Slipped extraocular muscles: characteristics and surgical outcomes

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ABSTRACT • RÉSUMÉ

Objective: To study the frequency and characteristics of slipped extraocular muscles after strabismus surgery and report the postoperative outcomes longitudinally.

Design: Retrospective chart review.

Participants: Electronic medical records of 493 patients who underwent strabismus surgery and were found to have a slipped muscle intraoperatively were reviewed.

Methods: Records were retrieved and operative reports were screened for the presence of slipped muscles. Data pertaining to the eye examination and surgery were collected, including vision, ocular motility in all positions, duction limitations, slipped muscle, empty sheath length, amount of slippage, amount of advancement, and amount of recession of the antagonist muscle.

Results: Twelve patients (mean age 29.1 ± 6.4 years; 5 males) were found to have 15 slipped medial rectus muscles. Average amount of slippage was 15.7 ± 2.0 mm; from limbus empty sheath length was 5.9 ± 1.9 mm. Average preoperative deviation was 32.2 ± 10.0 prism diopters (PD) exotropia. Mean follow-up after corrective surgery was 13.3 months (1 week to 42 months). Four patients were transiently overcorrected postoperatively (7.0 ± 7.0 PD esotropia). The rest had mean residual exotropia of 13.5 ± 9.2 PD with a change of 26.6 ± 10.3 PD from baseline ($p < 0.001$). Intraoperative mean muscle movement was 10.3 ± 2.2 mm with a mean postoperative change of 2.6 PD for each 1 mm of muscle advancement. There was no significant increase over time in the postoperative angle of deviation during all follow-up periods except for 1 patient who was re-explored after 4 years.

Conclusions: Slipped muscle should be suspected in the presence of limited ductions and consecutive deviations after strabismus surgery. A change of 2.6 PD for every 1 mm of medial rectus muscle advancement was observed and maintained over time.

Objectif : Étudier la fréquence et les caractéristiques du glissement des muscles extraoculaires après une intervention chirurgicale visant à corriger le strabisme et présenter les résultats postopératoires de façon longitudinale.

Nature : Étude rétrospective de dossiers.

Participants : Nous avons examiné les dossiers médicaux électroniques de 493 patients ayant subi une intervention chirurgicale visant à corriger leur strabisme et ayant reçu un diagnostic de glissement musculaire peropératoire.

Méthodes : Nous avons récupéré les dossiers et parcouru les rapports opératoires pour trouver la présence de glissement musculaire. Des données relatives à l'examen de la vue et à l'intervention chirurgicale ont été recueillies, y compris : la vision, la motilité oculaire dans toutes les positions, les limites de la duction, le glissement musculaire, la longueur de la gaine vide, l'ampleur du glissement, le degré d'avancement et l'ampleur de la récession du muscle antagoniste.

Résultats : 12 patients (âge moyen 29,1 ± 6,4 ans; 5 hommes) avaient 15 glissements du muscle droit interne. Le glissement moyen était de 15,7 ± 2,0 mm; la longueur de la gaine vide était de 5,9 ± 1,9 mm. La déviation préopératoire moyenne était de 32,2 ± 10 dioptries prismatiques (DP) d'exotropie. La durée moyenne du suivi était de 13,3 ± 1 mois (de 1 semaine à 42 mois). 4 patients ont subi une surcorrection postopératoire transitoire (7,0 ± 7 DP d'ésotropie). Les autres patients avaient une exotropie résiduelle moyenne de 13,5 ± 9,2 DP avec un changement de 26,6 ± 10,3 DP par rapport à la ligne de base ($p < 0,001$). Le mouvement musculaire moyen peropératoire était de 10,3 ± 2,2 mm avec un changement postopératoire moyen de 2,6 DP pour chaque millimètre d'avancement musculaire. Nous n'avons pas constaté d'augmentation significative de l'angle de déviation postopératoire au fil du temps lors de toutes les périodes de suivi, sauf pour un patient qui a été réopéré après 4 ans.

Conclusions : Un glissement musculaire doit être suspecté en cas de ductions limitées et de déviations consécutives après une intervention chirurgicale visant à corriger le strabisme. Un changement de 2,6 DP pour chaque millimètre d'avancement musculaire médial a été observé et s'est maintenu au fil du temps.

Slipped muscle is defined as detachment of the rectus muscle after attempted reattachment to the globe. The muscle retracts posteriorly within its capsule while the empty capsule is still connected to its initial insertion site at the sclera.[1–4] Slippage postsurgery occurs if the suture is superficially passed into the muscle capsule and the tendon is not fully included in the locking sutures.[1,2,5] It has been also associated in some reports with the term *pseudo-tendon* or *stretched scar*.[6] It was reported most commonly after recession of medial and inferior rectus muscles.[1,2,7] Both muscles have a limited contact arc with the globe compared with lateral and superior rectus muscles.[8] In 1 report, slipped muscle was considered the second most common severe complication after ocular perforation;[9] however, it was underdiagnosed.[7,10]

Outcomes may not always be satisfactory after recognizing and repairing a slipped muscle.[11] Several tests are suggested to detect slipped muscle after strabismus surgery, including limitation of ductions, consecutive tropia, widening of the palpebral fissure during duction in the

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field of involved muscle, and simultaneous relaxation of its antagonist, in addition to reduced saccadic velocity.[12] Furthermore, diagnostic imaging studies, such as computed tomography and magnetic resonance imaging, may determine the location of the slipped muscle as well as the absence or presence of its contact with the globe and hence differentiate it from a lost muscle.[7,10,13] An ophthalmologist should suspect a slipped muscle when a patient presents with limitation of duction or with unexpected overcorrection postoperatively. The gold standard to confirm a slipped muscle remains direct intraoperative inspection.

In this study we reported a series of slipped muscle surgeries, their preoperative characteristics, intraoperative findings, and postoperative course. Preoperative predictive signs of slippage were highlighted, and the amount of strabismus correction per millimetre of muscle advancement was computed immediately after surgery and studied longitudinally.

Materials and Methods

Patients and Evaluations

This was a retrospective chart review of patients who underwent strabismus surgery between January 2006 and September 2014 at the American University of Beirut Medical Center. The study was approved by the Institutional Review Board at the American University of Beirut, and consents were waived. Electronic records of 493 patients were reviewed and pre- and postoperative data were collected, including vision, ocular motility assessment with prism and cover tests for distance and near, and limitation of ductions according to a grading scale from −1 to −4. Distance-near discrepancy in the angle of deviation was calculated by subtracting the distance angle from the near angle. Intraoperative data collected included slipped muscle, length of empty sheath, amount of slippage from limbus, and amount of advancement. Total muscle advancement was calculated by recording the total amount of advancement of the slipped muscle and adding the amount of recession of the antagonist muscle if performed. Slipped muscles were identified in 12 cases, all being medial rectus muscles.

Surgical Approach

During surgery, attention was turned to the eye with suspected slipped muscle. A 6.0 silk traction suture was placed at the limbus at 12 and 6 o'clock positions. Conjunctival peritomy was performed nasally and winged on each side of the medial rectus muscle. Tenon's tissue anterior to the muscle insertion was entered on either side of the muscle. Next, the empty sheath was hooked first using a small muscle hook and then using a Jameson hook. Most of the time the hook had to be advanced quite posteriorly before the edge could be hooked. Dissection of intermuscular attachments was performed slowly and carefully, and bleeders were cauterized as needed. The medial rectus insertion site was finally determined from the limbus; the amount of empty sheath could be measured by sliding the muscle hook from the insertion site under transparent Tenon's capsule to the beginning of muscle fibres posteriorly. A 6-0 double-armed Vicryl suture was used to secure the muscle fibres and lock it on each side. The empty sheath was resected, and the muscle tendon was identified and then advanced and sutured to the appropriate distance from limbus directly to sclera; the muscle was advanced to the location where it could be safely sutured without excessive tension or up to the original insertion when possible. No adjustable sutures were used in our series.

In cases in which lateral rectus recession was performed, the eye was rotated nasally and the lateral rectus muscle was hooked as described previously. Then a double-armed 6-0 Vicryl suture was passed through the muscle about 1 mm from its insertion and double locked on each side. The muscle was then detached from the globe and attached directly to sclera at the appropriate recessed position.

In 1 case the slipped medial rectus muscle was found to be tight and fibrosed and could not be advanced. Nasal transposition of the vertical recti was performed. The inferior and superior rectus muscles were identified and hooked in the usual fashion. Attachments to the capsulopalpebral head were released. A double-armed 6-0 Vicryl suture was interwoven through each muscle at its insertion and double locked on each side. Each muscle was then disinserted and transposed nasally along the spiral of Tillaux, attaching the inferior rectus at the inferior border and the superior rectus at the superior border of the original medial rectus insertion. The conjunctiva was reapproximated using 8-0 Vicryl sutures.

Data Analysis

Patients' demographic and clinical characteristics were analyzed using SPSS version 21.0 (IBM/SPSS Inc, Chicago, Ill.) and summarized using descriptive analysis with means and standard deviations and medians for numeric variables. Mean change in visual acuity and mean angle of

Table 1—Demographic and baseline characteristics (N = 12)

Characteristics	Values
Age (years), mean ± SD	29.1 ± 6.4
Sex (male:female)	5:7
Slipped muscles	15 medial rectus
Amount slipped (mm)	
Mean ± SD	15.7 ± 2.0
Median (range)	15.0 (12.5–20.0)
Empty sheath (mm)	
Mean ± SD	5.9 ± 1.9
Median (range)	6.0 (2.0–9.5)
Previous surgeries	
Mean ± SD	2.2 ± 0.9
Median (range)	2.0 (1.0–4.0)
Mean vision ± SD (logMAR)	0.2 ± 0.5

Table 2—Mean angle of deviation of slipped muscles in prism diopters with ductions pre- and postsurgery (at 1 week to 1 month)

Patient No.	Preop Deviation (PD)	Postop Deviation (PD)	Preop D/N Discrepancy (PD)	Postop D/N Discrepancy (PD)	Total Muscle Movement in (mm)	Postop Change in Deviation (PD)	Preop Ductions	Postop Ductions
1	58XT	20 XT	−5	−6	10	38	−2	−0.5
2	28XT	3 ET	5	0	12	31	−0.5	0
3	33 XT	10 XT	5	0	11.5	23	−3	−0.5
4	30 XT	0	0	0	9	30	−1	0
5	38 XT	4 ET	5	0	12	42	0	0
6*	18 XT	6 XT	4	1	9	12	−1.5	−2.5
7	35 XT	5 XT	5	2	6.5	30	−2	−1
7*	30 XT	4 XT	0	−4	14	26	−1.5	−1
8	23 XT	2 ET	5	0	7.5	25	−1	NA
9	20 XT	19 ET	0	4	13	39	−4	−1.5
10	35 XT	20 XT	0	0	8	15	−1	0
11	38 XT	30 XT	5	0	11	8	−4	−4
12†	25 XT	23 XT	10	5	—	2	−3	−3
Mean ± SD	32.2 ± 10	10.2 ± 9. 2	2.4 ± 4.5	−0.25 ± 2.5	10.3 ± 2.2	26.6 ± 10.3	−1.8 ± 1.2	−1 ± 1.2
Median (range)	32.2 (18 to 58)	5.5 (0 to 30)	4.5 (−5 to 5)	0 (−6 to 4)	10.5 (6.5 to 14)	28 (8 to 42)	−1.5 (0 to 4)	−0.5 (0 to 4)
p	0.001		0.01				0.031	

D/N, discrepancy denotes difference between near and distance deviation (near minus distance); muscle movement, amount of medial rectus advancement + lateral rectus recession (in millimetres); PD, prism diopters.

p value refers to comparison between pre-op (preoperative) and post-op (postoperative) parameters.

*Bilateral medial rectus advancement.

†Patient 12 is not included in the analysis.

deviation before and after surgery were analyzed using the Wilcoxon signed rank test. The change in angle of deviation over time was also computed similarly. A p-value <0.05 was considered statistically significant.

Results

A total of 493 of strabismus muscle surgeries were performed over 9 years. Fifteen muscles from 12 patients (mean age: 29.1 ± 6.4 years; 5 males) were confirmed to be slipped intraoperatively by the same surgeon (Christiane Al-Haddad). All were medial rectus muscles with a prevalence rate of 3% (15/493). Mean follow-up after corrective surgery was 13.3 months (median = 13; range: 1 week to 42 months). Seven out of 12 patients were referred cases from other institutions and 4 of 12 patients were operated by ophthalmology residents. The average amount of slippage from limbus was 15.7 ± 2.0 mm, with an empty sheath mean length of 5.9 ± 1.9 mm. Most patients (9/12; 75%) underwent more than 1 strabismus surgery before their diagnosis, and the mean time interval between strabismus surgery and re-exploration was 137.0 ± 107.2 months (median = 11; range: 3–444 months). Bivariate analysis showed no significant correlation between time to re-exploration and length of the empty sheath ($p = 0.76$). There was no significant difference in visual acuity on logMAR scale between the pre- and postoperative periods ($p = 0.6$) (Table 1).

Table 2 presents preoperative and postoperative characteristics for each patient, including angle of deviation, limitation in ductions, and change in deviation directly postoperatively. In 2 cases bilateral slippage was confirmed and correction was performed during the same surgery (patients 6 and 7). Patient 7 was operated twice 4 years apart, first for unilateral medial slippage and consequently for bilateral slippage.

The average horizontal deviation preoperatively was 32 ± 10 prism diopters (PD) of exotropia (range 18–58 PD). Mean total muscle movement was 10.3 ± 2.2 mm during surgery. In 1 case (patient 12), transposition of the vertical recti was done because of inability to advance the fibrosed slipped medial rectus (this patient was mentioned in the tables but was not included in the numerical data analysis). The preoperative deviation was greater at near than distance in all cases except in patient 1. The average difference between near and far angle of deviation preoperatively was 2.8 ± 3.2 PD, ranging from −5 to 5 PD, significantly different from postoperative difference (−0.25 ± 2.5 PD; $p = 0.01$). During the first evaluation period after correction (1 week to 1 month postoperation), 4 patients were found mildly overcorrected, with a mean overcorrection of 7.0 ± 7.0 PD of esotropia (range 2–19). The average angle of residual postoperative exotropic deviation was 13.5 ± 9.2 PD (range 4–30 PD), with an average total change of 26.6 ± 10.3 PD; this was clinically and statistically significantly different from the baseline ($p < 0.001$).

The mean change of deviation observed immediately after surgery in our series was 2.6 PD for each 1 mm of muscle advancement; this remained stable longitudinally with the same numbers at 1–3 months, decreasing slightly to 2.4 PD/mm at 3–6 months, 2.2 PD/mm at 1 year, and 2.3 PD/mm after the first year of follow-up ($p = 0.8$).

The change in deviation over time is represented in Table 3, with no significant change in deviation all over follow-up periods compared with the immediate postoperative visit; 8 patients completed their follow-up to 3 months with an average change in deviation

Table 3—Postoperative change in angle of deviation over time in prism diopters

Patient No.	Immediate Postoperative Change in Deviation (PD)	1–3 Months, n = 8 Deviation	1–3 Months, n = 8 Change	3–6 Months, n = 7 Deviation	3–6 Months, n = 7 Change	6 Months–1 Year, n = 7 Deviation	6 Months–1 Year, n = 7 Change	More than 1 Year, n = 6 Deviation	More than 1 Year, n = 6 Change
1*	38								
2	31	4 ET	32						
3*	23								
4	30	4 XT	26	4 XT	26	5 XT	25	2 XT	28
5	42	5 ET	43	5 ET	43	6 ET	44	0	30
6†	12	0	18	5 XT	13	9 XT	9		
7	30	8 XT	27	12 XT	23	14 XT	21		
7†	26	5 XT	25	9 XT	21	11 XT	19	9 XT	21
8	25	5 XT	18	4 XT	19	6 XT	17	6 XT	17
9	39	10 ET	30	6 ET	26	7 ET	27	5 ET	25
10	15					17 XT	18	16 XT	19
11*	8								
12*	2								
Mean ± SD	26.6 ± 10.3	5.1 ± 2.8	27.3 ± 7.5	6.4 ± 2.8	24.4 ± 8.6	9.4 ± 4.3	22.5 ± 10.2	6.3 ± 5.7	23.3 ± 5.2
Median (range)	28 (8–42)	5 (0–10)	26.5 (18–43)	5 (4–12)	23 (13–43)	8 (5–17)	20 (9–44)	5.5 (0–16)	23 (17–30)
p			0.31		0.08		0.05		0.09

Change of deviation, it is the change from baseline; ET, esotropia; XT, exotropia.
p value: comparing the change in deviation over different time points to the immediate postoperative deviation.
*Patients lost to follow-up.
†Bilateral medial rectus advancement.

of 27.3 ± 7.5 PD. Eight patients completed their follow-up to 1 year, with an average change of 22.5 ± 10.2 PD.

Six patients completed their follow-up for an average of 2 years postsurgery (1.5–3.5 years) with no significant change in angle of deviation over time, except for patient number 7, in whom exotropia recurred after 4 years (30 PD) and who was re-explored for bilateral slipped medial rectus muscle.

Discussion

Slipped muscle is a rare but serious potential complication after strabismus surgery;[1,2,5] however, the literature is limited to case series.[2,7,14–16] In this retrospective study we reported a 3% prevalence of slipped muscles over an 8-year period. Intraoperative confirmation of slippage correlated well with preoperative predictive clinical signs, namely, limitation of ductions and distance–near discrepancy in angle of deviation. The change in deviation after surgery was an average of 2.6 PD per millimetre of muscle movement. We studied the change over time for a mean total follow-up of 13.3 months, with no need for re-operation in 91% (11/12) of cases. Our rate of 3% of slippage of medial rectus muscles after strabismus surgery is relatively much lower than that in a previously reported retrospective chart review (10.6%).[17] Incidence of slipped muscles varies widely across studies; Bradbury and Taylor reported only 0.07% in a series of 24 000 strabismus surgeries who were followed up for 6 months.[9] This variation may be because of the different centres reporting outcomes of strabismus surgeries. Busy referral centres will attract the more complicated strabismus cases, and hence more slipped muscles may result. Moreover, academic institutions similar to ours, where residents are involved in surgeries as a part of their training, may have higher incidence rate. The use of adjustable sutures has been associated with a higher risk of muscle slippage.[18] However, in our series, adjustable sutures were not performed.

All muscles in our series were medial rectus muscles, in line with previously published reports (Table 4).[2,7,14–16] This can be explained by the shorter contact arc of medial recti with the globe compared with lateral and superior rectus muscles.[13,19] In addition, the medial rectus muscle does not have any fascial attachments to an oblique muscle.[12,16] All of our cases were suspected before the intraoperative confirmation. The difference in deviation

Table 4—Studies reporting slipped muscles

Study	Number of Patient (Eyes)	Medial Rectus Involved	Relocated	Transposition	Only 1 Corrective Surgery	Age, Mean (Range), Years	Mean Follow-up Duration, Months
Plager and Parks (1988).[2]	52 (62)	48 (77%)	57 (92%)	5 (8%)	30/42 (71%)	NA	1.5
MacEwen et al. (1992).[14]	6 (6)	6 (100%)	6 (100%)	0	5/6 (83%)	NA	N/A
Murray (1998).[7]	12 (16)	16 (100%)	16 (100%)	0	15/16 (94%)	12.3 (3.5–30)	N/A
Sebastian and Marsh (2006).[15]	85 (85)	68 (80%)	68 (100%)	0	82/85 (96%)	38 (11–72)	4
Duranoglu et al. (2014).[16]	21 (21)	21 (100%)	21 (100%)	0	21/21 (100%)	17.4 (5–50)	28
Current study	12 (15)	15 (100%)	14 (93%)	1(7%)	14/15 (93%)	26.7 (6–41)	13

between distance and near and limitation of duction successfully predicted all slipped muscle cases before re-exploration, thus confirming the high predictability of these tests in detecting slipped muscles. Other authors evaluated vertical palpebral fissure, horizontal saccadic velocity, and differential intraocular pressure, and sometimes using MRI;[16,17] however these tests showed less reliability before the intraoperative confirmation.[16,17]

Time interval between first strabismus surgery and re-exploration of the slipped muscle in our study varied widely (3 months to 37 years), similar to previous reports (1–30 years).[7,16,17] This partly explains the underdiagnosis of this condition or the reluctancy of patients to pursue further surgery/assessment. Prospective longitudinal studies may be needed in which patients are closely followed-up after strabismus surgery and early signs of slippage are observed. With respect to amount of slippage and empty sheath, our results agreed with previous reports (5–10 mm).[7,15–17] In fact, contracture of the ipsilateral antagonist muscle can occur as early as 2 weeks after the initial surgery.[14] If explored early, the muscle should be found 5–6 mm away from the intended insertion; however, there was no direct clear correlation between time to re-exploration of slipped muscle and the length of empty sheath.[14]

Authors have attempted to construct a predictable correction nomogram for slipped muscles.[15] We found that for each 1 mm of muscle advancement, a change of 2.6 PD in angle of deviation occurred. This was quite close to what Sebastian and Marsh reported at 2.76 PD for the medial rectus muscle advancement only.[15] However, when the lateral rectus muscle was included in the analysis, a higher change in deviation per mm was observed (3.1 PD for each 1 mm).[15] The slight difference can be attributable to the relatively larger preoperative deviation in Sebastian and Marsh reaching up to 90 diopters.[15] The latter study also differed from our series and follow up time: our study had a younger age (29 years vs. 38 years) and longer follow up (13 months vs. 4 months). Although they had the largest series of patients with slipped muscles, results were reported only in the immediate postoperative period, with no data reported longitudinally. Lateral rectus muscle recession corrected more of the deviation with less movement compared with the medial rectus advancement.[15] On the other hand, this was less than what Duranoglu et al. reported at 3.2 PD on the same muscle.[16] This inconsistency could be because correlation between muscle advancement during surgery and the change in angle is not a simple direct linear correlation; it could be more of an exponential one. The effect of slipped muscle advancement can be very unpredictable and variable. Other factors may cause this variability: different surgical approaches between small and large deviations, with larger deviations being challenging and difficult to correct successfully; mechanical factors, wherein longer-standing slipped muscles may be more contracted and fibrosed and hence difficult to advance, similar to our case No. 12, and necessitating transposition surgery; and a tendency to resect the advanced muscle to variable degrees in an attempt to capture all of the slipped fibres and avoid further slippage.

Over more than a 1-year follow-up period, we did not identify a significant change in deviation after corrective surgery. Only 1 patient (No. 7) had a recurrent slippage of the same medial rectus muscle and needed recorrection after 4 years. This patient was diagnosed initially to have slipped muscle 8 years after his first strabismus surgery. Some authors have suggested using nonabsorbable sutures to avoid later slippage.[16] In addition, for patient No. 12, who was diagnosed 37 years after the initial strabismus surgery, advancement was not possible because of formation of fibrosis, and transposition of the vertical recti was performed instead; other authors encountered similar cases in their reports.[2] Hence, early diagnosis and management of slippage is essential to achieve satisfactory long-term results. Our study additionally confirms the stability in the postoperative angle of deviation after slipped muscle advancement over time. Once appropriate corrective surgery is performed on the slipped muscle in question, chances of reoperation will significantly decline. Accordingly, we did not identify a need for using nonabsorbable sutures.

The relatively small sample size and the retrospective nature are fact limitations of our work. However, we reviewed a large number of strabismus surgeries (493) during an interval of 8 years proving the long-term stability of slipped muscle corrective surgery.

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