2 (continued)

The video-oculographic study performed with the 3D-VOG system confirmed the presence of a variable horizontal and vertical deviation, with a very significant instability of the torsional component (**Figure 2A, see next page, Top**). Vision therapy was recommended as the magnitude of the deviation was in the limit of the indication of surgery. A complete programme of vision therapy including different types of exercises was followed during a 3-month period. As in the other case reported, the programme included exercises such as Brock string, Hart charts, prism bar vergence training, consciousness of diplopia training, variable anaglyphs, accommodative facility training with flipper, or aperture rule. The therapy finished with the compensation of the deviation (2Δ X(P) and 6Δ hyperphoria RE far and 8Δ X(P) and 3Δ hyperphoria RE near) which could be objectively monitored with the video-oculographic examination (**Figure 2B, see next page, bottom graphic**). The ranges of fusional vergence were excellent (NFV: far 10/6, near 40/35; PFV: far 40/35, near 45/40) and the near point of convergence was to the nose. The patient's parents were very satisfied with the outcome obtained, especially from a cosmetic point of view. Only certain instability remained in the torsional component, but not inducing binocular destabilization.

DISCUSSION

There is scientific evidence available on the nonsurgical treatment of accommodative and nonstrabismic dysfunctions, although it has been shown to be consistent only for the treatment of convergence insufficiency (23,24). Besides the limitation in the number of controlled studies evaluating the efficacy of vision therapy for most of binocular disorders, another controversial issue is the reduced number of studies using objective tests for registering the improvements achieved, without the need of the intervention of the patient or examiner (25).

In the current case report, we show a potential applicability of video-oculography for assessing the improvement achieved with vision therapy. Specifically, we evaluated by video-oculography using the 3D-VOG system the stability of the horizontal, vertical and torsional components in two different cases of distance IX(T) before and after a complete vision therapy program.

The 3D-VOG system allows the clinician registering the ocular movements in x/y axes due to a customized calibration that should be always performed prior to the measurement for each patient. Furthermore, this system allows characterizing the torsional movements using the iris pattern as a reference. The video-oculographic test is non-invasive, only requiring the use of a mask that is adapted to the patient's head. This mask does not interfere with the patient's capability of movement (freedom of movement in a 20º-visual field) and provides an exact oculomotor register. The 3D-VOG system has been successfully used for characterizing strabismic disorders (19), but not for non-strabismic anomalies.

In the two cases reported, the video-oculographic examination was complementary to other tests commonly used for the binocular evaluation of a patient, such as the measurement of the fusional vergence amplitude or the characterization of eye

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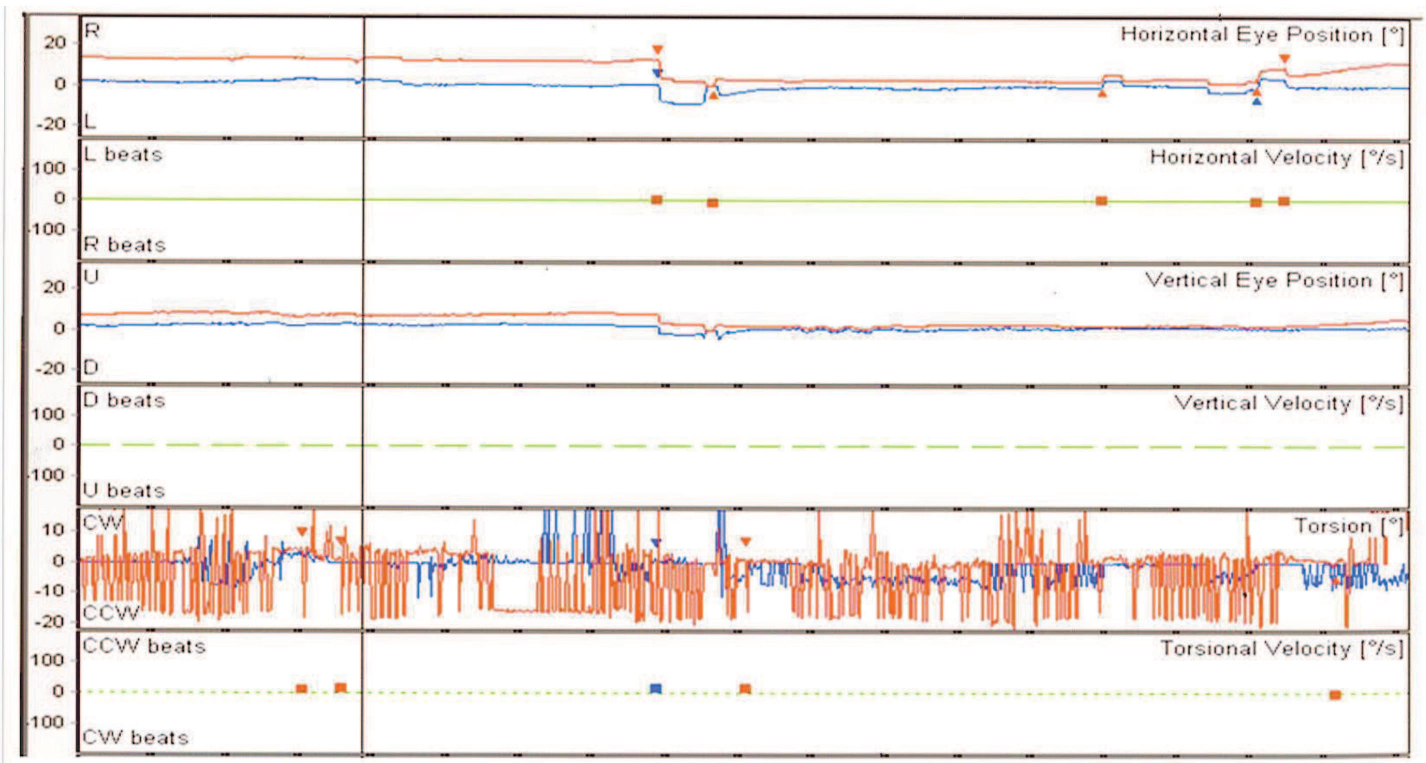
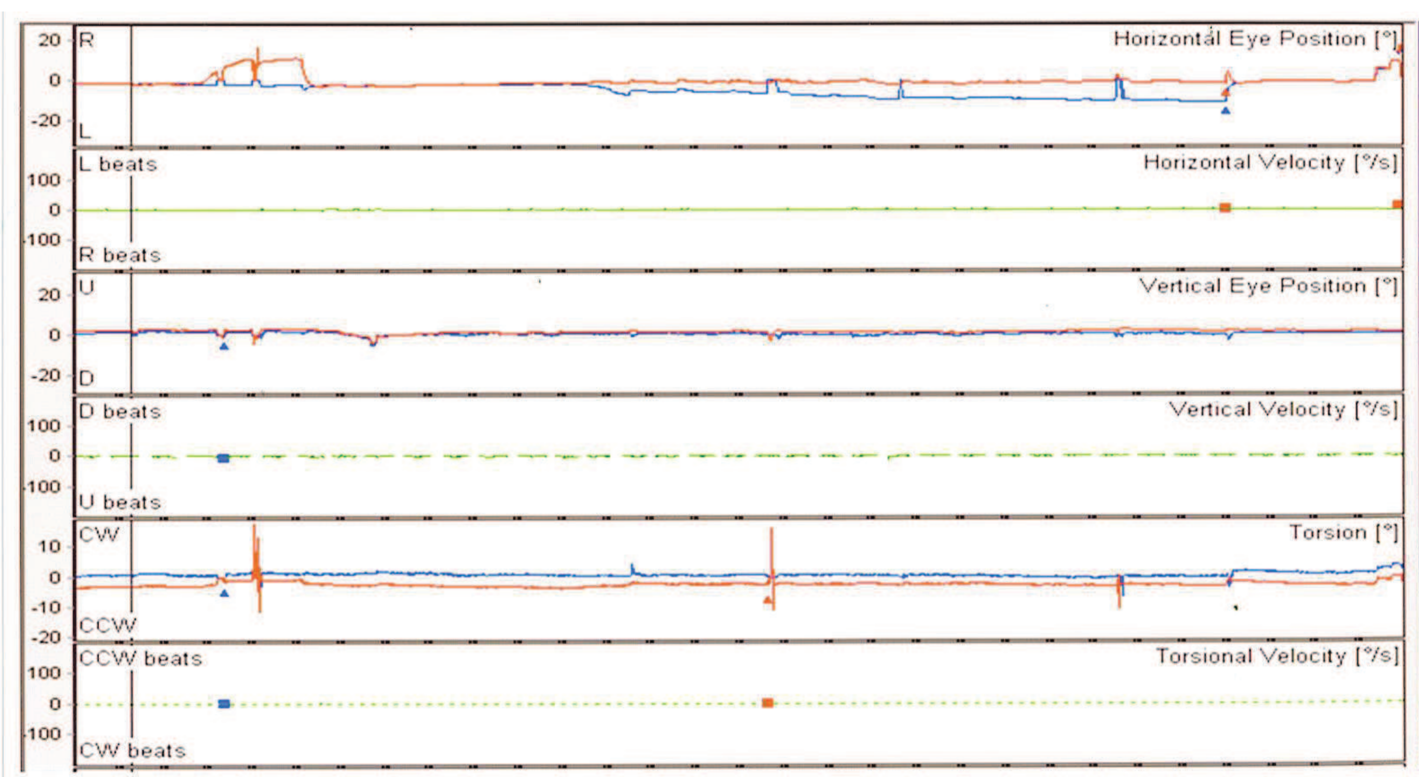
***Figure 2** (Laria & Piñero): Graphic display of the results of the video-oculographic analysis performed before **(A, Top)** and after **(B, Bottom)** a vision therapy programme in the second case reported simulating distance vision. In each display, changes in horizontal, vertical and torsional components during the period of time of the examination.*





binocular misalignment with the cover test, requiring the intervention of the examiner and/or patient's criteria. As two cases of IX(T) were evaluated, the video-oculographic register was especially used to monitor the stability of the ocular alignment, a critical issue for the success of the treatment in such cases. This evaluation could have been done even while introducing some elements of dissociation. It should be consider that fusional vergence amplitude can be acceptable prior to vision therapy treatment in some cases of IX(T) (26) and therefore its measurement is less useful as a parameter for evaluating port-therapy improvement. This occurred in our first case in which pre-therapy PFV amplitude was large, not suggesting the presence of a limitation in the range of fusional vergence. In such cases, the analysis of the stability of the ocular alignment seems crucial and the VOG allows the clinician to obtain a register of this stability. In addition, the torsional component could be monitored with the VOG examination, which is a deviation component not infrequent in patients with IX(T) (27).

The management of IX(T) at far distance by means of vision therapy has been suggested as a potentially useful therapeutic option since many years ago (28). However, it is not successful in all cases that may require a surgical intervention as a first option or even the combination of surgery and vision therapy (29). Figueira & Hing (30) in a retrospective analysis of the progress of 150 treated IX(T) patients concluded that surgery with orthoptic/occlusion therapy was more effective in reducing exodeviation (prism diopters per millimeter of horizontal rectus surgery) compared with surgery only. It is still unclear which factors are crucial for an appropriate selection of a surgical or non-surgical treatment for IX(T), although the magnitude of deviation seems to be one of them.

Thorburn et al (31) performed a review of the peer-reviewed literature on IX(T) of the divergence excess type and found that there was a lack of evidence for best practice and a need for not only high-quality clinical studies but also a better understanding of current practice patterns among clinicians so as to inform future research. We report a case of successful treatment with vision therapy of a case of 25 Δ of far IX(T) which was objectively evaluated by VOG. Randomized controlled studies on the treatment of IX(T) are necessary in the future to define consistent scientifically-based clinical criteria. In these studies, the inclusion of VOG as an additional examination test would be of great value for providing an objective validation of the outcomes obtained.

The second case report shows a significant improvement of the horizontal deviation in a case of IX(T) associated to significant levels of vertical and torsional components. To our knowledge, this is the first report showing an improvement in the vertical and torsional deviation in far IX(T) after a vision therapy programme. Van den Berg and colleagues (32) developed a model in the attempt of finding an explanation for the torsional components in X(T). They found the increased horizontal vergence effort resulted in excess cyclovergence (32). Shin et al (27) found that the amount of torsion was significantly correlated to the disease severity of IX(T). Indeed, these authors suggested that the assessment of ocular torsion could be considered as a supplementary tool for evaluating fusion in patients with IX(T) (27). Regarding the rehabilitation of the vertical deviation, some previous experiences on the treatment of vertical deviations by vision therapy have been reported (33). The achievement of the compensation of the horizontal deviation may be crucial for the vertical and even torsional alignment. More research on this issue is needed because the peer-reviewed literature is scarce.

CONCLUSION

In conclusion, 3D-VOG is a useful technique for providing an objective register of the compensation of the ocular deviation and the stability of the alignment achieved after vision therapy in cases of IX(T). Furthermore, it provides a detailed analysis of the torsional component allowing analyzing its improvement after vision therapy in such cases. More studies evaluating the efficacy of vision therapy should be performed using the VOG technology in order to complement the outcomes obtained with the classical clinical tests. This technology may have a crucial role in the validation of vision therapy techniques for a great variety of binocular disorders.

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