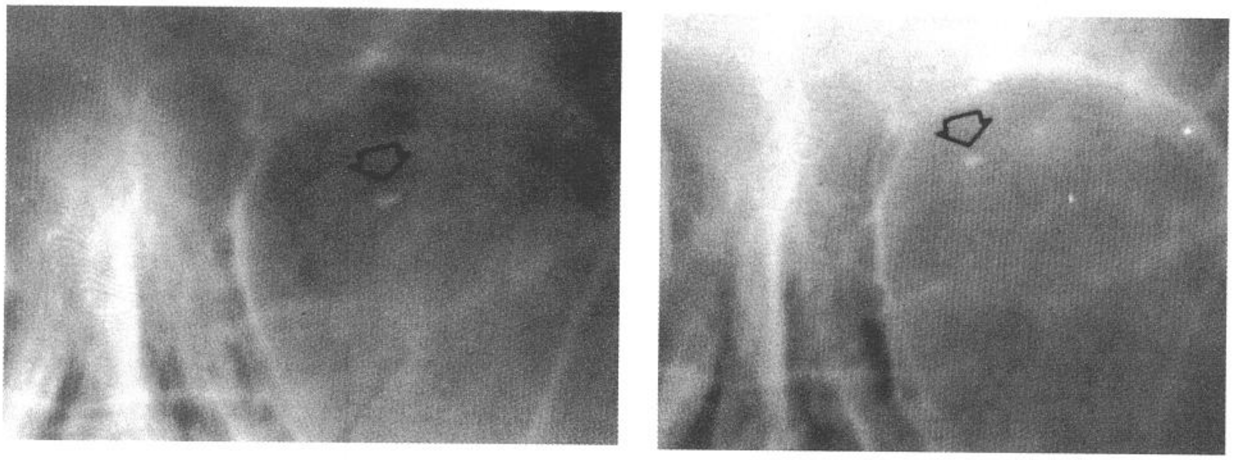

FIGURE 6-22 Behavior of the extreme cut end of the superior oblique tendon after scleral disinsertion. At 2 months postoperatively, the small steel thread suture (*arrows*) placed during the surgical procedure approaches the trochlear region in abduction-infraduction gaze (*left*), moving apart from the anterior segment of the eyeball that is displaced in this direction of gaze. (Reprinted with permission from J Prieto-Díaz. Disinsertion of the superior oblique for "A" pattern anisotropias. Binoc Vis 1987;2:7.)

formed through a temporal approach; in the scleral disinsertion, the superior oblique muscle is cut tangentially to the globe without performing any tenectomy. This operation offers a moderate effect. Rupture of the trabeculae is avoided, thereby avoiding unpleasant displacements of the tendon and postsurgical adherences to the globe, especially in the anterior medial quadrant. The objective is to move the sectioned tendon inside the sheath so that it remains adherent to it and not to the globe. Seemingly, this is what occurs. In the immediate postoperative period, no functional changes ever were observed—neither depression restriction in abduction nor overconvergence in downgaze. These disorders would occur if the tendon were reinserted anterior to the equator of the globe.

As a first step in studying the behavior of the superior oblique tendon in the postoperative period, we place a thin thread of stainless steel at the cut end of the tendon in six cases. Two months later, the small steel thread suture can be seen to approach the trochlear region in abduction-infraduction gaze and to move away from the anterior segment of the eyeball when it is displaced in this direction of gaze (Figure 6-22).

Inferior oblique disinsertion[100,101] fails because cut muscle fibers at the site rapidly adhere to the sclera. Disinsertion of the superior oblique is performed on the tendon, which retracts[25] and adheres to the surrounding tissue inside its sheath and not to the sclera. With the tangential disinsertion of the superior oblique tendon, we achieved good results in moderate A patterns. The average presurgical A pattern in 59 patients who underwent bilateral disinsertion of the superior oblique tendon was $22.9^{\Delta} \pm 5.7^{\Delta}$, a collapse of $21.1^{\Delta} \pm 6.0^{\Delta}$ was achieved, and a correction percentage of 92% was seen (Figure 6-23; see Table 6-7).

Split Lengthening of the Superior Oblique Tendon

The splitting tendon technique[28,102,103] performed via the nasal approach is a good treatment for certain cases of Brown's syndrome (those with an HT in primary position and superior oblique overaction). It is also effective with A pattern ($20–25^{\Delta}$).[102] However, it is associated with complications characteristic of nasal approach procedures. For example, too much tendon manipulation in this area tends to form undesirable postsurgical scars. Of 25 patients who had an average anisotropia of $26.5^{\Delta} \pm 9.5^{\Delta}$ and underwent bilateral split lengthening of the superior oblique tendon, we obtained[28] an average correction of $17.5^{\Delta} \pm 10.2^{\Delta}$, a correction percentage of 65.3% (Figure 6-24; see Table 6-7).

Recession with Posterior Transposition of the Superior Oblique Muscle

In cases of severe overaction of the superior oblique, usually the A pattern is larger than 30^{Δ}. In such cases, the recession with posterior transposition of the superior oblique, together with surgery on the horizontal recti mus-

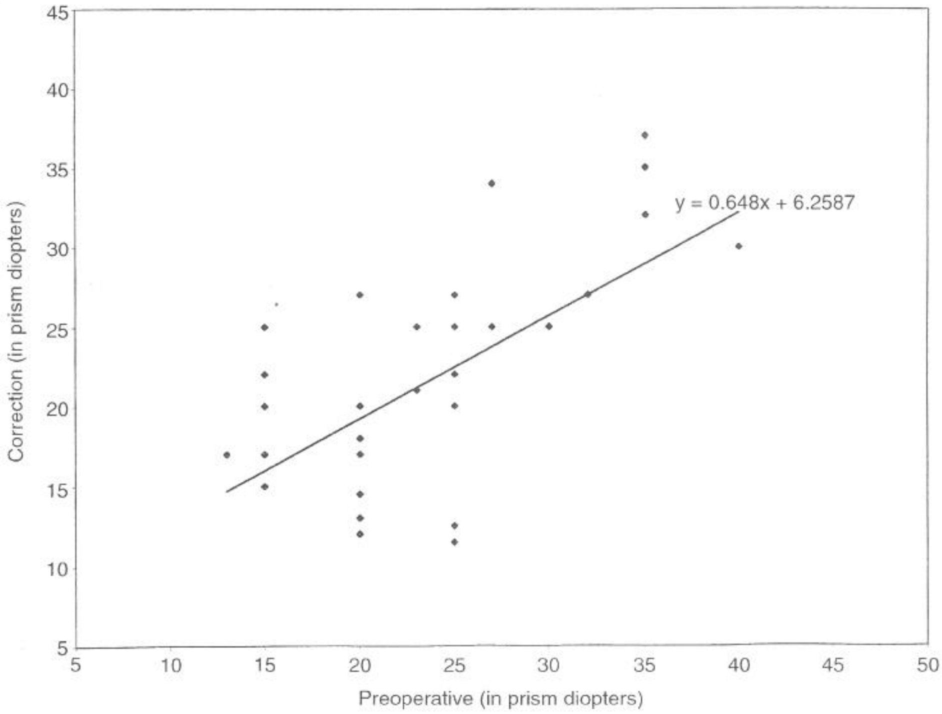

FIGURE 6-23 Results obtained in 59 cases of moderate A-pattern deviation in which bilateral disinsertion of the superior oblique tendon was performed. Average presurgical A pattern was 22.9$^{\Delta}$ ± 5.7$^{\Delta}$. Average correction of A pattern was 21.1$^{\Delta}$ ± 6.0$^{\Delta}$ (92%). (Data from the Institute of Ophthalmology Prieto-Díaz, La Plata, Argentina, 1998.)

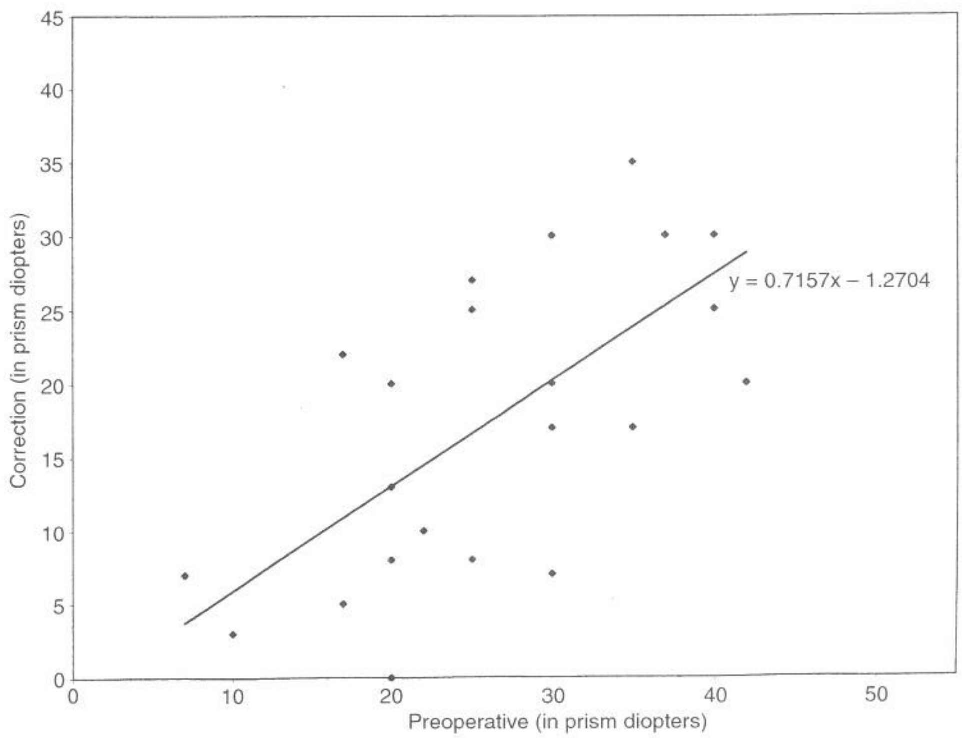

FIGURE 6-24 Results obtained in 25 cases of A-pattern deviation in which bilateral split lengthening of the superior oblique tendon was performed. Average presurgical A pattern was 26.5$^{\Delta}$ ± 9.5$^{\Delta}$. Average correction of A pattern was 17.5$^{\Delta}$ ± 10.2$^{\Delta}$ (65.3%). (Reprinted with permission from C Souza-Dias, C Uesugui. Efficacy of different techniques of superior oblique weakening in the correction of the A-pattern anisotropia. J Pediatr Ophthalmol Strabismus 1986;23:82.)

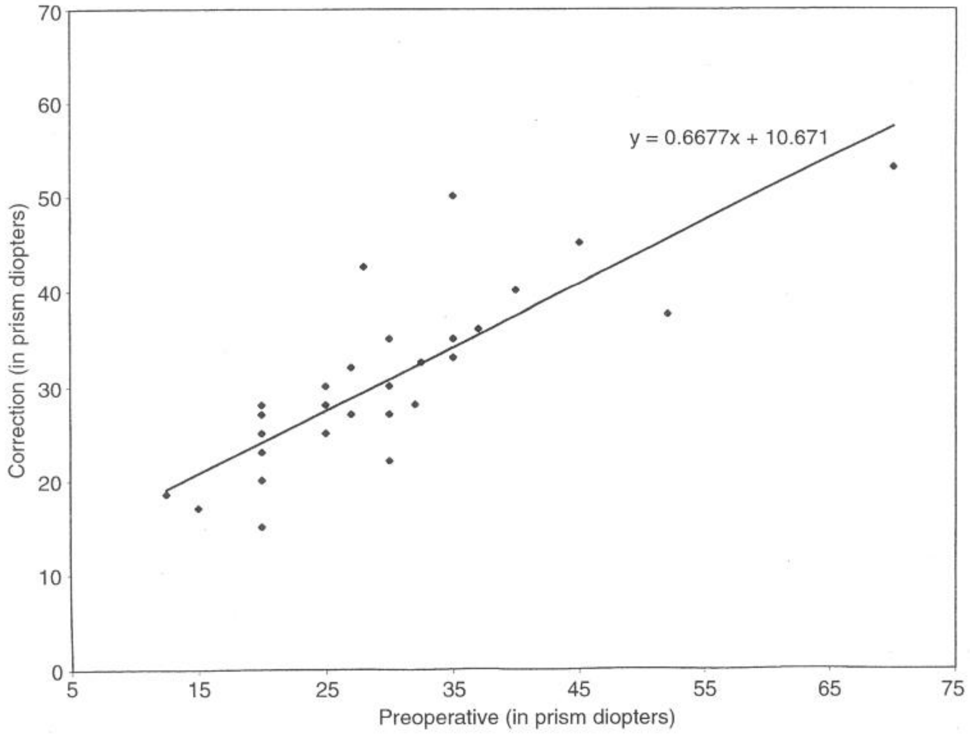

FIGURE 6-25 Results obtained in 40 cases of a large A-pattern deviation and severe superior oblique overaction (3+ or 4+) in which bilateral recession with posterior transposition of the superior oblique muscle was performed. Average presurgical A pattern was $29.7^{\Delta} \pm 10.3^{\Delta}$. Average correction of A pattern was $30.5^{\Delta} \pm 8.3^{\Delta}$ (102.7%). (Authors' data, 1998.)

cles (if necessary) is indicated.[43,48–52,74,92] This procedure is based on the original technique of superior oblique recession reported by Ciancia and Prieto-Díaz.[91] The first operation consisted in reinserting the superior oblique in its muscle line of action, 1 mm behind and 2 mm medially to the medial extremity of the bulbar insertion of the superior rectus muscle. This recession technique had to be modified later,[49–51,92] owing to postoperative complications. If a superior oblique recession is carried out in the line of muscle action (in the direction of the trochlea when the eye is in primary position), the tendon will be reinserted anterior to the equator. A noticeable functional change is induced: The muscle becomes an elevator in abduction, infra-abduction, and infraduction and becomes a severe adductor in almost all fields of gaze, especially in downgaze. This reaction results in a severe overconvergence on looking down and a limitation of depression, with moderate or severe retraction of the globe when affected patients attempt infra-abduction. These functional changes are due to the cocontraction of the superior oblique and inferior rectus muscles, which now are antagonists (see Figure 6-21).[48–50,92,104]

Contemporaneously with our finding about the functional complications caused by recession of the superior oblique in the line of muscle action, Scott et al.,[105] through laboratory studies using Robinson's mathematic model of ocular motility,[106] examined different superior oblique transpositions and evaluated the changes the muscle functions underwent if the muscle were reinserted exactly where we originally reinserted the tendon. These findings confirmed our clinical opinion and proved that reinserting the superior oblique muscle anterior to the equator causes it to become an adductor in almost all fields of gaze and to become an elevator in abduction, infra-abduction, and infraduction. Gobin[104] (1977) and then Haase and Schulz[48] (1984) arrived at the same conclusions. Haase and Schulz proposed the same solution we advocated.[49] Their laboratory studies, also using Robinson's mathematic model of ocular motility,[106] provided graphs comparable to those produced by Scott et al.[105]

To avoid these changes, we advised[49–51,74] that the superior oblique muscle be reinserted 12–13 mm from the limbus and 3–4 mm medially to the medial margin of the superior rectus muscle (i.e., in the direction of the trochlea [recession] and somewhat behind the muscular line of action [posterior transposition]). Good results have been obtained with this technique without observable changes in the superior oblique functions. In 40 cases with an average A pattern of $29.7^{\Delta} \pm 10.3^{\Delta}$, we obtained an average correction of $30.5^{\Delta} \pm 8.3^{\Delta}$, which translates to a correction percentage of 102.6% (Figure 6-25; see Table 6-7 and Figure 6-10).

Superior Oblique Recession with Hang-Loose Suture

We reported[65] a superior oblique recession with hang-loose suture to find a graded and eventually adjustable technique of recession (see Figure 12-19). This suture ensures that the superior oblique displacement is in its line of action inside its sheath and avoids unpleasant displacements of the tendon and postsurgical adherences to the globe, especially in the superomedial quadrant. The objective is to move the sectioned tendon inside or in relation to the superior oblique sheath, so that it remains adherent to the sheath and not to the globe. In the postoperative period, no functional changes were observed (neither depression in abduction nor convergence in downgaze). To study the behavior of the superior oblique tendon in the postoperative period through radiographs, we placed a thin suture of stainless steel at the cut end of the tendon. Thirty days after the operation, we found on radiographs that when the eye moved from primary position to infra-abduction, the steel suture moved toward the trochlea. This movement is contrary to what would happen with a tendon adherent anteriorly to the equator.

Carruthers et al.[46] performed a multicenter study of the effectiveness, safety, and complications of a similar technique of hang-loose superior oblique recession. They commented that no patient had postoperative overconvergence on downgaze or limitation of depression in abduction. They concluded that hang-loose recession of the superior oblique muscle is an effective and safe method for weakening an overacting superior oblique muscle (see Table 6-7).

Moderate and Selective Superior Oblique Muscle Weakening

The fan-shaped scleral insertion of the superior oblique near the equator of the globe causes the different tendinous fiber bundles to assume distinct predominant actions that vary significantly according to gaze position.[15,48,74,92,105,106,107] Figure 6-20 shows the relative participation of the anterior, medial, and posterior superior oblique tendon fibers with the eye in primary position and at 30-degree upgaze and 30-degree downgaze. These data are supported by Scott et al.[105] in a study using Robinson's mathematical model of ocular motility.[106]

Torsional Action

When the eye is in primary position or in downgaze, the anterior fibers exert their maximum torsional action. The torsional function decreases by only 50% from the anterior to the posterior fibers. Thus, an important torsional capacity exists in the entire tendon, both in primary position and in downgaze (see Figure 6-20A). This development accounts for the limited effect of the procedures of Harada and Ito[108] or of similar operations[107] in which the anterior fibers are severed or shortened to correct torsional torticollis.

Horizontal Action

The very anterior fibers of the superior oblique tendon have a small adducting function in primary position and in downgaze. The middle and posterior fibers have strong abducting function (see Figure 6-20B). From the anterior fibers backward, abduction increases dramatically: 146% and 112% in primary position and in 30-degree downgaze, respectively.[105]

Vertical Action

When the eye is in primary position (and particularly in downgaze), the anterior superior oblique tendon fibers exert a small amount of depressing action (see Figure 6-20C). Yet, when the eye is in infra-abduction, the fibers acquire an elevating function.[48,50,51,74,92,105] For this reason, when the superior oblique muscle is recessed in its line of action (when the tendon is reinserted anterior to the equator), the muscle becomes an elevator in abduction, infra-abduction, and infraduction. When the eye is in primary position or in downgaze, the depressing action is increased significantly from the anterior to the posterior fibers. Yet, this change is not as critical as the abducting action: 46.20% and 94.72% in primary position and in 30-degree downgaze, respectively.

Posterior Tenectomy

Despite the predominant torsional action of the anterior fibers, the entire tendon demonstrates an important torsional capacity. The middle and posterior fibers exert 50% of the entire torsional force. Therefore, in torsional torticollis due to intorsion of a fixating eye (DVD), a weakening of anterior fibers alone (e.g., in Harada and Ito's or similar procedures) has limited effect. Thus, a significant torsional torticollis remains. In such cases, we perform[74,92] an anterior tenectomy of the superior oblique muscle and an anterior transposition with 3- to 4-mm advancement of the ipsilateral inferior oblique muscle (Figure 6-26).

Although a mild or moderate V pattern can be ignored in the surgical planning for a severe horizontal deviation, a mild or moderate A pattern always should be treated surgically. Any postoperative exodeviation will increase the superior oblique overaction, especially in downgaze, and the A pattern will be worse.[64,74,92] This significant secondary A-pattern exotropia may be due to an unbalance in the

A B

FIGURE 6-26 **A.** Preoperative. Severe torticollis due to intorsion of the left fixating eye (dissociated vertical divergence). **B.** Postoperative, after anterior tenectomy of left superior oblique fibers and anterior transposition, with 4-mm advancement of ipsilateral inferior oblique muscle.

abduction-adduction forces in downgaze after medial recti recessions, with a predominance of the increased superior oblique abduction action (Figure 6-27).[74,92] In such cases, we have used the posterior tenectomy of the superior oblique successfully,[63,64,92] a procedure that has two objectives: moderate weakening of superior oblique muscles and moderate and selective weakening of the superior oblique abduction function. The first goal is achieved by cutting the tendon fibers close to the scleral insertion; the second goal is attained by cutting the posterior and middle fibers.

Figure 6-20B shows the efficacy of the posterior tenectomy in weakening abduction. The procedure produces a moderate weakening of the torsional action (<50%). When the middle and posterior fiber bundles are severed, virtually all the abducting function might be assumed to collapse. Yet, such is not the case, because the meshwork that attaches the tendon to its neighboring structures and the check ligament action of the recurrent fibers[15] preserve its abducting function.

Posterior tenectomy of the superior oblique, a surgical procedure with moderate and selective weakening action, is easily performed. It can be adjusted according to the extent of the vertical incomitance to be corrected. Of 63 patients with an average presurgical A pattern of $18.3^{\Delta} \pm 7.1^{\Delta}$, we obtained a correction of $15.5^{\Delta} \pm 6.7^{\Delta}$, or 84.6% (authors' data, 1998) (Figure 6-28; see Tables 6-7, 6-8). These results agree with those reported by other authors (see Table 6-8).[28,109,110] If posterior tenectomy of the superior oblique is performed symmetrically, no secondary HTs remain. By approaching the tendon at its scleral insertion (at the temporal side), the surgery can be performed quickly, and complications are few.

When both inferior recti muscles must be recessed more than 6 mm (as in infiltrative ophthalmopathy in Graves' disease), a moderate A-pattern exodeviation tends to occur in downgaze because the abducting effect of the superior oblique muscle is unchecked by the adducting effect of the recessed inferior rectus muscles. This exoshift can be avoided by a moderate selective weakening of the superior oblique abduction function with a posterior tenectomy (Figure 6-29).[35,74,92]

A deviation with marked overaction of the superior oblique muscles and decompensated DVD poses difficulty. Because of superior oblique overaction and a con-

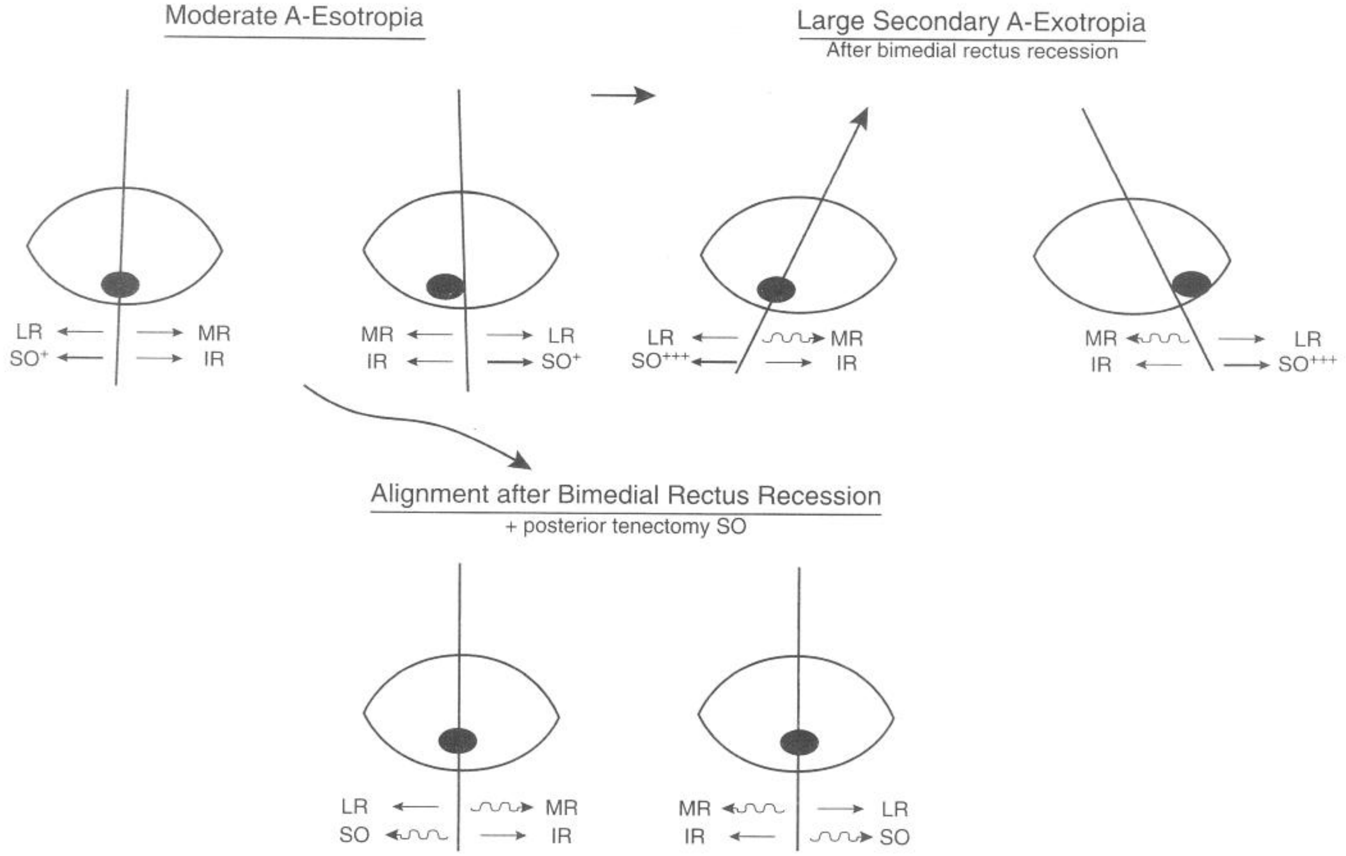

FIGURE 6-27 Mild or moderate A-pattern esotropia should be treated surgically (posterior tenectomy of the superior oblique muscle) because any postoperative exoshift will increase superior oblique overaction, mainly in downgaze, and A-pattern worsening would result. The secondary A-exotropia could be due to the presence, after medial recti recessions, of an imbalance in the abduction-adduction forces in downgaze, with a predominance of the increased superior oblique abduction action. (IR = inferior rectus; LR = lateral rectus; MR = medial rectus; SO = superior oblique.) (Reprinted with permission from J Prieto Díaz. Selective and Moderate Weakening of the Superior Oblique Muscle. In J Prieto-Díaz [ed], Actas del XII Congreso del Consejo Latinoamericano de Estrabismo, Buenos Aires, May 1996. La Plata, Argentina: Gráfica Lifra, 1996;535.)

spicuous A pattern, inferior oblique anterior transposition is contraindicated in the management of DVD. Therefore, large superior recti recessions must be performed, but significant weakening of the superior oblique muscle should be avoided. After large superior recti recessions and severe superior oblique weakening, a significant exoshift tends to occur in upgaze. This reaction results from the abducting effect of the inferior oblique action, which is increased by ipsilateral superior oblique weakening and is unchecked by the adducting effect of the recessed superior rectus muscles. A marked esoshift occurs in downward gaze because the adducting effect of the inferior rectus action—increased by the ipsilateral superior rectus weakening—is unchecked by the abducting effect of the weakened superior oblique muscles. The exoshift in upgaze and the esoshift in downgaze lead to overcorrection with a secondary V pattern (Figure 6-30).

In cases of decompensated DVD, severe weakening of the superior oblique counteracts the effectiveness of superior rectus maxirecession, which is due to the fact that both an elevator (superior rectus) and a strong depressor (superior oblique) are being weakened at the same time. In such cases, wher superior oblique overaction is moderate (2+), we perform a large (9- to 12-mm) superior rectus recession and a posterior tenectomy of the superior oblique. In cases of severe superior oblique overaction (4+), we perform a superior oblique scleral disinsertion.

Regarding the posterior tenectomy dynamics, when the superior oblique muscle overacts, all its functions will be affected by this situation. When the middle and posterior fibers are cut, the actions affected predominantly are abduction and depression. The superior oblique strength then will move toward the anterior fibers, which are exclusively rotators, and an anterior

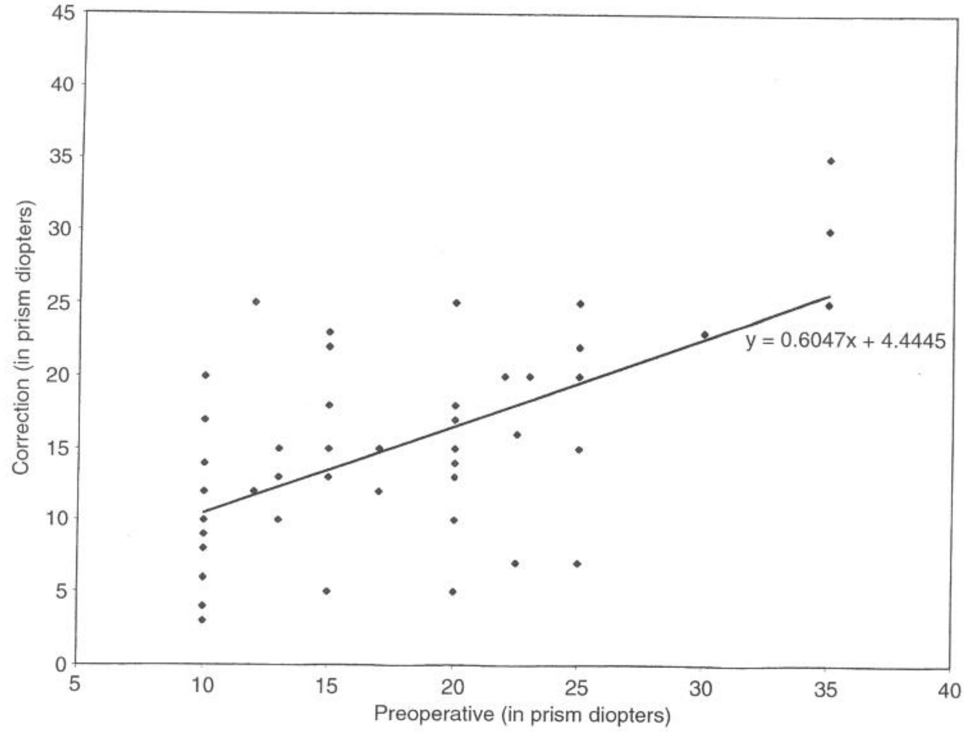

FIGURE 6-28 Results obtained with superior oblique posterior tenectomy in 63 cases of mild A-pattern deviations and mild to moderate superior oblique overaction. Average presurgical A pattern was $18.3^{\Delta} \pm 7.1^{\Delta}$. Average correction of A pattern was $15.5^{\Delta} \pm 6.7^{\Delta}$ (84.6%). (Authors' data, 1998.)

displacement of the line of muscular action will result. Thus, a severe increase in the intorsion action of the superior oblique muscle would be produced. In fact, we do not believe that this occurs. If the trabecular network relating to the superior oblique muscle is not destroyed when the posterior triangle is cut, the strength of the superior oblique muscle toward the anterior fibers will not be displaced. Although the anterior fibers exert intorsion action exclusively, the middle and posterior fibers contribute almost 50% of the torsional function of the superior oblique muscle. As a consequence, the torsion effect will remain balanced.

In considering indications for superior oblique weakening, we proposed a simple clinical and surgical scheme for three procedures according to the magnitude of the superior oblique overaction and the A pattern.[43,50,52] First, for A patterns having vertical incomitance of less than 20^{Δ} and mild overacting superior oblique muscles, we propose a posterior tenectomy. Additionally, for A patterns having between 20^{Δ} and 30^{Δ} and moderate overacting superior oblique muscles, we suggest a scleral disinsertion or full tenectomy near the scleral insertion. Finally, for A patterns having 30^{Δ} or more and severe overaction of the superior oblique muscles, we advocate a recession with posterior transposition or, in very severe superior oblique overaction, the Berke tenotomy.

Oblique Muscle Strengthening

We avoid so-called strengthening procedures of underacting muscles. Generally, we prefer to weaken the overacting ipsilateral antagonist. However, some occasions

TABLE 6-8
Results Obtained by Several Authors in Correcting the A Pattern with Superior Oblique Posterior Tenectomy

Author	*Number of Cases*	*Average Preoperative A-Pattern Deviation*	*Average Correction (Absolute %)*
Castanera[109]	50	$15.7^{\Delta} \pm 6.6^{\Delta}$	$13.3^{\Delta} \pm 5.2^{\Delta}$ (85.8%)
Prieto-Díaz*	63	$18.3^{\Delta} \pm 7.1^{\Delta}$	$15.5^{\Delta} \pm 6.7^{\Delta}$ (84.6%)
Shin et al.[110]	22	18.9^{Δ}	16.1^{Δ} (85.0%)
Souza-Dias[28]	23	$19.8^{\Delta} \pm 6.4^{\Delta}$	$17.4^{\Delta} \pm 5.6^{\Delta}$ (87.5%)

*Authors' data, 1998.