Adjustable suture strabismus surgery in infants and children

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PURPOSE To evaluate the success rate of adjustable suture techniques in horizontal eye muscle surgery in children aged 10 years and younger.

METHODS A retrospective review of children who had horizontal eye muscle surgery at or before the age of 10 years. Patients were divided into 1 of 2 groups according to whether a nonadjustable or an adjustable technique was used. The preoperative measurements, type of strabismus, and postoperative results were analyzed.

RESULTS A total of 98 cases in the nonadjustable group and 298 cases in the adjustable group were identified. Early success rate, defined as alignment within 8^{Δ} of straight at the end of 3 months, was notably greater in the adjustable group (79%) than in the nonadjustable group (64.5%). The difference was statistically significant ($p < 0.01$). In the adjustable group, adjustment was performed in 64% of the cases, either because of an undercorrection or overcorrection. The adjustment procedure was performed under topical proparacaine in 20% of cases and under intravenous propofol in 80%. No complications were reported during the adjustment procedure.

CONCLUSIONS The use of adjustable sutures can provide an improved success rate over nonadjustable sutures in eye muscle surgery in children aged 10 years or younger. (J AAPOS 2008;12:585-590)

For almost 3 decades, adjustable sutures have been a recognized technique in strabismus surgery[1] and can improve the success rate of the realignment of the eyes.[2] Although the immediate postoperative alignment of the eyes can reliably be improved, adjustable sutures have rarely been used in children. This lack of use has been attributed to the fear of insufficient cooperation from the child to complete the adjustment or to potential anesthetic or surgical risk during adjustment. In addition, it has frequently been asserted that the percentage of children that require adjustment after strabismus surgery is small enough that anesthesia and further manipulation are not warranted.

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Chan et al[3] described 89 consecutive patients, aged 7 to 15 years, who had strabismus surgery with adjustable suture techniques, with 27% being adjusted. The success rate was 74%. Dawson et al[4] reported a success rate of 76% in a series of 45 selected patients. Engel and Rousta[5] used an adjustable technique in a younger age group and showed a success rate of 88%, reflecting excellent short-term eye alignment. The main disadvantage of these studies was the lack of a control group to confirm an improved outcome in children with adjustable sutures versus nonadjustable sutures in the same surgeon's hands.

In a preliminary study, we assessed the success rate of 97 children who had eye muscle surgery with an adjustable technique compared with a matched group who had surgery with a nonadjustable technique. The success rate, defined then as alignment within 10^{Δ} of orthophoria, was notably greater in the adjustable group (85%) versus the nonadjustable group (75%).

To assess the possible advantage of adjustable strabismus surgery in children, we conducted an extensive retrospective controlled study to determine whether an adjustable technique under either topical proparacaine or intravenous propofol anesthesia, as compared with the standard nonadjustable technique, can improve the success rate of horizontal strabismus surgery in children.

Methods

The study protocol was approved by the Johns Hopkins Medicine Institutional Review Boards, with waiver of informed consent granted for this retrospective study. The study and data

collection were compliant with the Health Insurance Portability and Accountability Act of 1996.

A retrospective study was conducted of all children aged 10 years and under who had horizontal muscle surgery by the senior author (DLG) from 1990 through 2005 at our institution, a regional strabismus referral center. From 1990 to 1993 the vast majority of these surgeries were performed with the use of nonadjustable techniques. Starting in 1994, such surgeries were performed with the use of an adjustable technique exclusively at all ages.

All children who had unilateral or bilateral horizontal muscle surgery were included in the study, regardless of the complexity of the case. Patients who had vertical or oblique muscle surgery at the same time as the horizontal eye muscle surgery were also included in the study, but only the horizontal component was analyzed. Patients were included in the study only if they had a minimum postoperative follow-up of 3 months.

Exclusion criteria included children with restrictive strabismus, myasthenia gravis, paralytic strabismus, or a missing extraocular muscle. In addition, children who had eye muscle surgery for correction of a compensatory head posture associated with nystagmus or Duane syndrome were excluded from the study because of the difficulty of interpreting the success rate in terms of alignment of the eyes.

We analyzed the preoperative measurements, type of strabismus, and postoperative results. The angle of deviation was measured by the prism and alternate cover test for both distance and near with the full cycloplegic correction in place. In instances in which the angle of deviation could not be measured with the prism and alternate cover test, the Krimsky prism reflex method was used. For esotropic patients, the preoperative and postoperative angles of deviation were calculated for each subject as the mean of the distance and near angles if measured by the prism and alternate cover test, or simply as the Krimsky measurement if measured only at near. For exotropic patients, the distance angle was taken as the angle of deviation. A plus sign (+) was assigned to an esotropic angle, and a negative sign (−) was assigned to an exotropic angle. The measurements were mostly taken by certified orthoptists as a part of their routine clinical evaluation.

All patients with hyperopia of more than + 2.00 D were prescribed the full cycloplegic correction. All patients with amblyopia had treatment begun before surgery.[6] All surgeries were performed under general inhalational anesthesia and with the use of a cul-de-sac conjunctival incision. For recessions, the muscle was hooked and then secured with a double-armed suture before disinsertion. The muscle was then reattached to the sclera with a "hang-back" technique.[7,8] For resections, 2 mm was added to the intended amount of resection. The muscle was then secured to the globe, allowing it to hang back approximately 2 mm from the original insertion to allow for either advancement or recession of the muscle at the time of adjustment, whichever was needed.

In the majority of cases, the muscle was sutured to the sclera with a 6-0 absorbable polyglactin 910 suture. For large recessions of the medial rectus muscle (more than 6 mm), the muscle was often sutured to the sclera with a nonabsorbable 6-0 polyester suture in an attempt to prevent muscle slippage.

Patients were divided into 1 of 2 groups according to whether adjustable or nonadjustable sutures were used. In the nonadjustable group, the muscle was attached with nonadjustable sutures (with hang-back technique for recessions and fixed directly to the sclera for resections). In the adjustable group, the muscle was attached using adjustable sutures as described above.

In the nonadjustable group, the muscle sutures for recessions were tied in place, allowing the muscle to hang-back from the original insertion the desired amount as taken from standard tables.[9] In the adjustable group, an adjustable noose was placed around the muscle sutures, and the ends of the noose were secured to each other with an overhand knot. The noose was placed so that the muscle hung back from the original insertion at the desired distance. In addition, a 6-0 polyester suture was placed twice through the sclera as a traction suture[9] for retraction of the conjunctiva during adjustment. If the surgery involved more than one muscle, either 1 or 2 muscles were reattached using adjustable sutures according to the surgeon's judgment. More commonly, in recent years, all rectus muscles have been placed on adjustable sutures.

In the adjustable group, the alignment of the eyes was assessed in the recovery room 1 to 2 hours after surgery using the cover–uncover and the alternating-cover tests at both distance and near, using an accommodative target, such as a small picture or a toy, at near. The magnitudes of the resulting shifts, with these cover tests, if any, were estimated. For infants, Hirschberg estimation was relied upon, using the corneal light reflexes. Topical proparacaine 0.5% was instilled in the eyes to assist in relief of pain and to facilitate examination. In rare instances with infants who refused to open their eyes for assessment during adjustment, the infant was held by the examiner and lifted up with the face of the infant toward the examiner, with the arms of the examiner fully extended. The arms of the examiner were then suddenly relaxed, so that the infant "dropped" toward the examiner a few inches. In practically all instances, the infant reflexively opened his or her eyes, allowing assessment of the alignment.

After the alignment of the eyes was assessed, the adjustment for children who were able to cooperate was done under topical proparacaine, and the alignment of the eyes was then rechecked before tying the sutures. In younger children, as well as in those who were unable to cooperate while awake, the adjustment, if needed, and the tying of the sutures were done under intravenous propofol anesthesia, 3 mg/kg ± 1 mg/kg initially. This was administered through the intravenous line left in place from the original surgery.

General goals of adjustment were to leave the esotropic patients within 4^{Δ} of straight and the exotropic patients overcorrected (esotropic) in the distance by 3^{Δ}-6^{Δ}, with diplopia beyond 4 to 5 feet. These criteria were based on our own clinical experience.

The amount that the muscle was repositioned during adjustment was based on the residual misalignment of the eyes. However, the degree of adjustment was also occasionally influenced by the age of the patient (larger adjustment was often needed, and tolerated, in older patients), the response to previous surgeries (less effect desired if there had been an unexpected overcorrection before), the type of surgery performed (recession vs

Table 1. Preoperative data for the 2 groups

	Age (years) (range)	Sex (% male patients)	Preop angle (PD) (mean ± SD)* (range)	Prior operation (%)	Intermittency (%)	Vertical deviation (%)†	Distance/near disparity (%)‡
Nonadjustable group (n = 98)	4.2 ± 2.4 (0.5-10.5)	45	28.9 ± 11.5 (10-90)	21 (21)	18 (18)	31 (32)	37 (38)
Esotropia (n = 66)	3.9 ± 2.4 (0.4-10.5)	35	29.5 ± 11.8 (10-60)	12 (18)	4 (6)	21 (32)	18 (27)
Exotropia (n = 32)	4.8 ± 2.3 (1.2-10.2)	53	27.8 ± 11.1 (10-60)	9 (28)	14 (44)	10 (32)	19 (59)
Adjustable group (n = 298)	4.7 ± 2.5 (0.2-10.7)	42	29.3 ± 11.8 (10-80)	95 (32)	68 (23)	83 (28)	68 (23)
Esotropia (n = 167)	4.4 ± 2.6 (0.5-10.7)	44	32.1 ± 13.8 (10-80)	40 (24)	15 (9)	45 (27)	38 (23)
Exotropia (n = 131)	5.2 ± 2.4 (0.2-10.4)	39	26.8 ± 9.5 (10-50)	55 (42)	53 (40)	38 (29)	30 (23)

PD, prism diopter.

*Distance angle in exotropia, average of distance and near angles in esotropia, with refractive correction.

†Significant A or V pattern, hypertropia, dissociated vertical deviation, or oblique muscle overaction requiring surgery.

‡Difference between the distance and near angle of more than $10^{\triangle}$.

Table 2. Adjustment and tying of sutures

	Adjusted because of		Not adjusted	Adjusted under topical proparacaine (%)	Adjusted under intravenous propofol (%)	Adjustment amount (mm)
	Undercorrection	Overcorrection				
Entire adjustable group	116 (39%)	73 (25%)	108 (36)	60 (20)	238 (80)	1.2 ± 0.5 (range, 0.5-4 mm)
Esotropia	70 (42%)	32 (19%)	64 (39)	27 (16)	140 (84)	1.1 ± 0.3 (range, 0.5-3 mm)
Exotropia	46 (35%)	41 (31%)	44 (34)	33 (25)	98 (75)	1.2 ± 0.5 (range, 0.5-4 mm)

resection, more overcorrection needed with resections than recessions), the original degree of adjustment performed (large re-recessions can lead to late overcorrections), and so forth, based our own clinical experience.

The immediate postoperative alignment of the eyes before adjustment, and the amount of adjustment done, were recorded. If the adjustment was performed on more than one muscle, the amount of adjustment was considered to be equal to the algebraic sum of the adjustment done on both muscles.

For both the adjustable and nonadjustable groups, the horizontal alignment of the eyes before and after surgery was analyzed. The early success rate, defined as alignment within 8^{Δ} of orthophoria at the end of 3 months, was tabulated in both groups. In addition, sensory measurements including the Worth 4-Dot test for fusion, and stereopsis assessment by the Titmus Stereo Fly and Randot Stereotest (Stereo Optical, Chicago, IL) were recorded both before and after surgery.

Differences in outcome were also stratified for patients with esotropia and exotropia between both groups. In addition, success rates were stratified for primary surgeries versus repeat surgeries.

Statistical analysis of the differences in the success rates between both groups was performed with the Fisher's exact test. Statistically significant differences between both groups with respect to age and the preoperative angle were analyzed using the paired *t*-test. Because of the historical nonconcurrent nature of the study design, linear least squares regression analysis was performed to assess if there were statistically significant trends in the success rates in both the nonadjustable and the adjustable groups. In addition, the success rate of the first 98 patients in the adjustable group was computed and compared with the nonadjustable group (n = 98) to provide a closer time-matched control, although experience with the adjustable technique in children was still relatively new.

Results

A total of 98 patients in the nonadjustable group and 298 patients in the adjustable group were included in our study. The mean age in the nonadjustable group was 4.2 ± 2.4 years (range, 0.5-10 years) at surgery. In the adjustable group, the mean age was 4.7 ± 2.5 years (range, 0.5-10 years) at surgery, with the difference in mean ages not being statistically significant ($p = 0.2$). The difference in the preoperative angle in both groups was not statistically significant ($p = 0.4$). A summary of the preoperative data of the 2 groups is presented in Table 1, including the age at surgery, sex, angle of horizontal misalignment, and the percentages of patients in each group with previous surgery, intermittency, accompanying vertical deviation, and distance/near disparity of greater than 10^{Δ}.

Adjustment

In the adjustable group, as detailed in Table 2, adjustment was made in 189 of 297 cases (64%), either because of an overcorrection (73 cases, 25%) or undercorrection (116 cases, 39%). The average amount of adjustment was 1.2 ± 0.5 mm (range, 0.5–4 mm). Only one child refused to open his eyes in spite of repeated attempts. In this child, the sutures were tied without adjustment. In the remaining 108 cases, the alignment of the eyes was satisfactory, and the sutures were tied off with no adjustment.

In 60 cases, the adjustment was made under topical proparacaine (20%). In the remaining 238 cases (80%), the child was briefly anesthetized with intravenous propofol.

Table 3. Success rates in the nonadjustable and adjustable groups

	Success rate, ≤ ±8 PD (%)	Undercorrection, number and rate (%)	Overcorrection, number and rate (%)	Postoperative angle, mean ± SD (PD)	95% confidence interval of postoperative angle (PD)
Nonadjustable group (n = 98)	63 (64.5)	14 (14)	21 (21.5)	−4.1 ± 11.8 (range, 55 to 20)	−1.7 to −6.4
Esotropia (n = 66)	41 (62)	6 (9)	19 (29)	3.9 ± 12.8 (range, −55 to 20)	−7.0 to −0.9
Exotropia (n = 32)	22 (69)	8 (25)	2 (6)	−4.4 ± 9.6 (range, −40 to 14)	−7.7 to −1.0
Adjustable group (n = 298)	236 (79)	37 (12)	25 (8)	−0.8 ± 9.3 (range, 40 to 35)	−1.8 to 0.3
Esotropia (n =167)	131 (78)	18 (11)	18 (11)	0.2 ± 10.3 (range, −0 to 35)	−1.4 to 1.8
Exotropia (n =131)	105 (80)	19 (15)	7 (5)	−2.2 ± 8.36	−2.6 to −0.8

PD, prism diopter.

Table 4. Statistical significance of the difference in postoperative outcome at 3 months

	Number and percentage of patients with alignment within 8^{Δ} of orthophoria		
	Nonadjustable (%)	Adjustable (%)	*p*-value
Entire group	63 (64)	236 (79)	<0.01
Esotropia	41 (62)	131 (78)	0.025
Exotropia	22 (69)	105 (80)	0.2

Table 5. Comparison of the adjustable vs nonadjustable success rates for primary surgeries and for reoperations

	Number and percentage of patients with alignment within 8^{Δ} of orthophoria		
	Nonadjustable (%)	Adjustable (%)	
Entire group			
Primary	53/77 (69)	167/202 (83)	$p = 0.01$
Re-op	10/21 (48)	69/96 (72)	$p = 0.04$
	$p = 0.07$	$p = 0.03$	
Esotropia			
Primary	35/54 (64)	103/126 (82)	$p = 0.02$
Re-op	6/12 (50)	28/41 (68)	$p = 0.31$
	$p = 0.34$	$p = 0.07$	
Exotropia			
Primary	18/23 (78)	64/76 (84)	$p = 0.53$
Re-op	4/9 (44)	41/55 (75)	$p = 0.11$
	$p = 0.06$	$p = 0.17$	

No complication was encountered with the use of intravenous propofol. In the group given topical proparacaine, the mean age tended to be significantly greater (6.5 years) compared with those given intravenous propofol (4.21 years; $p < 0.001$).

Three-Month Follow-Up

Success rates are detailed in Tables 3 and 4. In the nonadjustable group, satisfactory horizontal alignment was achieved in 64.5% at the end of the third month. Undercorrection occurred in 14%, and overcorrection in 21.5%. In the adjustable group, satisfactory horizontal alignment was achieved in 79% of patients at the end of the third month. Undercorrection occurred in 12% and overcorrection in 8%. The greater success rate in the adjustable group compared with the nonadjustable group was statistically significant ($p < 0.01$). When comparing the success rate for esotropic patients between the 2 groups, it was still greater in the adjustable group (78% vs 62%, $p = 0.025$). On the other hand, although the success rate was greater in the adjustable group for exotropic patients than in the nonadjustable group (80% vs 69%), the difference was not statistically significant ($p = 0.20$), possibly because of the relatively smaller number of exotropic patients in the nonadjustable group.

In addition, the mean postoperative angle was lower in the adjustable group compared with the nonadjustable group (-0.8^{Δ} vs -4.1^{Δ}; Table 3). The 95% confidence interval of the 3-month alignment was both narrower and closer to orthophoria in the adjustable group (-1.8^{Δ} to 0.3^{Δ}) compared with the nonadjustable group (-1.7^{Δ} to -6.4^{Δ})

When analyzed separately for primary surgeries and for reoperations (Table 5), the success rate was greater in each adjustable group than in the comparable nonadjustable group, reaching statistical significance for the entire group of primary surgeries ($p = 0.01$), the entire group of reoperations ($p = 0.04$), and for the group of primary surgeries for esotropia ($p = 0.02$).

As also shown in Table 5, the success rate for reoperations was always lower than for primary surgeries, whether nonadjustable or adjustable surgery was used. This difference reached statistical difference only for the entire group of adjustable cases (reoperations were 11% points less successful that primary surgeries [$p = 0.03$]).

Although postoperative complications such as suture reactions, discomfort, slipped muscles, and so forth, were not specifically tabulated, we had no impression that these were different in frequency between the 2 groups.

Stereoacuity

Stereoacuity was considered as an indication of the functional outcome of the alignment of the eyes. The number of patients who had any measurable stereopsis on the Titmus Stereo Fly test at 3 months postoperatively was determined in both groups. Sixty-five percent of the children in the adjustable group had at least some measurable stereopsis compared with 63% in the nonadjustable group. This small difference was not statistically significant.

Learning Trend

Linear least squares regression analysis showed a positive trend—suggesting an improvement in success rate over time—in both the nonadjustable and adjustable groups, with regression coefficients of 0.16 and 0.18, respectively. However, neither of these was statistically significant.

When we analyzed the first 98 patients in the adjustable group, the success rate was found to be 75%. This figure was notably greater than the 64% in the nonadjustable group, but the difference missed statistical significance ($p = 0.08$). Again, the final success rate in the overall adjustable group of 298 patients was 79%.

Discussion

To justify the use of adjustable sutures in children, there should be both a better outcome and no increase in the complication rate. The results of our study satisfy both criteria, showing that adjustable suture strabismus surgery in children has a statistically better outcome than nonadjustable strabismus surgery, and we encountered no notable complications during the adjustment procedure. These positive factors, including the potential for fewer surgeries required and better chances for binocular function provided by earlier surgical alignment, should be positive enough to outweigh the disadvantages of extra time required for the procedure, the small risk from the propofol anesthesia when needed, any emotional trauma to the patients or to their parents from the procedure itself, the extra anesthesia cost and operating facility costs, and so forth. Such an analysis, however, is well beyond the scope of this study and deserves an entire investigation by itself, with data from multiple surgical practices.

Those who argue against the use of adjustable sutures in children typically object that children will not cooperate sufficiently after surgery to allow examination and/or manipulation. Patients may experience nausea, pain, and/or a potentially dangerous vasovagal reflux. Examination and manipulation may either interfere with the attachment of the muscle or may result in failure and termination of the needed procedure.

To facilitate examination and manipulation after surgery, a number of maneuvers have been recommended. In conscious children, Chan et al[3] recommend delaying the adjustment until the following day to allow better cooperation and to minimize the discomfort and nausea associated with adjustment. They minimized manipulations by adjusting only one muscle, avoiding the use of a lid speculum, and giving the child short periods of rest during adjustment. They used a limbal conjunctival approach, however, which in our experience is associated with more postoperative discomfort than the cul-de-sac approach. Surgeons used adjustment in the immediate postoperative period have tended to recommend either using sub-Tenon's ropivacaine to minimize the postoperative pain[10] or conscious sedation or anesthesia using midazolam or propofol.[11,12]

Another way to minimize maneuvers is to use one of several optionally adjustable techniques. Saunders and O'Neil[13] describe a way to avoid tying the knot for those who do not need adjustment. After passing the muscle sutures through the original scleral insertion, the sutures were used to make a second scleral pass in the sclera close to the limbus. They then tied a single overhand knot in each suture at a distance from the exit site equal to the desired amount of recession. The relatively large size of the overhand knot prevented posterior sliding of the sutures through the scleral tunnels. The main disadvantage of their technique, however, was that the suture ends had to be trimmed and buried under the conjunctiva even for those who did not need adjustment. And for those who needed adjustment, an extra maneuver had to be done to allow for adjustment. Using a similar technique, Engel and Rousta[5] describe a way to avoid manipulation entirely for children who do not need adjustment. After tying a sliding noose around the muscle sutures, the muscle sutures were used to make partial thickness scleral passes in the area of the fornix, leaving an additional 6-7 mm of suture length between the noose and the second scleral passes. The muscle sutures were then tied after this second scleral pass, and the ends were trimmed and buried. Tying of the sutures after the second pass secured the muscle, preventing slippage. Only children who needed adjustment required exploration of the incision. This was believed to be an advantage because the majority of children did not require adjustment.

Coats[14] has described an all-or-nothing technique in which he passed a "ripcord" suture around the muscle suture, pulling the muscle forward about 2 mm. The ripcord suture could simply be cut in those who were undercorrected, giving an additional 2 mm of recession. In those with good alignment, the ripcord suture was left in place. Hakim et al[15] describe a modification of this technique using a releasable suture, removal of which gives additional recession. But again, this all-or-nothing technique could only add extra recession but no advancement.

In our study, we used either topical proparacaine or intravenous propofol according to the clinical situation and the cooperation of the child. In all except one case, alignment of the eyes could be checked, and misalignment could be estimated with reasonable confidence. Adjustment was done in 64% of cases. This is counter to the previous reports that the majority of children do not require adjustment.[3] The greater adjustment rate in our study may reflect our tendency to perform bolder surgery when using adjustable sutures, knowing that initial overcorrections could be reversed. Also the rate may be higher because we included all consecutive eligible children in our study, even difficult reoperations and those combined with vertical surgery. And possibly because we were more comfortable in performing the procedure than other authors, we adopted a lower threshold for adjusting.

In our patients, postoperative pain was lessened with the use of cul-de-sac incisions with buried suture knots. Top-

ical proparacaine was used during adjustment. For those who had adjustment done under topical anesthesia, we rarely used a lid speculum. An assistant held the lids open with one hand, while pulling gently on the traction sutures with a forceps in the other hand to retract the conjunctiva and expose the sliding noose. Care was taken to avoid touching the lid margins with the traction sutures, which can irritate and frighten the patient. After being tied, the ~4 mm muscle suture ends were buried under the conjunctiva. The actual adjustment process generally required less than 5 minutes.

Another potential reason for not using adjustable sutures in children is uncertainty whether the alignment achieved during adjustment will persist.[16] Although the alignment can certainly change postoperatively, we see no reason why this should happen in children any more than in adults. Improved results in children, at least at 3 months' follow-up, have been confirmed in our study.

The percent success in our study is comparable to the percentages reported by Chan et al[4] (74%), Dawson et al[5] (76%), and Engel and Rousta[5] (88%). Of interest, Bleik and Karam[17] have reported a statistically significant change from the immediate postoperative alignment to alignment after 24 hours. However, they took the immediate postoperative measurements 7-22 minutes after surgery. It is also our impression that measuring so soon postoperatively is not accurate.

Another common conviction is that strabismus surgery in children is straightforward and does not benefit from postoperative adjustment. Our results suggest otherwise. Adjustable surgery also potentially reduces the need for reoperation. Although the reoperation rate was lower in our adjustable group than the nonadjustable group, we did not have complete enough long-term data to make this comparison meaningful.

In our study, intravenous propofol was not associated with any notable side effects, other than a mild burning sensation during its intravenous infusion, lessened by infusion of lidocaine immediately before. Our anesthesiologists quickly became comfortable with its use in the recovery room. In addition, recovery from propofol is usually fast and safe.

It is worth noting, however, that adjustable suture strabismus surgery in children requires extra time and staff as well as additional recovery room space. In addition, with intravenous propofol anesthesia, only a single adjustment can be made, unless the patient is put back to sleep a second time, which we have done only 3 times in the past 10 years. It was not practical to keep all patients in the recovery room after the first adjustment, with an intravenous line in place, in case a second adjustment was desired. We only did this when an unexpectedly large adjustment was necessary initially.

This is a large study of the use of adjustable sutures in children (298 cases) and includes a control series. Although the study was retrospective and nonrandomized, we have tried to minimize selection bias by including all consecutive eligible patients who were operated in the time period specified. In addition, all surgeries, both study and control ones, were performed by the same experienced surgeon. Still, the nonconcurrent nature of the study design may render it subject to historical bias. The skill of the surgeon could have improved over time, although the positive learning curves that we calculated were not statistically significant. Prospective case–control studies are still needed to assess the long-term success rate of adjustable strabismus surgery versus nonadjustable surgery, in both straightforward horizontal cases as well as in reoperations and in complicated cyclovertical cases.

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