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Dynamic Stabilization of the Scapula for Serratus Anterior Dysfunction: A Retrospective Study of Functional Outcome and Results

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Background: Twenty-six patients (12 male and 14 female) with symptomatic scapular winging caused by serratus anterior dysfunction were managed by split pectoralis major tendon transfer (sternal head) with autogenous hamstring tendon augmentation from 1998 to 2006.

Methods: Twenty-five patients showed positive results upon long thoracic nerve palsy on electromyography. The mean duration of symptoms until surgery was 48 months (range, 12–120 months). Four patients had non-traumatic etiologies and 22 patients had traumatic etiologies. On follow-up assessment for functional improvement, a Constant-Murley score was used. Twenty-one patients were completely evaluated, while five patients who had less than 12 months of follow-up were excluded.

Results: Pain relief was achieved in 19 of the 21 patients, with 20 patients showing functional improvement. The pain scores improved from 6.0 preoperatively to 1.8 postoperatively. The mean active forward elevation improved from 108° (range, 20°–165°) preoperatively to 151° (range, 125°–170°) postoperatively. The mean Constant-Murley score improved from 57.7 (range, 21–86) preoperatively to 86.9 (range, 42–98) postoperatively. A recurrence developed in one patient. Of the 21 patients, ten had excellent results, six had good results, four had fair results, and one had poor results.

Conclusions: Most patients with severe symptomatic scapular winging showed functional improvement and pain relief with resolution of scapular winging.

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Key Words: Split pectoralis major tendon transfer; Serratus anterior dysfunction; Scapular winging; Long thoracic nerve palsy

Introduction

When the balance of periscapular muscles is broken, abnormal scapulothoracic movement can develop. The most symptomatic abnormal scapulothoracic movement is scapular winging.[1)] The causes for scapular winging can be divided into three groups; serratus anterior dysfunction, trapezius palsy and facioscapulohumeral muscular dystrophy. Scapular winging caused by serratus anterior dysfunction is the most common disorder. Since the serratus anterior muscle has only one innervation via the long thoracic nerve, incidents such as trauma, viral infection, brachial neuritis, and iatrogenic injuries can lead to its dysfunction.[2-7)]

The serratus anterior muscle originates from the anterolateral surface of the first 8 or 9 ribs, and inserts at the anterior surface of the medial border of the scapula. This muscle functions in the protraction and lateral rotation of the scapula, and stabilizes the scapula while elevating the arm. The long thoracic nerve that innervates the serratus anterior muscle is long in shape and located subcutaneously over the ribs of the thorax ; therefore, it is very vulnerable to both direct and indirect injury.[8)]

Although most patients with serratus anterior palsy can be

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Table 1. Patients Data (Causes & Results)

Case No.	Sex/Age (yr)	Injured side	Causes of injury	Prior surgery	Apprehension test/ instability symptom	Electromyographic data	Scapula stabilization test	Postop complication	Postop winging	Pain score	Active flexion (preop/postop)	Constant-Murley score	Final result
1	F/30	R (D)	Ski injury	No	No	LTN palsy	+	No	No	5/0	110/170	64/98	E
2	M/45	L	Idiopathic	C6-7 laminectomy	No	LTN palsy	+	No	No	4/0	90/150	61/93	E
3	M/31	L (D)	Idiopathic	Long thoracic nerve decompression	Yes	LTN & DSN palsy	+	No	Mild	8/2	165/165	76/86	G
4	M/21	L	Traction	No	No	LTN palsy	+	-	-	7/-	80/-	58/-	-
5	M/33	R (D)	Idiopathic	No	No	LTN palsy	-	No	No	7/2	90/160	64/88	G
6	F/38	L	MVA	No	No	LTN palsy	- (no correction)	No	No	2/0	140/150	77/98	E
7	N/51	L	Work-related	No	No	LTN palsy	+	Pectoralis muscle spasm	No	10/5	100/160	54/91	E
8	F/25	R (D)	MVA	No	No	LTN palsy	+	No	No	10/2	80/155	40/93	E
9	F/33	R (D)	MVA	Bankart/Putti-Platt	No/secondary	LTN palsy	+	Recurrence	Severe	8/8	90/80	44/42	P
10	F/46	R (D)	Traction	Anterior capsular shift	Trace/secondary(?)	Normal	+	No	No	5/0	90/150	48/85	G
11	F/34	L	Work-related	No	No	LTN palsy	+	No	No	5/2	90/140	52/78	F
12	F/35	R (D)	MVA	No	No	LTN palsy	+	No	No	5/2	90/150	45/88	G
13	M/33	L	Work-related	Cervical discectomy	No/secondary	LTN palsy	+	Scapulothoracic bursitis	No	10/5	160/160	55/75	F
14	F/16	R (D)	Soccer injury	No	No	LTN palsy	+	No	No	5/0	130/160	72/98	E
15	F/30	R (D)	MVA	No	Yes	LTN palsy	+	No	No	5/2	80/160	58/88	G
16	M/38	R (D)	Work related	No	No/secondary	LTN palsy	+	Idiopathic pain syndrome	No	5/2	150/160	77/79	F
17	F/18	R (D)	Lacrosse injury	No	No/secondary	LTN palsy	+	No	No	2/0	160/170	86/98	E
18	F/31	R (D)	Work-related	No	No	LTN palsy	+	No	Mild	5/2	150/150	71/86	G
19	M/50	L (D)	MVA	No	No	LTN palsy	+	-	-	5/-	110/-	56/-	-
20	M/33	R (D)	Idiopathic	No	No/secondary	LTN palsy	+	No	No	5/0	140/150	64/96	E
21	M/38	L (D)	Work-related	Acromioplasty	No	LTN palsy	- (no correction)	-	-	8/-	80/-	42/-	-
22	F/21	L	Work-related	No	No	LTN palsy	+	No	No	5/0	90/170	54/98	E
23	F/29	L	MVA	Posterior capsulorraphy	No/secondary	LTN palsy	+	No	Mild	7/2	20/130	21/76	F
24	M/48	R (D)	Traction	No	No	LTN palsy	- (no correction)	No	No	8/2	60/125	28/91	E
25	F/38	R (D)	Roller skating injury	No	No	LTN palsy	+	-	-	7/-	80/-	-/-	-
26	F/39	R (D)	Work-related	Cervical discectomy	No	LTN palsy	+	-	-	5/-	150/-	-/-	-

F: female, M: male, R: right, L: left, D: dominant, MVA: motor vehicle accident, preop: preoperative, postop: postoperative, LTN: long thoracic nerve, DSN: dorsal scapula nerve, E: excellent, G: good, P: poor, F: fair.

treated conservatively, prolonged scapular winging after 12 to 24 months of non-operative management is an indication of surgery.[3,9] Different techniques have been introduced for the surgical stabilization of winged scapula.[10-16] Today, the split pectoralis major tendon transfer is widely used for surgical management of scapular winging.[13,15,17-21] However, owing to their being few examples and short follow-up periods, there is little information available regarding this technique for large groups and complete functional outcomes. This study was conducted to evaluate the functional outcome and clinical results in a relatively large group of patients with scapular winging caused by long thoracic nerve injuries.

Methods

Patient Selection

Between 1998 and 2006, 26 patients with serratus anterior dysfunction caused by long thoracic nerve palsy were treated with a split pectoralis major tendon transfer (sternal part) with autogenous hamstring tendon augmentation. All clinical and electromyographic data were reviewed retrospectively. For the final follow-up evaluation, five patients who had less than 12 months follow-up were excluded from the 26 patients due to too short follow-up period.

There were twelve men and fourteen women. The average age of the patients at the time of surgery was 34 years (range, 16–51 years). The dominant shoulder was involved in 18 of the 26 patients. Long thoracic nerve palsy resulted from idiopathic non-traumatic causes in four patients, and traumatic causes in 22 patients. Of the twenty-two patients who had a traumatic serratus anterior dysfunction, seven patients were involved in motor vehicle accidents, eight patients had work related injuries, four patients had sports injuries and three patients had minor traction injuries (Table 1). All patients had painful dysfunction of the shoulder, specifically posterior periscapular pain, scapular winging and weakness or loss of forward flexion of the arm.

In 25 of the 26 patients, long thoracic nerve injuries were documented in the electromyographic data. All patients were initially treated conservatively for at least 12 months: Most cases had the neuroplaxia-like paresis of long thoracic nerve, therefore we recommended rest and inhibition of lifting activity above the level of the scapula, which usually leads to complete recovery. The Costant-Murley score was used for postoperative functional evaluation.[22] The final results of the 21 patients were graded as excellent, good, fair and poor. Patients were scored as excellent when they were satisfied with their results, exhibited painless, full use of the arm for daily living activity, and had a full range of motion in the shoulder without scapular winging (Fig. 1). Patients received a score of good when they were satisfied with their results but had one or two of the following symptoms, including mild pain when using the arm for daily living activity, mild limitation of motion in the shoulder and mild scapular winging. Patients were scored as fair when they were not fully satisfied with their results, reporting mild pain when using the arm for daily living activities, and mild limitation of motion in the shoulder with or without mild scapular winging. Patients were scored as poor when they were not satisfied with their results, and noted recurrences of painful scapular winging.

Surgical Procedure

All procedures concerning the split pectoralis major tendon transfer with hamstring tendons augmentation for serratus anterior dysfunction have been explained in detail in previous articles.[15,23,24)]

A brief description of the surgical procedure is as follows (Fig. 2).

Postoperative Rehabilitation

A shoulder immobilizer with an abduction brace was applied in the operating room and worn for the first six weeks.

Fig. 1. (A) Scapular winging in patient with serratus anterior dysfunction. (B) Postoperative image showing scapular stabilization one year after surgery.

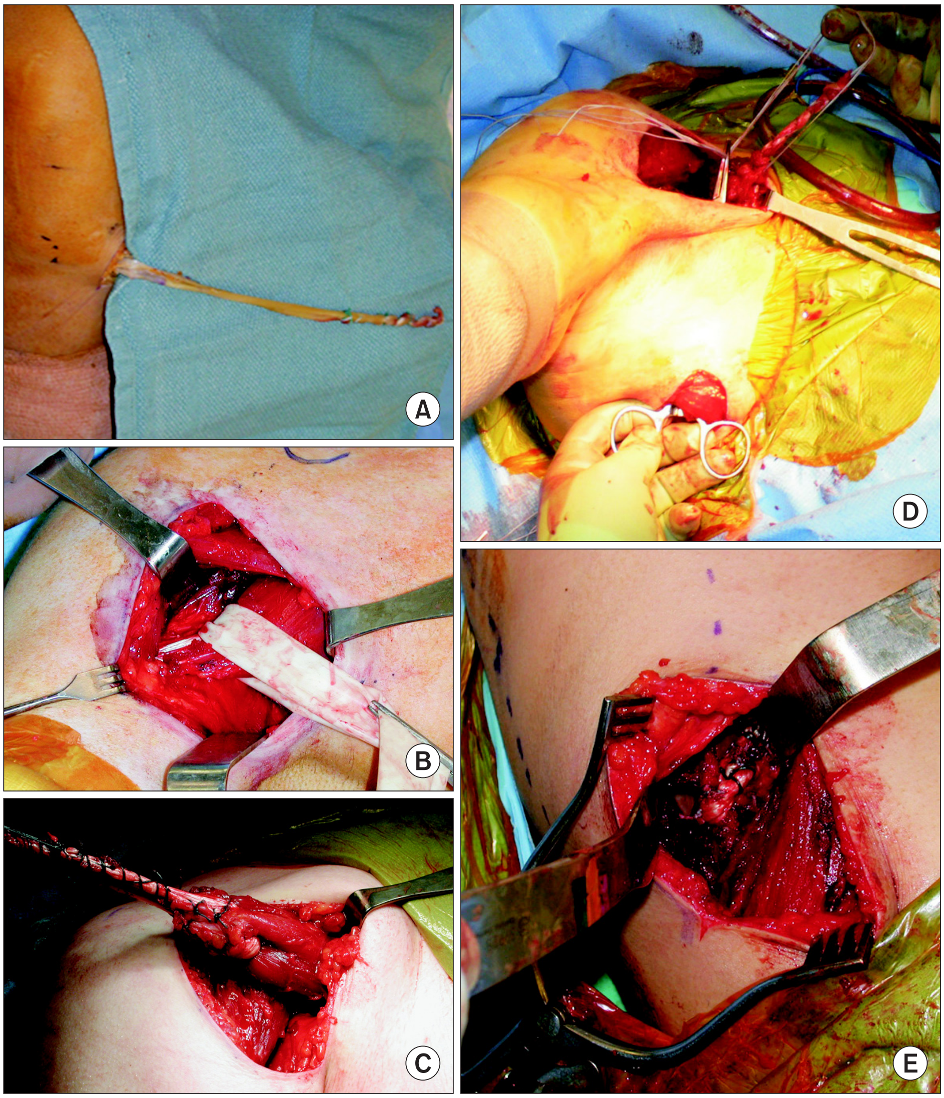

Fig. 2. Surgical procedure. (A) Hamstring autograft harvesting and preparation. (B) Split pectoralis major tendon dissection. (C) Preparation of pectoralis major tendon with hamstring autograft for transfer. (D) Preparation for recipient site of scapula and transfer path. (E) Securing of graft to inferior pole of scapula.

During this period, pendulum exercises and passive shoulder motion were encouraged to ensure the smooth gliding of the transferred tendon and graft, and to avoid scar formation. The sling was worn for the entire six weeks and taken off only for therapy. After six weeks, the sling was discontinued and active assisted range of motion as well as a home pulley unit was used. Water therapy was used if available. At three months, isometric strengthening exercises with elastic bands were started. A biofeedback program using Myotrac® (Thought Technology Ltd., Montreal West, QC, Canada) was started under the supervision of a well trained physical therapist. At six months, heavy labor or lifting was permitted. It was recommended that contact sports be avoided for one year after surgery.

Results

Twenty-six patients that underwent the procedure were evaluated clinically and electromyographically. The average follow up period was 42 months (range, 12–92 months).

All but one patient showed chronic denervation of the long thoracic nerve during electromyographic evaluation. The one exception was a patient who had normal electromyographic data despite typical scapular winging due to serratus anterior dysfunction. One of the twenty-five patients who had abnormal electromyographic data in the long thoracic nerve had a combined nerve injury in the dorsal scapular nerve, which might have developed via an idiopathic cause or a viral infection. Traumatic long thoracic nerve palsy was observed in 22 of the 26 patients as a result of accidents (7 patients), sports and minor injuries (7 patients), and work-related (mainly heavy lifting) injuries (8 patients) (Table 1).

The mean period from the beginning of symptomatic scapular winging to surgery was 48 months (range, 12–120 months). Seven patients had previous operations including one cervical laminectomy, one cervical discectomy, one long thoracic nerve decompression, one anterior capsular shift, one posterior capsular shift, one Putty-Platt procedure, and two acromioplasties in one patient. A scapular stabilization test improved the forward elevation of the arm in 22 patients, but could not stabilize the scapula in four patients (Table 1).

Instability was a concern in nine patients. Two patients had positive apprehension tests, while the other seven felt instability symptoms without apprehension signs on physical examination, despite three of these seven patients having prior instability operations (two had open surgery for anterior instability and one had arthroscopic posterior capsulorrhaphy). Instability symptoms were relieved in seven patients after surgical dynamic stabilization of the scapula. Two patients showed glenohumeral instability with scapular winging, and their positive apprehension signs remained after surgical correction for scapular winging. These patients were advised to get surgery for glenohumeral instability.

Twenty of the patients experienced pain relief from the procedure, with eight patients experiencing no pain and twelve patients experiencing mild pain. The pain scores of patients improved from an average of 6.0 out of 10 preoperatively to an average of 1.8 out of 10 postoperatively. The mean active forward elevation improved from 108° (range, 20°–165°) preoperatively to 151° (range, 125°–170°) postoperatively. The mean Constant-Murley score improved from 57.7 (range, 21–86) preoperatively to 86.9 (range, 42–98) postoperatively (Table 2).

Preoperatively, severe scapular winging was observed in all patients. After performing a split pectoralis major tendon transfer with autogenous semitendinous and gracilis augmentation, the winging was completely corrected in 18 of the 21 patients, mild winging remained in two patients, and severe scapular winging was recurrent in one patient. Although one patient had scapular winging caused by multiple nerve injuries, involving both the long thoracic nerve and dorsal scapular nerve, he had an excellent outcome.

Postoperative complications developed in 4 of the 21 patients (19.0%). A recurrence of scapular winging 11 months after surgical dynamic stabilization occurred in one patient (4.8%), which was managed with a scapulothoracic fusion. A pectoralis major muscle spasm developed in one patient, but improved with physical therapy. A scapulothoracic bursitis developed in one patient and was treated with injection therapy into the bursa. Idiopathic upper extremity pain syndrome developed in one patient and was managed in the pain clinic department. No other complicated symptoms were developed on the donor sites for harvesting of the semitendinous and gracilis tendons. All complications developed in trauma-related patients with one failure in a motor vehicle accident group, and the other three complications in the work-related injuries group.

In the final follow-up, ten of the twenty-one patients (47.6%) had excellent results, six patients (28.6%) had good results, four

Table 2. Analysis of Final Results by the Causes of Injury

Variable	Non-traumatic; idiopathic, viral (4 shoulders)		Motor vehicle accident (6 shoulders)		Sport & minor trauma (5 shoulders)		Work-related (6 shoulders)		Total (21 shoulders)	
	Preoperative	Postoperative	Preoperative	Postoperative	Preoperative	Postoperative	Preoperative	Postoperative	Preoperative	Postoperative
Active flexion (°)*	121 (90–165)	156 (150–165)	83 (20–140)	138 (80–160)	110 (60–160)	155 (125–170)	123 (90–150)	157 (140–170)	108 (20–165)	151 (80–170)
Constant-Murley score (0–100)*	66.3 (61–76)	90.8 (86–96)	47.5 (21–77)	80.8 (42–98)	59.6 (28–86)	94.0 (85–98)	60.5 (42–77)	84.5 (75–98)	57.7 (21–86)	86.9 (42–98)
Pain score (0–10)*	6.0 (4–8)	1.0 (0–2)	6.2 (2–10)	2.7 (2–8)	5.0 (2–8)	0.4 (0–2)	6.7 (5–10)	2.7 (0–5)	6.0 (2–10)	1.8 (0–8)
Postoperative complication	None		Recurrence (1)†		None		Muscle spasm (1)† Scapulothoracic bursitis (1)† Idiopathic upper extremity pain (1)†		Complication rate: 4/21 (19.0)‡ Recurrence rate: 1/21 (4.8)‡	
Final patient satisfaction	S: 4/4†		S: 4/6† I: 1/6† N:1/6†		S: 4/5† I: 1/5†		S: 2/6† I: 3/6† N: 1/6†		S: 15/21 (71)‡ I: 4/21 (19)‡ N: 2/21 (10)‡	

S: completely satisfied, I: improved but not completely satisfied, N: non-satisfied.
*Values are presented as median (range). †Values are presented as number only. ‡Values are presented as number/total number (%).

patients (19.0%) had fair results, and one patient (4.8%) had poor results.

Discussion

Although the majority of cases of serratus anterior dysfunction due to long thoracic nerve palsy recover spontaneously with conservative management, a 26% mean failure rate for conservative treatment was reported.[2)] If symptomatic serratus anterior dysfunction persists for more than 16 months under conservative treatment, then surgical management is indicated.[15)] Nerve transfer using the thoracodorsal nerve for acute long thoracic nerve palsy has been reported,[25)] but this procedure has lower success rates and is not effective on patients with nerve palsy lasting more than a year.[26)]

For patients with chronic long thoracic nerve palsy, several different surgical techniques (scapulothoracic fusion, scapulopexy, tendon transfer) were introduced to stabilize the scapula[10,11,14)] Dynamic stabilization of the scapula using the pectoralis major tendon transfer enables return of almost normal symptomatic and functional improvement; therefore, it is widely used for the surgical management of symptomatic refractory scapular winging by serratus anterior dysfunction.[4,13,15,17,21)] Although many different muscles, such as the pectoralis minor, rhomboid, and levator scapula are used for tendon transfers,[27,28)] the pectoralis major muscle is most useful because of its similar excursion and power to the serratus anterior muscle.[2,29)]

Split pectoralis major tendon transfer resolved the problem of cosmetic concerns around the breast, and augmentation with twisted, multilayered fascia lata[9,13)] or hamstring autograft[15)] was introduced to decrease the failure rate on the attached site of the transferred tendon. Direct contact of the transferred split pectoralis major tendon to the inferior angle of the scapula was recommended for improving tendon to bone healing.[17)]

Long thoracic nerve palsy can be developed by non-traumatic and/or traumatic episodes. Vastamäki and Kauppila[6)] investigated etiologic factors in the isolated paralysis of the serratus anterior muscle in 197 patients, and found that non-traumatic episodes (22.8%), such as idiopathic or viral infections, were less common than traumatic episodes (77.2%), such as traction or compression injuries. In our series, all patients with an irreversible long thoracic nerve injury had surgical dynamic stabilization of the scapula, and this was caused by minor or major trauma in 20 of the 26 patients (83%).

Warner and Navarro[15)] reported that long thoracic nerve palsy could not be confirmed in many patients with scapular winging by electromyographic findings, and proposed the possibility of an inadequate electromyographic study or direct injury to the serratus anterior as its cause. However, in this series, we were able to obtain positive electromyographic findings for long thoracic nerve palsy in 23 of the 24 patients. These findings indicate that the accuracy of electromyographic diagnosis has recently improved because of increased concerns of long thoracic nerve injuries.

The scapular stabilization test[15)] helped confirm loss of scapular stabilization, but there is no relationship between the success of scapular stabilization surgery and positive test results. This was demonstrated when we achieved excellent results after split pectoralis major tendon transfer with hamstring augmentation in three patients, whose scapular winging could not be corrected with the scapular stabilization test owing to the fixed stiffness of the scapula.

As previously described,[13)] there is a relationship between scapular winging and glenohumeral instability, in that scapular winging can make patients feel instability symptoms. However, actual apprehension tests can be negative in patients that develop instability symptoms secondarily via the scapular dyskinesis if we attempt physical examination in the supine position with a well-stabilized scapula.

In our series, nine patients were concerned with instability symptoms. In seven patients instability symptoms disappeared after surgical dynamic stabilization of the scapula with split pectoralis major tendon transfer (Table 1). However two patients with positive apprehension tests still had glenohumeral instability, despite correcting their scapular winging by surgical dynamic stabilization, and an additional surgery for glenohumeral instability was recommended.

In most of the patients, we were able to achieve improvements in range of motion, correction of scapular winging, and significant pain relief in the shoulder.

Specifically, scapular winging was completely corrected by surgery in 17 of the 21 patients, while mild winging remained in 3 of the 21 patients.

Overly intensive rehabilitation[17)] or premature return to heavy lifting[18)] were noted as a cause of failure, as these could cause stretching or tearing of the graft extension or augmentation. By using hamstring augmentation, we can obtain a very strong connection between the transferred pectoralis major tendon and the scapula. It is well known that hamstring tendons are much stronger than the fascia lata, as shown in biomechanical studies.[30)]

In our series we experienced one failure 11 months after surgery. This was a late development of recurrence compared to other failure reports for pectoralis major tendon transfer with fascia lata augmentation.[17,18)] This indicates that the cause of failure in our series was not the weak strength of the connection between the transferred tendon and the augmented autograft, but rather a problem in bone healing of the transferred tendon. In other words, the hamstring autograft was strong enough for augmentation of the transferred tendon in dynamic scapular stabilization, but the transferred tendon to bone healing is another important factor that must be considered to ensure good outcomes. Therefore, as Connor et al.[17] recommended, obtaining direct contact between the transferred split pectoralis major tendon and the inferior angle of the scapula is important to inducing the tendon to heal to the bone.

Complication rates after a split pectoralis major transfer for serratus anterior dysfunction are variable in the literature.[15,17,18,21] Although many different kinds of complications have been reported, recurrence was the worst among the following complications: graft failure, adhesive capsulitis, infection, herniation of thigh muscle, and seroma on the thigh.[15,17-19,21] All reported failures usually developed as graft failures within a few months of surgery due to aggressive physical therapy or heavy manual labor.[17,20] However, changing the graft augmentation technique to use twisted, multilayered fascia lata or hamstring tendons, decreases the earlier reported failure rates.[13,15,17]

Conclusion

Split pectoralis major transfer with hamstring augmentation can stabilize the winged scapula by long thoracic nerve palsy, and result in good functional outcome and pain relief. Augmented hamstring tendon grafts provide a strong enough connection between the transferred pectoralis major tendon and the scapula. Although failures have been reported in previous series, as well as our own, these all developed within 12 months. Therefore at least one year of protection is needed to inhibit chronic stretching or tearing of the grafted tendon.[17,18] Accordingly, it is important to create a supportive environment around the transferred tendon for tendon to bone healing to decrease the failure rate.

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