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Intraoperative Findings in Consecutive Exotropia With and Without Adduction Deficit

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Abstract

Purpose—Consecutive exotropia (XT) may be associated with limited adduction in the previously operated eye(s). Limited adduction has been reported to be caused by one or more anatomical abnormalities of medial rectus and lateral rectus muscles or their insertions. We studied the relative frequency of grades of adduction deficit and relative frequency of abnormal anatomical findings for each grade of severity of adduction deficit.

Design—Retrospective cohort study

Participants—Patients undergoing surgery for consecutive exotropia.

Methods—Preoperative duction deficits were graded on a –5 (severe limitation) to 0 (normal) scale. For each patient, operative reports were reviewed to classify intraoperative factors: 1) medial rectus attachment type (normal, abnormal [slipped or stretched scar], attached to pulley, behind pulley, or mixed [a tenuous normal attachment but with muscle fibers also attached to the pulley or behind the pulley]); 2) distal medial rectus fiber location (millimeters from original insertion); 3) lateral rectus tightness (normal, mild restriction, moderate restriction).

Main outcome measure—Relationship of grade of adduction deficit to each intraoperative factor.

Results—124 (87%) of 143 eyes (129 patients) had an adduction deficit. Eyes with abnormal (n=23), pulley (n=9), behind pulley (n=8), or mixed (n=7) attachments had worse adduction deficits than normal attachments (n=96) ($P<0.02$). There was a significant correlation between distal medial rectus muscle fiber location (0–19.5mm recessed) and grade of adduction deficit ($P<0.0001$). Eyes with mild or moderate lateral rectus tightness on forced duction testing

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(N=48/143 eyes) had worse adduction deficits than eyes without tightness ($P<0.001$). Nevertheless, despite overall correlation there was considerable individual variability. For example, for -1 and -2 adduction deficits, medial rectus attachment could be at the pulley, behind the pulley, or include the pulley (19 [22%] of 87), and the lateral rectus was tight in 36 (41%) of 87.

Conclusions—Adduction deficits are common in patients with consecutive XT. In general, more severe preoperative adduction deficits are associated with medial rectus insertion abnormalities and abnormal forced ductions, but there are frequent exceptions. Severe medial rectus insertion abnormalities, including lost muscles, may be found despite mild preoperative adduction deficits, which should be considered during surgical planning.

Graphical abstract

Précis

We found significant association between severity of adduction deficit and abnormal medial and lateral rectus muscle findings, in patients with consecutive exotropia. Nevertheless severe medial rectus insertion abnormalities may be found despite mild adduction deficits.

Consecutive exotropia (XT) is not uncommon following surgery for esotropia,¹ with a reported incidence of up to 27%² with long-term follow-up, and may be associated with limited adduction in the previously operated eye(s). Limited adduction may be caused by one or more anatomical abnormalities of medial rectus and lateral rectus muscles or their insertions, such as the presence of a slipped or lost medial rectus muscle³ or an abnormal muscle attachment,⁴ also referred to as a stretched scar.^{5, 6} Other causes of adduction deficit may be an excessively recessed medial rectus muscle or a contracted lateral rectus muscle. Each of these factors influences the surgical plan for a particular patient. Therefore it would be helpful to know prior to surgery whether a specific severity of adduction deficit is indicative of a specific anatomical abnormality of the medial rectus or lateral rectus.

The aim of this study was therefore to report the relative frequency of grades of adduction deficit and the relative frequency of abnormal anatomical medial rectus and lateral rectus muscle findings for each level of severity of adduction deficit.

Patients and Methods

The procedures used in this study conformed to the Declaration of Helsinki and were approved by the institutional review board at the Mayo Clinic, Rochester, Minnesota. All procedures and data collection were conducted in a manner compliant with the Health Insurance Portability and Accountability Act.

Patients

The medical and surgical records of patients undergoing surgery for consecutive XT by a single surgeon (JMH) between 1995 and 2016 were retrospectively reviewed. For this present study, we included patients with consecutive XT measuring ≥ 10 prism diopters (PD) by prism and alternate cover test (PACT) at distance fixation that developed after previous surgery for comitant esotropia. We only included eyes that had undergone previous medial

rectus recession and that were now undergoing medial rectus muscle advancement or resection for consecutive XT. This procedure was the surgeon's standard surgical approach for patients undergoing surgery for consecutive XT. Patients were included if they were undergoing medial rectus surgery, whether or not they were undergoing surgery on other extraocular muscles. Those undergoing first-time consecutive XT surgery and those undergoing surgery for recurrent consecutive XT surgery were both included. We excluded patients with paralytic strabismus (including cranial nerve palsies, internuclear or supranuclear disorders, gaze palsies), restrictive strabismus (including Graves' orbitopathy, blow-out fractures, Duane syndrome, Browns syndromes, post-scleral buckle surgery), ocular myasthenia gravis, and exotropia in the presence of retinal disease.

For patients undergoing bilateral surgery for consecutive XT, both eyes were included and analyzed separately, because we were interested in evaluating the relationship between variables for each eye independently, and we expected no interaction between the eyes for the variables of interest. Similarly, for patients undergoing repeat surgery for recurrent consecutive XT, each episode of surgery was included as a separate occurrence.

Preoperative grading of duction deficits—As part of the preoperative ocular motility examination, duction deficits were graded on a -5 to 0 scale, based on previously described grading systems.⁷⁻⁹ All grades of adduction deficit were included. A grading of -5 indicates the eye is unable to reach midline; -4, able to achieve midline but no further; -3, able to rotate past midline but 75% deficit; -2, able to rotate past midline but 50% residual deficit; -1, able to rotate past midline but 25% residual deficit; "trace" adduction deficit was defined as, less than -1 limitation of rotation, but duction incomplete (and was analyzed as -0.5); 0, full duction.

Type of medial rectus muscle attachment and location of true muscle fibers—The type of medial rectus muscle attachment was classified based on the operative report: 1) normal attachment to the sclera: medial rectus muscle fibers directly attached to the sclera; 2) abnormal attachment to the sclera:⁴ medial rectus muscle fibers not directly attached to the sclera but connected either by a thin translucent membrane or thick scar; 3) muscle fibers attached to the anterior portion of the pulley, but not the sclera; 4) mixed attachment - features of a tenuous normal attachment but with muscle fibers also attached to the anterior portion of the pulley or behind the pulley; 5) distal end of the muscle fibers found behind the pulley, but not attached to the pulley. Previous studies have differentiated between slipped muscle and stretched scar, describing them as separate clinical entities.^{5, 6, 10} Nevertheless we have reported⁴ that it can be difficult to clearly differentiate between these two conditions based on visual inspection alone, since some muscles contain features of both stretched scar and slipped muscle. Therefore for the purposes of this present study we combined what may be defined as stretched scar and slipped muscle and classified them both as "abnormal attachment." We did not submit the excised tissue for histologic examination.

Data on the location of the distal end of the medial rectus muscle fibers were also retrieved from the operative report and recorded in millimeters (mm) from the original insertion. For short distances e.g. <5 mm a caliper was used, and for longer distances a flexible plastic mm

ruler was used. If muscle fibers were located at the original insertion, the distance was recorded as 0 mm. When the location of the distal muscle fibers was recorded as inserted into the pulley but there was no record of the exact distance in mm from the insertion, we calculated the median of all available values for attachment to the pulley and imputed that value. When location of the distal muscle fibers was recorded as behind the pulley and there was no record of the exact distance, we imputed a value 1 mm more remote than the most extreme value for insertion into the pulley. This approach was adopted for behind pulley attachments because there were fewer available data from which to calculate a median value for insertions behind the pulley.

Where available we also collected data on the width of the medial rectus muscle. However, because muscle width data were not recorded for every patient and we did not feel we could assume normality unless otherwise stated, we planned to include these data for descriptive purposes only.

Lateral rectus tightness—Extraocular muscle tightness was graded intraoperatively by a single examiner (JMH), using the forced duction test¹¹ with specific attention to restriction to adduction. All forced duction testing was performed under deep general anesthesia and before starting any surgical procedure. Most patients received a short-acting depolarizing muscle relaxant (succinylcholine) and forced duction testing was performed at least 10 minutes after its administration when there should be no residual effect of the relaxant.¹²

For the purposes of this present study, lateral rectus tightness was classified as either: normal (no restriction), mild or moderate, based on the subjective resistance encountered to attempted full adduction. All cases of restriction to adduction were attributed to a tight lateral rectus muscle because in each case the intraoperative restriction resolved after disinsertion of the lateral rectus, indicating that there was no reverse leash from a mechanical process, such as posterior medial rectus scarring to the globe, or additional lateral restrictions. All patients were included regardless of the tightness of the lateral rectus.

Analysis

The relationship of grade of adduction deficit (0 to -5) to each intraoperative factor was evaluated by comparing: 1) medial rectus status analyzed first as a 5-way comparison (normal, abnormal, at the pulley, behind the pulley, or mixed), and second as a 3-way comparison (normal, abnormal, lost [combining at the pulley and behind the pulley, but excluding mixed attachment]) (Kruskal-Wallis tests with Dwass, Steel Critchlow-Flinger pairwise comparison with adjustment for multiple comparisons); 2) position of the distal end of the medial rectus muscle fibers using Spearman rank correlations, and 3) grade of lateral rectus tightness on forced duction testing (normal, mild, moderate), using Spearman rank correlations. Available data on muscle width was reported as a descriptive summary. We elected not to use generalized estimating equations (GEE) for our primary analysis due to the non-normal distribution of the data and the fact that we only had six bilateral cases and two patients with a second surgical episode. Nevertheless, when we used GEE methods in secondary analyses, we confirmed our primary findings with medial rectus attachment and

the difference between normal and moderate lateral rectus tightness. All statistical analyses were performed using SAS software (version 9.4, SAS Institute Inc., Cary, North Carolina).

In secondary analyses, for each grading of adduction deficit, the probable cause was classified as one or more of the following: 1) medial rectus status not normal (abnormal, attached to pulley, behind pulley or mixed); 2) medial rectus muscle excessively recessed, such that the lever arm was reduced (impeding adduction), which for this present study was defined as the position of the distal end of the medial rectus muscle fibers being more than 7 mm posterior to the original insertion; 3) lateral rectus tightness on forced duction testing (either mild or moderate). The proportion of eyes in each category was represented in Venn diagrams.

Results

Patients

One hundred forty-three eyes of 129 patients were included. Seventy-six (59%) patients were female and 124 (96%) reported race as White. One-hundred (78%) of 129 patients were undergoing consecutive XT surgery for the first time and 29 (22%) were undergoing surgery for recurrent consecutive XT. Two patients underwent two surgeries for consecutive XT during the study period and data from each surgery was included for analysis. Six patients underwent bilateral medial rectus surgery and data from both eyes were included for analysis. The mean age at surgery was 36 ± 19 (range, 2 – 82) years. Overall, 19 (13%) of 143 eyes had normal adduction and 124 (87%) had an adduction deficit (Table 1).

Frequency of abnormal findings and relation to adduction deficit

Medial rectus muscle attachment status: Overall, 96 (67%) of 143 eyes had a normal medial rectus muscle attachment to the sclera, 23 (16%) had an abnormal attachment to the sclera, 9 (6%) were attached to the pulley, 8 (6%) were found behind the pulley, and 7 (5%) were mixed attachment type (Table 1). All 20 (100%) eyes with normal adduction also had normal medial rectus muscle attachment (Table 1). When comparing adduction deficit by medial rectus attachment type as a 5-group comparison (normal, abnormal, at the pulley, behind the pulley, and mixed type), eyes with not-normal medial rectus muscle attachments (abnormal, at pulley, behind pulley, and mixed) had worse adduction deficits than eyes with normal medial rectus muscle attachments (Table 2, $P < 0.02$ for all comparisons).

When comparing adduction deficit by medial rectus attachment type as a 3-group comparison, eyes with a lost medial rectus muscle (attached at the pulley or behind the pulley) had worse adduction deficits than eyes with an abnormal medial rectus muscle attachment ($P = 0.02$) and eyes with a normal medial rectus muscle attachment ($P < 0.0001$). Eyes with abnormal medial rectus muscle attachments also had worse adduction deficits than eyes with normal medial rectus attachments ($P = 0.003$, Table 2).

Medial rectus distal muscle fiber location: Across all eyes, medial rectus distal muscle fiber location ranged from being at the insertion to -19.5 mm behind the insertion. There was a significant correlation between the medial rectus muscle fiber position and the grade of adduction deficit in the corresponding eye ($r = 0.59$ [$r^2 = 0.29$] $P < 0.0001$), with adduction

deficit worsening the further back the medial rectus muscle fibers were located in relation to the original insertion.

Lateral rectus muscle tightness: Overall, 95 (66%) of 143 eyes had normal adduction by forced duction testing, 36 (25%) had mild lateral rectus tightness and 12 (8%) had moderate/ marked lateral rectus tightness (Table 1). Of the 20 eyes with normal adduction on clinical testing, all 20 (100%) also had a normal lateral rectus forced ductions (Table 1).

When comparing the distribution of adduction deficits between the different grades of lateral rectus tightness on forced duction testing, eyes with mild or moderate lateral rectus tightness had worse adduction deficits than eyes with no lateral rectus tightness (median [quartiles] = -1 [-2 , -1] for mild, $P=0.0003$ and -2 [-3 , -1] for moderate, $P=0.002$ vs -1 [-1 , -0.5] for normal). Median adduction deficits were somewhat worse for eyes with moderate lateral rectus tightness than for eyes with mild lateral rectus tightness, although this difference did not reach statistical significance ($P=0.3$).

Cause of adduction deficit by severity of preoperative adduction deficit

Normal adduction: For the 19 eyes with normal preoperative adduction, all demonstrated no lateral rectus tightness on intraoperative forced duction testing, and in all cases the medial rectus muscle attachment status was normal. In addition, no eyes with normal adduction were classified as having an excessively recessed medial rectus muscle.

Mild adduction deficits (-0.5 and -1): The most common assigned cause of a mild adduction deficit was lateral rectus tightness on intraoperative forced duction testing (17% for -0.5 adduction deficit [Figure 1 A] and 20% for -1 deficit [Figure 1B]). Nevertheless, a large proportion of patients with -0.5 and -1 adduction deficits (19, [66%] and 30, [54%] respectively) did not meet any of the pre-determined criteria for assigning cause of the adduction deficit (Figure 1, A and B). Of the eyes that did not meet our pre-determined criteria for assigning cause, 1 (5%) of 19 with -0.5 adduction and 9 (30%) of 30 with -1 adduction deficit also had an abnormally narrow medial rectus muscle described in the operative report.

Moderate adduction deficit (-2): The most common assigned cause for -2 adduction deficit (11 [35%] of 31 eyes), was a combination of 3 different causes 1) the medial rectus muscle attachment status being not normal (either abnormal attachment, attached to the pulley, attached behind pulley, or mixed attachment type), 2) excessive recession of the medial rectus and 3) lateral rectus tightness on forced duction testing (Figure 1 C). The second most common cause (7, 23%) was excessive recession of the medial rectus in combination with medial rectus status being not normal (Figure 1, C). There was no identified cause for the adduction deficit in only 5 (16%) of eyes, and none of these were documented as having an abnormally narrow medial rectus muscle.

Severe adduction deficits (-3 to -5): For eyes with severe adduction deficit the most common cause (4 [50%] of 8 eyes) was again a combination of 3 different causes 1) medial rectus muscle status being not normal with 2) excessive recession of the medial rectus and 3)

lateral rectus tightness on forced duction testing (Figure 1 D). There were no eyes for which the cause of adduction deficit was not identified.

Discussion

Patients with consecutive exotropia often present with a deficit of adduction ranging in severity from mild (graded -0.5 or -1) to moderate (-2) or severe (-3 to -5). The majority of eyes with mild adduction deficit had normal intraoperative forced adduction testing and normal medial rectus muscle attachment. Nevertheless, eyes with mild adduction deficit could also have mild or moderate lateral rectus tightness on intraoperative forced duction testing, and some eyes with -1 adduction deficit had a medial rectus muscle attachment which was not normal, including “lost” muscles (at the pulley or behind the pulley, Table 1). Eyes with moderate adduction deficits (-2) were more likely to have mild or moderate lateral rectus tightness on intraoperative forced duction testing, but there was a wide spectrum of medial rectus muscle attachment type including normal, abnormal, lost muscles (at the pulley and behind the pulley), and a wide range of location of the distal end of the medial rectus fibers (from 4 to 16 mm recessed). Only with very severe adduction deficit (-4 and -5) was there most often a finding of attachment type being behind the pulley (the exception was the patient with a -5 deficit who had an abnormal attachment with an 8 mm pseudotendon). With a -4 or -5 adduction deficit, the location of the distal end of the medial rectus fibers was at least 13.5 mm behind the normal insertion. These findings suggest that severity of preoperative adduction deficit is a poor predictor of the medial rectus muscle attachment type and the location of the distal end of the medial rectus fibers, especially in patients with mild or moderate deficits. Severe medial rectus insertion abnormalities may be masked by apparently benign mild preoperative adduction deficits and the surgeon needs to be prepared for any combination of medial rectus muscle and lateral rectus muscle findings in an individual case.

In our study of patients with consecutive XT, adduction deficit (-0.5 or greater) was found in 87%. This rate is comparable with that reported by Mittelman and Folk¹³ who found adduction deficit present in 82% of patients with consecutive XT. Other studies report lower rates of adduction deficit in consecutive exotropia patients (e.g. 69%,¹⁴ 65%¹⁵, 33%¹⁶). It is possible that our rate of 87% is higher than some other studies because we included “trace” (-0.5) in our definition of adduction deficit whereas other studies may have classified this low level of deficit as normal. Recalculating the rate of adduction deficit in our study with -0.5 grouped with normal, our rate of adduction deficit would be 66%. In addition, the reported rate may differ depending on the population studied, with higher rates of adduction deficits possible in patients who have undergone multiple previous surgeries.

Few previous studies have evaluated intraoperative horizontal muscle findings and their association with the presence or severity of adduction deficit in consecutive XT. In frequently referenced ophthalmic texts, the presence of adduction deficit in consecutive XT is said to suggest the possibility of a slipped medial rectus muscle,³ especially if adduction is markedly limited.¹⁷ Von Noorden states that severe restriction of motility along with large angle consecutive XT may indicate disinsertion of the medial rectus muscle.¹ Although we found that a moderate or severe limitation of adduction (-2 or worse in this present study) is

associated in some cases with a slipped or lost medial rectus muscle, there were many cases of moderate or severe adduction deficit that were associated with either a normal muscle attachment or an abnormal attachment, sometimes referred to as stretched scar.⁴⁻⁶ Nevertheless, the question of medial rectus muscle status in cases where adduction is only mildly limited is less frequently addressed. It may be expected that better adduction is more likely to be consistent with normal medial rectus status, but as illustrated in the present study, a mild (–1) limitation of adduction is not inconsistent with the presence of an abnormally attached or lost medial rectus muscle. Cherfan and Traboulsi¹⁸ highlighted this possibility, pointing out that the grade of adduction limitation is not always useful in differentiating slipped and lost muscles, and Plager and Parks¹⁹ found that three of eight patients with “irretrievable” (lost) medial rectus muscles were able to adduct 15 degrees past the midline. Our study illustrates that the grade of adduction deficit cannot be used to differentiate muscles with abnormal attachment from lost muscles and also cannot be used to differentiate normal from abnormal insertions, since good ability to adduct the eye (with a deficit of only –1, or –2) can be present in patients with normal attachments, abnormal attachments, or lost medial rectus muscles. Good (or better than expected) adduction in the presence of an abnormal or lost medial rectus muscle may be explained by other mechanical factors such as attachments from the pulley to the globe. A study by Hakim et al²⁰ found that for 76% of rectus muscles and 100% of oblique muscles, eye movement remained normal after the muscle had been disinserted, suggesting contracture of the orbital portion of the muscle with an effect on corresponding Tenon’s fascia and pulley structures.

When assigning cause of adduction deficit in consecutive XT, we considered other possible causative factors such as tightness of the lateral rectus muscle, demonstrable by finding restriction to adduction on intraoperative forced duction testing. There are few other reports describing the prevalence of lateral rectus tightness in patients with consecutive XT. In the present study, across all levels of adduction deficit, 48 (34%) of 143 eyes had a lateral rectus tightness on forced duction testing, and in 20 (14%), lateral rectus tightness was the only assigned cause of the adduction deficit (interestingly only occurring for mild or moderate deficits [–0.5 to –2]). A finding of positive restriction to adduction may also be caused by a mechanical reverse-leash effect from a medial rectus being attached behind the equator of the globe, but we are confident that, for the eyes included in this study, the restriction was in fact attributable a tight lateral rectus muscle, since it was recorded that forced ductions normalized in all cases when the lateral rectus was disinserted.

We also considered that adduction deficits could be caused by excessive recession of the medial rectus muscle. Although excessive recession could be defined by whether or not there is resulting overcorrection of the angle of deviation, we were specifically interested in whether there was reduced adduction ability due to the posterior attachment of the medial rectus muscle. For the purposes of this present study we defined such excessive recession as finding the distal end of the medial rectus muscle fibers more than 7 mm posterior to the original insertion. Using this definition, we classified 19 (13%) of 143 medial rectus muscles as excessively recessed (although this included cases where the distal end of the medial rectus muscle fibers were not attached to the globe). In our study cohort and using our a priori definitions for assigning cause of adduction deficit, it is interesting that excessive recession of the medial rectus was never assigned as the only cause of adduction deficit, but

it frequently occurred in combination with an abnormal or lost attachment type. Others have described an alternative approach to defining excessive recession, suggesting 1 mm behind the equator is safe, but that more than 1.5 mm posterior to the equator may cause consecutive XT.²¹ We were unable to perform such calculations in the present study since we did not have data on axial length or the exact location of the equator. Reduced medial rectus muscle width is an additional factor that may explain the adduction deficit. In the present study it appeared that reduced muscle width was associated with some cases of mild adduction deficit, but we had incomplete data and more rigorous prospective data collection is needed to further understand this potential factor.

The findings of the present study highlight the importance of carefully assessing the status of both the medial and the lateral rectus muscles when surgically correcting consecutive XT, since the lateral rectus muscle may be tight in addition to abnormalities of medial rectus muscle attachment. We currently recommend addressing any lateral rectus tightness at the time of surgery in addition to advancing / resecting the medial rectus, and we speculate that neglecting to address a co-existent tight lateral rectus muscle at the time of surgery for consecutive XT may increase the risk of subsequent, recurrent exodeviation.

Regarding the role of adduction deficit in the pathogenesis of consecutive XT, for the majority of our patients, adduction was normal or only mildly limited. While for some patients mechanical factors (such as limited adduction and/or a tight lateral rectus) undoubtedly play a role in the development of consecutive XT, we speculate that for other patients consecutive XT develops as the result of central causes such as poor or absent motor fusion or poor visual acuity. Nevertheless, mild adduction deficit does not exclude the possibility of abnormal medial and lateral rectus muscle findings.

There are some limitations to this present study. We had few eyes with severely limited adduction (−3 to −5) and our findings in this group may therefore not be entirely representative. Low numbers of eyes with severely limited adduction also prevented us from performing multivariate regression analyses. This more rigorous form of analysis may have helped elucidate which specific causative factors were most associated with each level of adduction deficit.

Adduction deficit is a common finding in patients with consecutive XT. In general, more severe preoperative adduction deficits are associated with medial rectus insertion abnormalities and abnormal forced ductions. Nevertheless, severe medial rectus insertion abnormalities may be masked by apparently benign mild preoperative adduction deficits, and this possibility should be given consideration when planning surgery. Surgical management of consecutive XT should involve careful intraoperative evaluation of both medial and lateral rectus muscles to develop an appropriate surgical plan.

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Figure 1.

Venn diagrams showing classification of cause for different levels of adduction deficit, in eyes undergoing surgery for consecutive exotropia. Cause was assigned as either: abnormal medial rectus (MR) muscle attachment, or lost (found at pulley or behind pulley); excessively recessed medial rectus (found >7 mm back from original insertion); tight lateral rectus (LR)

Table 1

Relationship between grade of adduction deficit and medial rectus status, distal medial rectus muscle fiber location and lateral rectus tightness in n=143 eyes; n=129 patients with consecutive (n=6 had bilateral surgery; n=2 had 2 surgeries)

Adduction deficit	Medial rectus status				Medial rectus muscle fiber location (from insertion)			Intraoperative lateral rectus tightness			
	Normal (n=96)	Abnormal (n=23)	At pulley (n=9)	Behind pulley (n=8)	Mixed (n=7)	Range (mm) *	Interquartile range (mm) *	Median (mm) *	Normal (n=95)	Mild limitation (n=36)	Moderate limitation (n=12)
0 (n=19)	19/19 (100%)	0	0	0	0	0.0 to -6.0	-4.0, -5.5	-4.0	19/19 (100%)	0	0
-0.5 (n=29)	24/29 (83%)	5/29 (17%)	0	0	0	-2.0 to -9.0	-4.5, -6.0	-5.0	22/29 (76%)	6/29 (21%)	1/29 (3%)
-1 (n=56)	41/56 (73%)	9/56 (16%)	2/56 (4%)	1/56 (2%)	3/56 (5%)	0.0 to -12.0	-4.5, -6.75	-6.0	39/56 (70%)	13/56 (23%)	4/56 (7%)
-2 (n=31)	12/31 (39%)	6/31 (19%)	6/31 (19%)	3/31 (10%)	4/31 (13%)	-4.0 to -16.0	-6.0, -13.0	-9.0	12/31 (39%)	16/31 (52%)	3/31 (10%)
-3 (n=4)	0	2/4 (50%)	1/4 (25%)	1/4 (25%)	0	-7.0 to -19.5	-8.0, -15.25	-10.0	1/4 (25%)	0	3/4 (75%)
-4 (n=3)	0	0	0	3/3 (100%)	0	-16.0 to -16.0	-16.0 to -16.0	-16.0	2/3 (67%)	1/3 (33%)	0
-5 (n=1)	0	1/1 (100%)	0	0	0	-13.5 to -13.5	-13.5 to -13.5	-13.5	0	0	1/1 (100%)

* where no data in the operative report, we imputed (n=1 eye) median of all "at pulley" values (-12mm); for "behind pulley", imputed (n=5 eyes) -16mm

Table 2

Adduction Deficit by Medial Rectus Attachment Type

Medial rectus attachment type	N	Level of adduction deficit		
		Median	Range	Quartiles
Normal	96	−1	0 to −2	−0.5, −1
Abnormal	23	−1	−0.5 to −5	−1, −2
At Pulley	9	−2	−1 to −3	−2, −2
Behind Pulley	8	−2.5	−1 to −4	−2, −4
Mixed	7	−2	−1 to −2	−1, −2