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Adjustable Bilateral Superior Oblique Tendon Advancement for Bilateral Fourth Nerve Palsy

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Abstract

Purpose—Bilateral fourth nerve palsy may be symmetric or asymmetric with combined vertical and excyclotropic deviations and so there may be an advantage to independent adjustment of vertical and torsional components. We report a surgical technique that allows such independent adjustment.

Design—Retrospective interventional case series.

Methods—15 patients, age 17 to 73 years, underwent adjustable bilateral superior oblique tendon advancements for bilateral fourth nerve palsy (11 symmetric (2 prism diopters [pd] hyperdeviation in straight ahead gaze) and 4 asymmetric). Motor alignment was assessed with double Maddox rods and prism and alternate cover tests preoperatively, pre- and post-adjustment and 6-weeks postoperatively.

Results—Preoperative torsion ranged from 7° to 30° excyclotropia (mean 17 ± 7 degrees) and hyperdeviation from 0 to 10pd. Preadjustment torsion ranged from 5° excyclotropia to 40° incyclotropia, and hyperdeviation from 0 to 8pd. 12 (80%) of 15 were adjusted to a target of 0pd hyperphoria and 10° incyclotropia (actual mean 9° incyclo, range 2° incyclo to 13° incyclo). At 6 weeks postoperatively there was expected excyclodrift (to mean 4° excyclo, range 0° incyclo to 15° excyclo), but 13 (87%) had 5° or less excyclotropia and 14 (93%) had 2pd or less hyperdeviation. Mean torsional correction from preoperative to pre-adjustment was $31^\circ \pm 14^\circ$ ($P<0.0001$), and from preoperative to 6 weeks was $13^\circ \pm 6^\circ$ ($P<0.0001$).

Conclusions—Adjustable bilateral superior oblique tendon advancement allows independent control of torsional and vertical components of the deviation, and therefore may be useful in cases of bilateral superior oblique palsy.

INTRODUCTION

Bilateral fourth nerve palsy may be symmetric or asymmetric. A purely torsional deviation may be expected if the palsy is symmetric, but if asymmetric, a vertical deviation in straight ahead gaze may also be expected. Many surgical techniques for addressing symmetric cases

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use the principle of advancing the anterior fibers of the superior oblique tendon described by Harada and Ito.¹ Fells² described a modification of the Harada-Ito procedure, disinserting the anterior fibers of the superior oblique, which was then further modified by Metz and Lerner to enable use of adjustable sutures.³ In asymmetric cases, some authors⁴ advocate tucking the more severely affected superior oblique tendon and performing a Harada-Ito type procedure on the other eye. An adjustable version of the superior oblique tuck⁵ and an adjustable version of the original Harada-Ito procedure have also been described.⁶ Alternatives to tucking the superior oblique tendon include advancement of the entire superior oblique tendon anterolaterally without disinsertion or resection either with or without the use of an adjustable suture^{7, 8, 9} and full-tendon advancement of the superior oblique described by Ludwig et al at the 1999 meeting of the American Academy of Ophthalmology.⁷ In 2006, Holmes and Leske¹⁰ described the adjustable version of the superior oblique total tendon advancement.

In the present study, we report a series of patients with symmetric or asymmetric bilateral superior oblique palsy who underwent bilateral superior oblique tendon advancement on adjustable sutures, to illustrate the utility of this surgical technique for simultaneous and independent correction of vertical and torsional components of the deviation.

METHODS

Approval of the Mayo Clinic Institutional Review Board was obtained for this retrospective chart review study and all data were collected in a manner compliant with the Health Insurance Portability and Accountability Act. The surgical database of one surgeon (JMH) was searched for all cases of bilateral superior oblique palsy that underwent bilateral superior oblique full-tendon advancement on adjustable sutures. In order to assess the vertical and torsional effects of this procedure, cases were excluded if the patient underwent simultaneous inferior oblique surgery, any vertical rectus surgery, horizontal rectus transposition, or any previous superior oblique surgery. Simultaneous horizontal rectus muscle recession or resection without transposition was allowed. Patients were also excluded if they had oscillopsia or were not able to perform double Maddox rod testing.

All patients underwent clinical assessment preoperatively, preadjustment, immediately postadjustment (within one minute of completion of the adjustment), and at six weeks postoperatively (at least 40 days to 5 months). At each assessment, the angle of deviation was measured at distance (3 m) and near (1/3 m) using the prism and alternate cover test (PACT), and torsion was assessed in straight ahead gaze and down gaze using double Maddox rods (recorded as total net torsion between both eyes in degrees). Any limitations of ductions were evaluated on a 0 to -5 scale, where -4 indicated ability to only reach the midline, or straight ahead position. For the purposes of analysis, a Brown syndrome was defined as a new limitation of elevation in adduction that was documented as -1 or worse.

Surgical Technique

At the start of the procedure, after induction of general anesthesia and before any intraoperative rotation of the eye, the 12 o'clock and 6 o'clock positions at the limbus were marked with a blue skin marking pen as described previously.^{11, 12} Forced ductions,

including Guyton's exaggerated traction test¹³ and the torsional forced duction test,¹⁴ were performed on both eyes to assess superior oblique tendon laxity. A silk traction suture was placed at 12 o'clock through partial scleral thickness at the limbus, and a superior temporal fornix conjunctival incision was made with Westcott scissors through Tenon's capsule. The superior rectus muscle was isolated with a small and large hook. The superior oblique tendon insertion, usually found at the temporal edge of the superior rectus muscle, was then isolated with a small hook. The entire tendon width was loaded onto the small hook using serrated smooth forceps and care was taken to ensure no tendon fibers were left behind. A straight mosquito clamp was placed on the insertion of the superior oblique tendon. The superior oblique tendon was then cut from the sclera. The decision whether to resect part of the tendon and how much to resect (5 mm to 7 mm) was made according to the surgeon's judgment regarding the laxity of the tendon on the Guyton exaggerated traction test¹³ and the torsional forced duction test¹⁴ at the start of the procedure and how far the tendon could be pulled down toward the lateral rectus. A 6-0 double-armed Vicryl suture was imbricated in a double-locking manner at the end of the tendon fibers (or further back if a resection was planned). The lateral rectus muscle was then isolated with a small and large hook. The new insertion of the superior oblique tendon was marked 8 mm and 12 mm posterior to the superior pole of the lateral rectus muscle. Scleral bites were taken in a cross-swords manner at these points. The sutures were pulled through, tied together in a figure-eight knot, and a separate piece of 6-0 Vicryl suture was tied around the two sutures in the form of a noose. Positioning of the tendon relative to the superior border of the lateral rectus muscle (Figure 1) was determined by intraoperative monitoring of torsion using the two blue dots placed at the limbus at the start of surgery.¹⁴ To try to reduce the incidence of overcorrections and postoperative Brown syndrome, intraoperative traction testing was performed to confirm that each eye could still extort at least 10 degrees and the inferior limbus of each eye could still elevate well above the intercanthal line. An additional silk traction suture was placed through partial scleral thickness just posterior to the new insertion of the superior oblique fibers. Intraoperatively, each noose was adjusted (Figure 2) so that the preplaced blue dots at 12 o'clock and 6 o'clock showed the desired overcorrection of the cyclotropia, split between the eyes. In developing this procedure we defined our target initial postoperative alignment to be 10 degrees of incyclotropia. The initial position of the blue dots at the start of the procedure represents a new zero and therefore, if a patient had 20 degrees of preoperative excyclotropia, we would want to induce 30 degrees of incyclotropic correction with our surgery to result in a final alignment of 10 degrees incyclotropia. Using this surgical plan, for a patient with 20 degrees of preoperative excyclotropia and no hypertropia, we would adjust intraoperatively so that the blue dots indicated 15 degrees of incyclotropia in each eye, for a total correction of 30 degrees and a final alignment of 10 degrees of incyclotropia, Figure 3). The conjunctiva was massaged back into position and sutured using 8-0 Vicryl suture when needed to leave a small conjunctival opening through which the adjustment could be performed. The adjustable suture was taped to the skin lateral to the lateral canthus until the patient was awake for adjustment.

Adjustment

Alignment was assessed 2 to 8 hours following surgery after full recovery from general anesthesia. Assessment was performed in the patient's room in the outpatient surgical ward,

typically using the face of a seated accompanying family member as the 3-meter distance target and the anesthetic drop bottle as the 1/3-meter near target, and using double Maddox rods in a trial frame (as performed in the office examinations). The target postadjustment alignment was vertical orthophoria and an incyclotropia of 10 degrees. This target incyclotropia was chosen because our previous experience with superior oblique tightening procedures was one of postoperative excyclotropic drift. If the vertical alignment was at target angle but the torsional alignment was not at 10 degrees of incyclotropia, both superior oblique tendons were adjusted symmetrically (when possible) to achieve 10 degrees incyclotropia. If there was hypertropia in one eye but torsion was at the target angle, the superior oblique tendon was pulled forward in the hypertropic eye and let back in the hypotropic eye symmetrically until vertical orthophoria was achieved. If both torsional and vertical alignment needed adjustment, the superior oblique tendon was pulled forward in the hypertropic eye and let back in the hypotropic eye asymmetrically until orthotropia was achieved. Following adjustment, the sutures were tied down over the sliding nooses, trimmed, and tucked underneath the conjunctiva.

Statistical Analysis

Alignment data are presented as means and standard deviations. Change in alignment from preoperatively to: 1) preadjustment, and 2) 6 weeks postoperatively was evaluated using signed-rank tests. We also calculated motor success rate at 6 weeks postoperatively, defined as ≥ 2 pd vertical deviation by PACT at distance straight ahead and near, with between 5 degrees excyclotropia and 5 degrees incyclotropia (a residual motor deviation where we would expect motor and sensory fusion).

In order to assess the effect of superior oblique tendon advancement on any horizontal alignment and any V pattern, we performed a secondary analysis of horizontal alignment in patients who were not undergoing horizontal rectus muscle surgery. All statistical analyses were performed using SAS version 9.4 (SAS Institute Inc., Cary, NC).

RESULTS

Patients

We identified 15 patients with bilateral fourth nerve palsy. Eight were male and ages ranged from 17 to 73 years (mean 44.8 ± 17.2 years, median 40 years). Nine were post-traumatic, 3 were post-neurosurgery, one was post-intracranial bleed, and 2 were unknown etiology. All underwent bilateral superior oblique full tendon advancement on an adjustable suture. 10 of 15 had onset of diplopia less than 2 years before strabismus surgery. Five of 15 patients have been previously described by us in a brief preliminary report (not available on PubMed or to the general public) in the Transactions of the International Strabismological Association.⁹ Twelve of 15 patients had no previous eye muscle surgery, 2 had one previous surgery (a right inferior oblique recession in one case and a right inferior rectus recession with a left lateral rectus resection in the other) and one patient had 2 previous surgeries (a right superior rectus recession with a left lateral rectus recession followed by a right superior rectus resection with a right inferior oblique recession). Twelve patients had isolated bilateral fourth nerve palsy, 2 had combined fourth and partial third nerve palsies (patients 11 and 14,

Table 1), and 1 had bilateral combined fourth and partial sixth nerve palsies (patient 12, Table 1). Three underwent horizontal rectus muscle surgery in addition to superior oblique tendon advancement.

Preoperative Alignment

Preoperative assessment was within 9 days (median 1 day) prior to surgery. Preoperative horizontal alignment ranged from 35 pd esodeviation (in one patient with a coexistent sixth nerve palsy) to 18 exodeviation (including 2 patients with coexistent third nerve palsies). At distance, hyperdeviation ranged from 0 to 10 pd (mean 2.7 ± 3.0). Eleven patients had a hypertropia 2 pd (Table 1). At near fixation, the hyperdeviation ranged from 0 to 8 pd (mean 3.0 ± 2.6). Torsion in the straight ahead position ranged from 7 to 30 degrees excyclotropia (Table 1) (mean 16.7 degrees excyclotropia ± 6.7 degrees). Preoperative torsion in downgaze ranged from 7 to 30 degrees excyclotropia (mean 20.6 degrees excyclotropia ± 5.9 degrees) (Table 1, data for downgaze were available for 14 of the 15 patients).

In order to assess the effect of superior oblique tendon advancement on any horizontal alignment and any V pattern, we performed a secondary analysis of horizontal alignment in the 12 patients who did not have horizontal rectus muscle surgery. Horizontal alignment ranged from 2 pd esotropia to 10 pd exotropia (mean 1.8 exotropia ± 3.5). Except for one patient, all had a V pattern with a mean upgaze alignment of 5.2 pd ± 5.3 exotropia and a mean downgaze alignment of 4.7 pd ± 4.8 esotropia. The difference in horizontal alignment between up and down ranged from 0 to 20 pd (mean 9.8 ± 5.7 of V pattern), where the downgaze alignment was more esotropic (or less exotropic) than upgaze in all but 1 patient, where it was the same.

Surgery Performed

All 15 patients had bilateral superior oblique tendon advancement. For 4 (27%) a 5-mm to 7-mm resection of both superior oblique tendons was performed in addition to the advancement. Three patients had simultaneous surgery on horizontal recti; a left lateral rectus recession (for a partial third nerve palsy), a right lateral rectus resection with a left medial rectus recession (for a partial sixth nerve palsy), and a left medial rectus recession (for a small esotropia).

Adjustment

Before adjustment, vertical alignment ranged from 0 to 8 pd hypertropia (mean 1.1 pd ± 2.4) and torsion ranged from 5 degrees excyclotropia to 40 degrees incyclotropia (mean 14.0 degrees incyclotropia ± 14.1 degrees). Total torsional correction across all 15 patients from preoperative to preadjustment was a mean of 30.7 ± 14.3 degrees ($P < 0.0001$).

Twelve patients (80%) underwent adjustment of the vertical and/or torsional components to achieve the desired target angle. Adjustment of the superior oblique tendon ranged from 5 mm recession to 3 mm advancement (Table 1) and was symmetric in 4 patients (achieving a change in the torsional component only), and asymmetric in 8 (achieving a change in both vertical and torsional alignment).

Immediately postadjustment, horizontal alignment ranged from 6 esotropia to 4 exotropia (mean 1.6 esotropia $\pm$ 3.3 pd). Vertical alignment showed no hyperdeviation was present in any of the 15 patients and torsion on double Maddox rod ranged from 2 degrees incyclotropia to 13 degrees incyclotropia (Table 1) (mean 8.6 degrees incyclotropia $\pm$ 2.7 degrees). The target angle of 10 degrees incyclotropia was not achieved in several patients for a number of reasons 1) early in developing this technique the target angle was only 7 degrees incyclotropia 2) we were unable to further advance the superior oblique tendon, and in retrospect a small resection may have been desirable.

Six-week Outcomes

At the six-week postoperative visit (41 to 149 days, median 59 days), horizontal alignment ranged from 20 pd esotropia to 4 pd exotropia (mean 1.9 $\pm$ 6.0 pd esotropia); 13 patients had a horizontal alignment between 4 pd esotropia to 4 pd exotropia, one had 10 pd esotropia (preoperatively was 35 pd esotropia secondary to a combined fourth and sixth nerve palsy), and one patient had 20 pd esotropia. Vertical alignment ranged from 0 to 12 pd hypertropia (mean 1.3 pd $\pm$ 3.0); 14 patients had a hyperdeviation of 2 pd, one patient had 12 pd (combined fourth and sixth nerve palsies). Overall, at 6 weeks postoperatively, torsion ranged from 0 to 15 excyclotropia (mean 4.1 degrees excyclotropia $\pm$ 3.8 degrees) and 13 patients (87%) had 5 degrees or less excyclotropia. This amount of excyclodrift from the end of adjustment to 6 weeks postoperatively represented a mean excyclodrift of 12.5 degrees (range 4 degrees to 20 degrees, with a median 13 degrees and quartiles of 10 degrees and 14 degrees).

Regarding torsion in downgaze, at 6 weeks postoperatively, measurements ranged from 15 degrees excyclotropia (a marked undercorrection) to 2 degrees incyclotropia (a residual slight overcorrection) (Table 1, mean 6.6 degrees excyclotropia $\pm$ 5.0 degrees, data available for 13 or the 15 patients).

Regarding whether or not we induced a Brown syndrome with this procedure, 2 of the patients had limitations of elevation preoperatively (one with Parinauds syndrome and one due to prior strabismus surgery), and therefore 13 patients were included for this specific analysis. Four (31%) of the remaining 13 patients had documented limitation of elevation in adduction, but this was graded as no more than -1 on the 0 to -5 scale.

Overall, 13 patients (87%) achieved motor success 6-weeks postoperatively (2 pd of hyperdeviation and no more than 5 degrees of cyclotropia). Of the two not meeting success criteria, one patient (patient 12) who had combined bilateral fourth and bilateral sixth nerve palsies following resection of an astrocytoma had 10 pd esotropia, 12 pd hypertropia and 15 degree excyclotropia. The other patient had an isolated bilateral fourth nerve palsy with 1 pd hypertropia (within target) but 10 degrees of excyclotropia. Total mean torsional correction across all 15 patients from preoperative to 6-weeks was 12.7 $\pm$ 5.8 degrees ($P < 0.0001$).

Analysis of change in horizontal alignment in the 12 patients who did not have simultaneous horizontal rectus muscle surgery, showed a change in horizontal alignment ranging from a 3 pd esoshift to 10 pd exoshift (mean 1.8 pd exoshift $\pm$ 3.6). Regarding change in V pattern in the 11 of these 12 patients with alignment measured in upgaze and downgaze both

preoperatively and at 6 weeks, the difference between horizontal alignment between upgaze and downgaze, at 6 weeks, ranged from -1 pd (A pattern) to 5 pd (V pattern) (mean 1.5 ± 2.0 pd) which represented a mean reduction in V pattern from preoperatively to postoperatively of 8.6 ± 5.1 pd ($P=0.002$).

DISCUSSION

We found advancing both superior oblique tendons on adjustable sutures to be a useful surgical technique for both symmetric and asymmetric bilateral superior oblique palsy, allowing independent control of both vertical and torsional components of the deviation. Postoperative excyclodrift was common, similar to that reported for the Harada-Ito procedure,¹⁵ confirming the need to set the torsional alignment to an incyclotropic overcorrection at the time of adjustment.

Our surgical technique is very similar to the Fells' modification of the Harada-Ito¹ procedure and to the adjustable Harada-Ito described by Metz and Lerner,³ except, in our procedure, the entire superior oblique tendon is advanced toward the border of the lateral rectus muscle, rather than just the anterior fibers. Advancement of the superior oblique tendon (without adjustable sutures) was previously described by Ludwig at the 1999 meeting of the American Academy of Ophthalmology (as an oral paper presentation) and was later published as part of a workshop on surgical techniques at the 2013 annual meeting of the American Association of Pediatric Ophthalmology and Strabismus.⁷ Ludwig described this technique as an alternative to superior oblique tendon tuck when correcting superior oblique weakness of any cause, including congenital and acquired superior oblique palsy whether unilateral and bilateral, suggesting that it avoids the restriction of upgaze that may follow the tuck procedure.

We suggest that the usefulness of performing superior oblique full-tendon advancements on adjustable sutures is illustrated by our finding of a need to perform postoperative adjustment for 80% of patients in the current study to optimize both the vertical and torsional alignment. These adjustments were made in the context of targeting zero vertical misalignment and 10 degrees of incyclotropia at the end of the surgical procedure, in other words we made every attempt to place the tendons where we felt they needed to be. Nevertheless, we still needed to adjust 80% of patients to achieve our target vertical and torsional alignment. Although we do not know what would have happened to each of these patients if we had not performed an adjustment, it is unlikely that the patient with 40 degrees of incyclotropia prior to adjustment would have had a satisfactory postoperative outcome without adjustment. Of note, this patient underwent surgery prior to our implementation of marking the limbus at 12 and 6 o'clock to monitor the intraoperative changes in the torsional position of the eye.^{11, 12} We therefore believe that such a large initial overcorrection is now unlikely. One possible argument against using an adjustable suture technique is the variability of excyclodrift following adjustment. Nevertheless, the vast majority of patients had an excyclodrift within a fairly tight range (quartiles of 10 and 14), so we believe that using an adjustable technique still offers the advantage of fine-tuning smaller overcorrections or undercorrections that are still difficult to detect using limbal marks^{11, 12} or observing fundus torsion under general anesthesia. Such an adjustable suture technique may thereby maximize the proportion of

patients who have a final torsional alignment that remains within a range that can be fused or tolerated without torsional diplopia or other symptoms of strain or asthenopia. In fact, given the common undercorrections in downgaze (Table 1), it is possible that it might be better to set the immediate post-adjustment torsional alignment as an even greater overcorrection than 10 degrees of incyclotropia, but such a strategy has not yet been evaluated.

Bilateral superior oblique tendon advancement also limits the number of rectus muscles operated upon, which may be important for patient who have previously undergone multiple previous surgeries or in patients with multiple cranial nerve palsies where surgery on the horizontal rectus muscles may be needed where anterior segment ischemia could be a concern.

Although not the subject of the current report, we have also found superior oblique tendon advancement on an adjustable suture to be useful when addressing an acquired unilateral fourth nerve palsy where both vertical and torsional deviations are barriers to fusion. For example, in a case of a total sixth nerve palsy and profound ipsilateral fourth nerve palsy, we have performed a transposition of the superior rectus to the lateral rectus with myopexy, as described by Mehendale et al¹⁶ in combination with a medial rectus recession to address the esotropia and an adjustable superior oblique tendon advancement on the same eye to address both the vertical and torsional deviations. Using this latter approach does not allow independent adjustment of the vertical and torsional components, in contrast to the bilateral approach we are reporting in the current manuscript.

The main weakness of our study is the small number of cases and the limited follow-up. Although we have longer follow-up on several of these cases, we are concerned that there may be bias in those who returned versus those who did not, for example patients who did return at a later date may have preferentially been those who were experiencing residual or induced problems, hence our focus in the current manuscript was on complete 6-week postoperative data. Our report would have been strengthened by collection of standardized diplopia data, but the majority of our examinations were performed before we developed the Diplopia Questionnaire.^{17, 18} Although we have performed many more of these procedures over the years than reported in the current manuscript, they are not included in this report because these additional cases underwent simultaneous vertical and oblique muscle surgery or horizontal rectus transposition at the time of their bilateral superior oblique full-tendon advancement which did not allow us to distinguish the effect of bilateral superior oblique tendon advancement from the effect of surgery on other muscles. An additional weakness is that several patients in the current report had coexisting cranial palsies that may have affected their response to bilateral superior oblique tendon advancement. Finally, although we have termed this procedure “superior oblique tendon advancement,” we cannot rule out an element of anteriorization of the superior oblique tendon with the described procedure, but we believe the descriptive term is a convenient and useful representation of what is actually performed at surgery.

In summary, our initial results suggest that bilateral superior oblique tendon advancement on adjustable sutures may be a useful technique to address bilateral superior oblique palsy,

whether symmetric or asymmetric. Further studies are needed to determine whether or not this technique offers any advantage over other surgical techniques.

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Figure 1.

Diagrammatic representation of the surgical technique, showing advancement of the superior oblique tendon on an adjustable suture.

Figure 2.
Intraoperative photograph of superior oblique advancement on an adjustable suture, left eye. Sliding noose (black arrow) can be adjusted to either advance or recess the tendon at the time of adjustment. LR=lateral rectus muscle; SO= superior oblique; SR=superior rectus muscle

Figure 3.

Postoperative incyclotropia (surgeon's view). At the conclusion of surgery the amount of induced incyclotropia can be judged by the position of the preplaced blue dots that were originally at 12 and 6 o'clock at the start of the procedure.^{11, 12}

Table 1

Preoperative, Pre-adjustment, Post-adjustment, and 6-Week Postoperative Alignment and the Amount of Adjustment on Right and Left Superior Oblique Muscles.

Patient number	Preoperative			Pre-Adjustment		Post-Adjustment		Adjustment ^a (mm)		6-Week Postoperative		
	Vertical PACT	Torsion straight ahead ^b	Torsion in downgaze ^b	Vertical PACT	Torsion by DMR	Vertical PACT	Torsion by DMR	RSO	LSO	Vertical PACT	Torsion straight ahead ^b	Torsion in downgaze ^b
1	2 LHT	10 Ex	NA	0	7 In	0	7 In	0	0	0	0	NA
2	1 LHT	27 Ex	28 Ex	0	5 Ex	0	10 In	3	3	1 LHT	10 Ex	13 Ex
3	2 RHT	17 Ex	15 Ex	0	25 In	0	11 In	-1	-2	0	3 Ex	3 Ex
4	8 RHT	8 Ex	7 Ex	0	10 In	0	7 In	0	-1	1 RHT	2 In	2 In
5	0	7 Ex	20 Ex	0	15 In	0	7 In	-5	-5	0	3 Ex	3 Ex
6	0	13 Ex	20 Ex	0	40 In	0	10 In	-4	-4	0	2 Ex	11 Ex
7	2 RHT	17 Ex	20 Ex	4 RHT	35 In	0	10 In	-3	-5	0	3 Ex	5 Ex
8	2 LHT	17 Ex	17 Ex	0	35 In	0	13 In	-4	-3.5	0	5 Ex	10 Ex
9	2 RHT	17 Ex	20 Ex	4 RHT	10 In	0	10 In	3	-2	1 RHT	2 Ex	3 Ex
10	0	10 Ex	22 Ex	0	0	0	9 In	2	2	0	4 Ex	10 Ex
11	2 RHT	15 Ex	15 Ex	0	8 In	0	8 In	0	0	0	5 Ex	5 Ex
12	6 LHT	24 Ex	24 Ex	8 LHT	7 In	0	5 In	-2	3	12 LHT	15 Ex	15 Ex
13	10 RHT	30 Ex	30 Ex	0	10 In	0	10 In	0	0	1 RHT	3 Ex	NA
14	1 LHT	18 Ex	26 Ex	0	18 In	0	10 In	-1	-4	2 RHT	2 Ex	8 Ex
15	3 RHT	21 Ex	24 Ex	0	5 Ex	0	2 In	1	3	1 RHT	2 Ex	2 Ex

Ex= Excyclotropia. HT= Hypertropia. In= Incyclotropia. LSO= Left superior oblique. PACT= Prism and alternate cover test. RSO= Right superior oblique. NA= Not available.

^aNegative values indicate recession and positive values indicate advancement.

^bAll torsion measurement made by Double Maddox rod