Improved Ocular Alignment with Adjustable Sutures in Adults Undergoing Strabismus Surgery

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Objective: To assess whether outcomes of strabismus surgery are improved by using the adjustable suture technique and to determine which subgroups of strabismus patients benefit most from the adjustable suture technique.

Design: A retrospective chart review.

Participants: A total of 535 adults who underwent strabismus surgery between 1989 and 2010.

Methods: Success was defined as ≤10 prism diopters (PD) for horizontal deviations and ≤2 PD for vertical deviations. Differences in the proportion of successful strabismus surgery were analyzed using a chi-square test with an alpha of 0.05.

Main Outcome Measures: Ocular alignment in primary position at a 7-day to 12-week follow-up examination.

Results: A total of 491 patients met the inclusion criteria (nonadjustable suture, n = 186; adjustable suture, n = 305). The success rates for the nonadjustable and adjustable groups were 61.3% and 74.8%, respectively (χ^2=9.91, P=0.0016). Adjustable suture use was particularly beneficial for patients undergoing a reoperation for childhood strabismus (success rate: nonadjustable, 42.4%; adjustable, 65.7%; P=0.0268; n = 100). The differences in outcomes were not statistically significant for patients with childhood strabismus undergoing a primary surgery (nonadjustable, 65.0%; adjustable, 81.4%; P=0.1354; n = 90) or with thyroid orbitopathy (nonadjustable, 76.7%; adjustable, 74.1%; P=0.8204; n = 57).

Conclusions: Strabismus surgery using adjustable sutures was associated with improved short-term ocular alignment compared with strabismus surgery without the use of adjustable sutures. Adjustable sutures were most beneficial for patients undergoing reoperations for childhood strabismus.

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The prevalence of adult strabismus is estimated to be 4%.[1] Strabismus may be present in adults for a variety of reasons, including uncorrected or residual childhood strabismus, intracranial injury or disease, thyroid orbitopathy, impaired vision in 1 eye, and surgically induced trauma to the extraocular muscles. Strabismus in adults may be associated with diplopia, torticollis, impaired stereopsis, and negative psychosocial effects, which may negatively affect daily living and quality of life.[2,3] Strabismus surgery in adults has a high rate of success and has been shown to be beneficial in improving diplopia, binocular fusion, and psychosocial functioning.[3–6] Furthermore, adult strabismus surgery has been shown to be cost-effective, with a health value similar to that of cataract surgery.[7]

The use of adjustable sutures has been advocated to improve the outcome of strabismus surgery; however, its efficacy has not been established.[8] Although some case series have reported improved outcome using adjustable sutures, others have shown no benefit.[8–10] A recent Cochrane survey found no evidence to support the use of adjustable sutures when performing strabismus surgery.[8] We performed a retrospective study of more than 500 adults who had undergone strabismus surgery at one institution with and without adjustable sutures to determine whether the patients who underwent strabismus surgery using an adjustable technique had better outcomes than the patients who underwent nonadjustable surgery.

Materials and Methods

Subjects and Data Collection

A retrospective chart review was conducted on adults who underwent strabismus surgery at the Emory Eye Center between 1989 and 2010. Approval for the study was obtained from the Emory University Institutional Review Board. A list of adults who underwent strabismus surgery between 1989 and 2010 was generated using surgical logs and Current Procedural Terminology codes. A total of 629 charts were acquired for review based on availability; 94 patients were excluded for the following reasons: insufficient information in the chart, the strabismus was secondary to a congenital fourth nerve palsy, or the surgery was to correct congenital nystagmus rather than strabismus. We excluded patients with congenital fourth nerve palsies because they are generally treated with an inferior oblique recession, which is not amenable to the

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adjustable suture technique. Patients with acquired fourth nerve palsy were included in the study.

Three surgeons (SRL, AKH, AVD) performed all of the surgeries; 2 surgeons frequently used adjustable sutures, whereas the third surgeon used them infrequently. Several different adjustable suture techniques were used. One surgeon primarily used a "bow-tie" technique, and the other surgeons used a "cinch knot" technique. Surgery was carried out using regional anesthesia, conscious sedation, or general anesthesia. Regional anesthesia was primarily used for the first few years of the study, whereas general anesthesia was primarily used for the last 15 years of the study. The majority of the muscles placed on adjustable sutures were recessed. Patients who underwent the adjustable suture technique had the adjustment performed on the same day or the following day, using topical 0.5% proparacaine instilled before adjustment.

Case report forms (CRFs) were completed for each patient. Each patient was de-identified and assigned an identification number. If the patient had more than 1 preoperative examination, the examination temporally closest to the surgery or the examination with the most complete information was used for the analysis. The following clinical information was recorded on the preoperative CRF: best-corrected visual acuity, versions, cause of strabismus, ocular comorbidities, type of strabismus, previous surgical treatment, and if there was a reason for excluding the patient from the adjustable procedure. Preoperative deviations in primary, near, and downward gaze were recorded. We did not exclude patients who had both horizontal and vertical deviations. The surgery CRF detailed the surgical procedure, use of adjustable suture and amount adjusted, and any intraoperative complications. For this study, we only looked at the initial strabismus surgery that each patient had at our institution; we did not look at any subsequent surgeries they may have had at Emory University.

Information from the initial follow-up examination was recorded on postoperative CRFs. The initial follow-up examination ranged from 7 days to 12 weeks. We used the examination between 2 and 4 weeks for the initial follow-up if it was available or if there were multiple follow-up examinations between the 7-day to 12-week period because it was the most consistent initial follow-up period among the 3 surgeons. The initial follow-up CRF detailed postoperative parameters, such as best-corrected visual acuity; any postoperative complications; and ocular alignment in primary, near, and downgaze. The appropriate forms for each patient were faxed, validated, and stored in the DataFax System.

Statistical Analysis

We chose to focus on the success of ocular alignment in the distance in primary gaze because it was the most consistently recorded data point, and the goal of most strabismus surgeries is to achieve acceptable alignment in primary gaze. Before starting the chart review, success, based on ocular alignment in primary gaze position, was defined as $\leq$10 prism diopters (PD) for horizontal deviations and $\leq$2 PD for vertical deviations as they have been defined in previous studies.[1,11,12] Patients who only had a dissociated vertical deviation at follow-up examinations were considered orthotropic because dissociated vertical deviations are usually a latent phenomenon. The means and percentages for patient characteristics were compared across adjustable suture groups using the Student *t* test and chi-square test. Differences in the proportion of successful strabismus surgery were analyzed using the chi-square test. The chi-square test was used to compare the success rate of all those surgeries performed without adjustable sutures with those performed with adjustable sutures. Statistical calculations were performed using SAS software (SAS Inc., Cary, NC), and statistical significance was set as a 2-sided *P* value of 0.05.

Subgroup Analysis

We conducted analyses on subgroups that met the 7-day to 12-week inclusion criteria. For our subgroup analyses, we focused on the causes with the greatest number of patients: childhood-onset strabismus undergoing a primary surgery, childhood-onset strabismus undergoing a reoperation, and thyroid orbitopathy. We did not perform a subgroup analysis on patients with strabismus arising from multiple causes (e.g., childhood strabismus and thyroid orbitopathy) to minimize confounding factors. Differences in the proportion of successful strabismus surgery for the childhood strabismus group undergoing a primary surgery were analyzed using the Fisher exact test. Differences in the proportion of successful strabismus surgery for the other subgroups were analyzed using a chi-square test.

Histograms

Histograms were created using the vertical and horizontal deviation measurements that were available for all 491 patients. These measurements were taken from the postoperative visit closest to 4 weeks for the adjustable and nonadjustable groups.

Results

Preoperative Results

A total of 535 patients met the initial inclusion criteria. Of these patients, 491 had ocular alignment in primary gaze recorded in the chart during the 7-day to 12-week postoperative follow-up period. There were 285 women and 206 men. The predominant causes included childhood strabismus, trauma, thyroid orbitopathy, vision loss, retinal detachment surgery, cerebral vascular accidents, and myotoxicity from regional anesthesia (Table 1). The total number of causes listed exceeds 535 because some of the patients fit into multiple categories (e.g., a patient with a traumatic cause may have also had a cranial nerve palsy). The 79 patients in the "miscellaneous" category had causes that included chronic progressive external ophthalmoplegia, arteriovenous malformations, meningiomas, brainstem tumors, and aneurysm clippings. The patients were also divided into groups based on the type of deviation they had: esotropia, exotropia, hypertropia, or combined horizontal and vertical deviations. Within the nonadjustable group, 22.5% had an esotropia only and 19.3% had an exotropia only. Within the

Table 1. Causes of Strabismus

Cause	No.
Childhood strabismus	210
Trauma	105
Thyroid orbitopathy	68
Cranial nerve VI palsy	37
Vision loss	31
Retinal detachment surgery (with or without scleral buckle placement)	27
Cranial nerve III palsy	24
Cerebrovascular accident	20
Cranial nerve IV palsy (noncongenital)	17
Myotoxicity from local anesthesia	12
Duane syndrome	9
Glaucoma shunt surgery	5
Brown syndrome	1
Miscellaneous	79

Table 2. Preoperative Alignment in Primary Position

Alignment Type	Nonadjustable Group	Adjustable Group
ET only		
No. of patients	n = 42	n = 74
Amount (average PD)	$41^{\Delta}\pm22^{\Delta}$ (range, 10–95)	$34^{\Delta}\pm18^{\Delta}$ (range, 12–110)
XT only		
No. of patients	n = 36	n = 68
Amount (average PD)	$40^{\Delta}\pm22^{\Delta}$ (range, 4–95)	$39^{\Delta}\pm19^{\Delta}$ (range, 5–90)
Vertical deviation only		
No. of patients	n = 16	n = 20
Amount (average PD)	$15^{\Delta}\pm8^{\Delta}$ (range, 5–35)	$12^{\Delta}\pm5^{\Delta}$ (range, 2–25)
Horizontal and vertical deviation combination		
Horizontal ET		
No. of patients	n = 38	n = 48
Amount (average PD)	$25^{\Delta}\pm20^{\Delta}$ (range, 2–90)	$24^{\Delta}\pm17^{\Delta}$ (range, 1–85)
Horizontal XT		
No. of patients	n = 51	n = 84
Amount (average PD)	$34^{\Delta}\pm23^{\Delta}$ (range, 2–90)	$29^{\Delta}\pm16^{\Delta}$ (range, 2–65)
Vertical		
No. of patients	n = 89	n = 132
Amount (average PD)	$12^{\Delta}\pm15^{\Delta}$ (range, 1–90)	$12^{\Delta}\pm11^{\Delta}$ (range, 1–60)

ET = esotropia; PD = prism diopter; Δ = prism diopter; XT = exotropia.

adjustable group, 15.0% had an esotropia only and 13.8% had an exotropia only. We believe that this balance of patients with esotropia only and exotropia only within each group is important, because there may be an improved outcome with strabismus surgery for patients with esotropia compared with patients undergoing strabismus surgery for an exotropia. For the nonadjustable group with only a horizontal or vertical deviation, the mean preoperative deviations were esotropia, 41 PD; exotropia, 40 PD; and hypertropia, 15 PD. In the adjustable group with only a horizontal or vertical deviation, the mean preoperative deviations were esotropia, 34 PD; exotropia, 39 PD; and hypertropia, 12 PD. For those with a combined horizontal and vertical deviation in the nonadjustable group, the mean preoperative horizontal and vertical deviations were esotropia, 25 PD; exotropia, 34 PD; and hypertropia, 12 PD. For those with combined horizontal and vertical deviation in the adjustable group, the mean preoperative deviations were esotropia, 24 PD; exotropia, 29 PD; and hypertropia, 12 PD (Table 2).

Surgery Results

Of the 491 patients analyzed, 305 underwent surgery when at least 1 muscle was put on an adjustable suture and 186 underwent surgery without adjustable sutures. A total of 174 women and 131 men underwent surgery using adjustable sutures, and 111 women and 75 men underwent surgery without adjustable sutures (χ^2=0.3277, P=0.5670). The mean age at surgery for the adjustable group was 45.0 years (range, 12.4–85.7 years) versus 45.4 years (range, 12.4–88.1 years) for the nonadjustable suture group (t test=0.26, P=0.7922). Of the 305 patients who underwent surgery using the adjustable suture technique, 251 (82.3%) subsequently needed adjustment postoperatively. In most cases, the use of adjustable sutures was dictated by surgeon preference. However, in 17 patients (3.46%), adjustable sutures were not used because of patient preference, poor patient cooperation, or intraoperative findings that would preclude the use of an adjustable suture. The intraoperative complications for the nonadjustable group included 2 corneal abrasions, 2 cases of ptosis, 1 case of conjunctival laceration, and 1 case of postoperative bleeding. In the adjustable group, there were 11 cases of corneal abrasions, 5 cases of ptosis, and 1 conjunctival buttonhole.

Initial Postoperative Follow-up

The initial follow-up examination ranged from 7 days to 12 weeks. The mean follow-up time was 33.8 days for the nonadjustable surgery group and 32.7 days for the adjustable group. The success rates for the nonadjustable and adjustable groups were 61.3% and 74.8%, respectively (χ^2=9.91, P=0.0016) for the 7-day to 12-week follow-up period. The difference in success rate among the 3 surgeons was not statistically significant (P=0.5594). The mean postoperative deviations for the nonadjustable group at the initial follow-up examination were esotropia, 10 PD; exotropia, 18 PD; and hypertropia, 8 PD. The mean postoperative deviations for the adjustable group at the initial follow-up examination were esotropia, 8 PD; exotropia, 13 PD; and hypertropia, 5 PD. For those with combined horizontal and vertical deviation in the nonadjustable group, the mean deviations were esotropia, 13 PD; exotropia, 14 PD; and hypertropia, 11 PD. For those with combined horizontal and vertical deviation in the adjustable group, the mean deviations were esotropia, 10 PD; exotropia, 14 PD; and hypertropia, 8 PD (Table 3).

Figures 1 and 2 show histograms comparing postoperative ocular deviations for horizontal and vertical deviations, respectively, for the adjustable and nonadjustable groups in 5-PD bins. For horizontal deviations, there is a higher percentage of patients in the orthotropic, 5-PD, and 10-PD bins in the adjustable group compared with the nonadjustable group. Although there is a small percentage of patients in the 25- and 30-PD bins, there are more extreme outliers in the nonadjustable group, including a patient with a 90-PD deviation. For vertical deviations, there is also a higher percentage of patients in the orthotropic and 5-PD bins in the adjustable group. In addition, aside from 1 extreme outlier, there are fewer extreme outliers in the adjustable group compared with the nonadjustable group.

The postoperative complications for the nonadjustable group at the initial follow-up examination included 1 case each of cellulitis, conjunctival inclusion cyst, dellen, conjunctival ab-

Table 3. Postoperative Alignment in Primary Position

Alignment Type	Nonadjustable Group	Adjustable Group
ET only		
No. of patients	n = 21	n = 41
Amount (average PD)	$10^{\Delta}\pm5^{\Delta}$ (range, 2–20)	$8^{\Delta}\pm8^{\Delta}$ (range, 1–40)
XT only		
No. of patients	n = 26	n = 32
Amount (average PD)	$18^{\Delta}\pm19^{\Delta}$ (range, 1–95)	$13^{\Delta}\pm8^{\Delta}$ (range, 1–35)
Vertical deviation only		
No. of patients	n = 13	n = 28
Amount (average PD)	$8^{\Delta}\pm9^{\Delta}$ (range, 1–35)	$5^{\Delta}\pm5^{\Delta}$ (range, 1–25)
Horizontal and vertical deviation combination		
Horizontal ET		
No. of patients	n = 28	n = 22
Amount (average PD)	$13^{\Delta}\pm13^{\Delta}$ (range, 2–60)	$10^{\Delta}\pm6^{\Delta}$ (range, 1–20)
Horizontal XT		
No. of patients	n = 24	n = 30
Amount (average PD)	$14^{\Delta}\pm19^{\Delta}$ (range, 1–90)	$14^{\Delta}\pm23^{\Delta}$ (range, 1–134)
Vertical		
No. of patients	n = 52	n = 52
Amount (average PD)	$11^{\Delta}\pm14^{\Delta}$ (range, 1–90)	$8^{\Delta}\pm5^{\Delta}$ (range, 1–30)

ET = esotropia; PD = prism diopter; Δ = prism diopter; XT = exotropia.

scess, traumatic mydriasis, ectropion, and pyogenic granuloma. The postoperative complications for the adjustable group included 4 cases of suture granulomas and 1 case each of cellulitis, conjunctival inclusion cyst, eyelid retraction, pyogenic granuloma, and spastic entropion.

Subgroup Analyses

Childhood Strabismus. There were 90 patients with childhood strabismus only who had not undergone previous surgery and 100 patients with childhood strabismus only who had undergone previous strabismus surgery. In the group undergoing primary surgery, the success rate was 65.0% in the nonadjustable group and 81.4% in the adjustable group (P=0.1354). In the group undergoing a reoperation, the success rate was 42.4% in the nonadjustable group and 65.7% in the adjustable group (χ^2=4.91, P=0.0268) (Table 4).

Thyroid Orbitopathy. There were 57 patients with thyroid orbitopathy who underwent strabismus surgery: 27 with the adjustable technique and 30 with the nonadjustable technique. The success rates were 76.7% for the nonadjustable group and 74.1% for the adjustable group (χ^2=0.05, P=0.8204). Of 57 patients, 54 were undergoing a primary operation and 3 were undergoing a reoperation. The reoperation group was not sufficiently large to

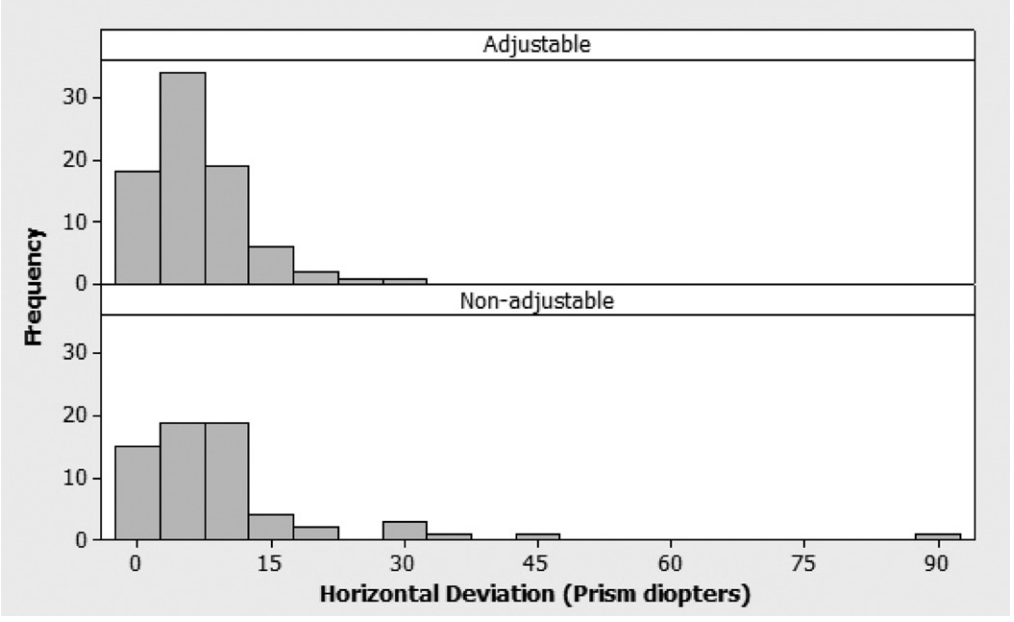

Figure 1. Histogram of horizontal deviations in 5 prism diopters bins for adjustable (*top*) and nonadjustable (*bottom*) groups.

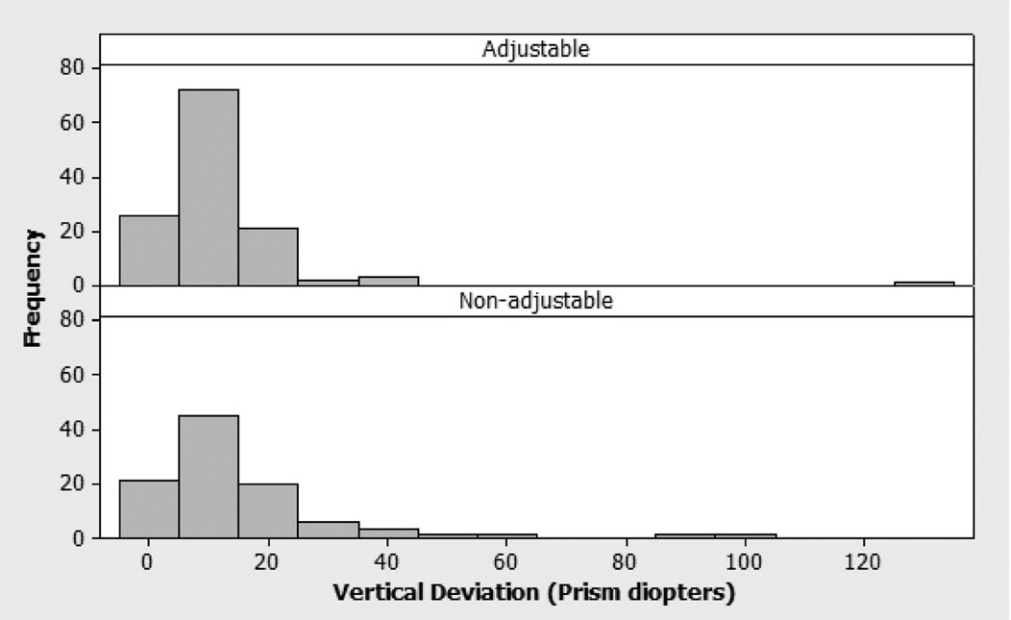

Figure 2. Histogram of vertical deviations in 5 prism diopters bins for adjustable (*top*) and nonadjustable (*bottom*) groups.

conduct a test of significance to compare the outcome between primary operations and reoperations (Table 4).

Discussion

Overall, we observed a statistically significant difference in the proportion of patients who have a successful surgical outcome as defined in this study. Patients who underwent strabismus surgery using adjustable sutures were more likely to have a successful outcome than patients who underwent surgery using a nonadjustable technique, as determined at the 7-day to 12-week follow-up period. The success rate improved from 61.3% to 74.8% when adjustable sutures were used. A high percentage of patients in the adjustable group received postoperative adjustment (82.3%). This is a higher percentage than what has been reported by Velez et al[13] (45%), Bishop and Doran[10] (54%), and Tripathi et al[9] (69.5%). This may reflect differences in our surgical nomograms, surgical techniques, or patient selection. The adjustable technique was particularly helpful in patients with childhood-onset strabismus undergoing a reoperation. In this group, the success rate in aligning the patient within 10 horizontal PD or 2 vertical PD of orthotropia in primary position increased from 42.4% to 65.7% when adjustable sutures were used—a statistically significant difference. Although we found an improved success rate with adjustable sutures in patients with childhood-onset strabismus undergoing their first operation, the difference was not statistically significant. We did not find any improvement in the ocular alignment of patients with thyroid orbitopathy using the adjustable suture technique. The combined intraoperative and postoperative rates of complications for the nonadjustable and adjustable groups were 7.0% and 8.5%, respectively. These rates, however, may not include all complications, because some minor complications (e.g., conjunctival buttonholes and tears) were not always documented. There were no vision-threatening complications in either treatment group.

Strabismus in adults can be challenging to correct with surgery. The success of this procedure may be improved with the use of adjustable sutures. Previous studies have shown that the use of adjustable sutures may be particularly beneficial for certain types of strabismus. Currie et al[14] reported a success rate of 77% in 26 adults after surgical correction of large-angle exotropias using the adjustable suture technique. Keech and Heckert[11] reported a success rate of 78% in a cohort of 51 patients who underwent strabismus surgery with adjustable sutures for acquired vertical deviations. Keech et al[15] reviewed 333 patients who had undergone strabismus surgery using the adjustable su-

Table 4. Success Rates by Group

Group	Nonadjustable Group (n)	Nonadjustable Group Success (%)	Adjustable Group (n)	Adjustable Group Success (%)	*P*
Overall	186	61.3%	305	74.8%	0.0016
Childhood strabismus—reoperation (n = 100)	33	42.4%	67	65.7%	0.0268
Childhood strabismus—primary operation (n = 90)	20	65.0%	70	81.4%	0.1354
Thyroid orbitopathy (n = 57)	30	76.7%	27	74.1%	0.8204

ture technique and proposed that the use of adjustable sutures was most helpful for patients with vertical and complex deviations.

We found the adjustable suture technique to be most helpful in patients with childhood strabismus undergoing reoperations. This is not surprising because the success rate of strabismus surgery is generally acknowledged to be lower with reoperations. Weston et al[12] reported a lower success rate for patients with esotropia or exotropia undergoing reoperations (81% and 74%, respectively) compared with patients undergoing primary surgeries (88% for both groups). We also found that patients with childhood strabismus undergoing a reoperation (nonadjustable group, 42.4%; adjustable group, 65.7%) had a lower success rate than patients undergoing a primary operation (nonadjustable group, 65.0%; adjustable group, 81.4%). The lower success rate associated with reoperations likely arises from many factors, including postoperative adhesions and a selection bias for deviations that are less amenable to accurate surgical alignment.[16,17]

Our histograms of postoperative ocular deviations for both vertical and horizontal deviations show that there was a higher percentage of patients who were orthotropic or had only a small postoperative deviation in the adjustable group. In addition, there were fewer outliers in the adjustable group compared with the nonadjustable group. This was particularly true for vertical deviations. The improved mean ocular alignment in the adjustable group therefore reflects a reduction in the number of outliers and a higher percentage of patients who had excellent alignment.

We found a nearly identical success rate for the adjustable and nonadjustable groups in patients with thyroid eye disease. Lueder et al[18] followed 47 patients with thyroid orbitopathy treated with adjustable sutures for a mean of 41 months. Of those patients, only 47% had an "excellent" outcome, defined as the resolution of their double vision in the primary and reading positions without the use of prisms. It is difficult to compare our success rate with that reported by Lueder et al,[18] because we used a different definition of "success." Thyroid eye disease typically has a restrictive component that may limit surgical options and postoperative attempts to adjust muscle placement. Postoperative changes from inflammation or disease flare further contribute to making surgical outcomes less predictable. Fawcett et al[19] determined that a shorter duration of constant eye misalignment and the presurgical capacity for binocularity are the factors most predictive of the restoration of macular binocular vision for adults with acquired strabismus. Because thyroid eye disease is an acquired form of strabismus that begins after binocular visual maturation, compared with most forms of childhood strabismus, the excellent fusional potential of these patients may allow them to overcome residual deviations that patients with poor fusion would not be able to control.

There were some limitations to our study. Because this was a retrospective, nonrandomized study, bias was inherently present. One of the surgeons performed strabismus surgery using adjustable sutures less frequently than the other 2 surgeons, which may have biased our results, particularly if 1 surgeon was consistently more or less successful than the other 2 surgeons in achieving a successful ocular alignment. To explore this confounding variable, we analyzed the success rate of the 3 surgeons independently of the surgical technique and did not find a statistically significant difference in outcomes. Because of time limitations, we were not able to analyze the medical record of every adult patient who underwent strabismus surgery at Emory University between 1989 and 2010. Instead, we randomly reviewed the medical records for a subset of patients who met our inclusion criteria. Ideally, we would have matched each patient in the adjustable group with one in the nonadjustable group. We also used a wide time interval for the initial follow-up examination, although the mean follow-up time was nearly equal between the 2 groups. Because of this, certain patients may have experienced more postoperative drift from the time of surgery until they were examined. Weston et al[12] found that most postoperative drift occurs within the first 8 weeks after surgery when adjustable sutures are used. Other studies have reported that strabismus surgery using fixed scleral sutures is associated with a longer duration of postoperative drift compared with strabismus surgery using adjustable sutures.[20,21] We did not look at success rates, changes in ocular alignment, and need for additional surgeries with a longer follow-up interval because there was not a consistent time point for long-term follow-up examinations. In addition, the sample sizes for our subgroups were small. Finally, we did not calculate the Intensity/Complexity Index of each surgery performed. The average surgical complexity of the nonadjustable and adjustable groups, as well as each subgroup, may have helped us determine whether it was an important parameter in the success of the surgeries. Preferentially using adjustable sutures in higher complexity cases may have created a selection bias that might argue against their efficacy because these cases are inherently less likely to succeed.

Given the retrospective nature of our study, we elected to define success solely on the basis of ocular alignment rather than on the elimination of diplopia or psychosocial considerations, because these factors were not consistently recorded in the chart pre- or postoperatively. Hatt et al[22] prospectively analyzed the responsiveness of 2 health-related quality of life (HRQOL) questionnaires, which address diplopia, motor function, and psychosocial functioning in adult patients with strabismus. Their results indicate that the questionnaires are indeed responsive to improved HRQOL in this patient population, particularly the 20-item Adult Strabismus questionnaire. These findings warrant the administration of HRQOL questionnaires pre- and postoperatively to establish a standardized and more comprehensive definition of a "successful" outcome based on both objective and subjective factors.

The decision to define ocular alignment $\leq$10 PD for a horizontal deviation and $\leq$2 PD for a vertical deviation as "successful" was somewhat arbitrary. Although this definition has been used in many other strabismus surgery studies, a definition based on physiologic considerations might be preferable.[1,11,12] For instance, Leske and Holmes[23] have reported that stereopsis is achieved more often if a patient has a horizontal deviation $\leq$4 PD. Perhaps a residual horizontal deviation of $\leq$4 PD would be a better end point

because it is based on the physiologic goal of stereopsis. Because we based our definition of success entirely on ocular alignment, it may not accurately reflect patients' perception of success. Many patients with what we defined as "unsuccessful" outcomes may have been happy with the outcome if their goal was to restore a more normal appearance to their eyes or to achieve better control of a large intermittent deviation. In contradistinction, other patients whom we defined as having a "successful" outcome may have been unhappy with the outcome if they still had diplopia or reduced stereopsis postoperatively. Although our results showed improved ocular alignment outcomes when adjustable sutures are used, potentially negative factors such as patient cooperation and discomfort during adjustment must be weighed against the benefits of their use. Testing patients' ability to tolerate conjunctival manipulation and assessing cooperation preoperatively may aid in determining which patients would be suitable candidates for adjustable suture use.

In conclusion, we found that strabismus surgery using adjustable sutures was associated with better short-term alignment compared with strabismus surgery using fixed sutures. Adjustable sutures were most helpful in patients undergoing reoperations for childhood strabismus. Prospective randomized clinical trials with longer follow-up periods and greater numbers of patients with particular causes are needed to further elucidate the potential benefits of strabismus surgery using adjustable sutures.

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