

Outcomes After Dermal Allograft Reconstruction of Chronic or Subacute Pectoralis Major Tendon Ruptures

Julie A. Neumann,^{*†} MD, Christopher M. Klein,[†] BS, Carola F. van Eck,[†] MD, Hithem Rahmi,[†] DO, and John M. Itamura,[†] MD

Investigation performed at the Kerlan-Jobe Orthopaedic Clinic at White Memorial Medical Center, Los Angeles, California, USA

Background: Avoiding delay in the surgical management of pectoralis major (PM) ruptures optimizes outcomes. However, this is not always possible, and when a tear becomes chronic or when a subacute tear has poor tissue quality, a graft can facilitate reconstruction.

Purpose: The primary aim was to evaluate the clinical outcomes of PM reconstruction with dermal allograft augmentation for chronic tears or for subacute tears with poor tissue quality. A second aim was to determine patient and surgical factors affecting outcome.

Study Design: Case series; Level of evidence, 4.

Methods: Nineteen consecutive patients (19 PM ruptures) with a mean \pm SD age of 39.1 ± 8.4 years were retrospectively reviewed at 26.4 ± 16.0 months following PM tendon reconstruction with dermal allograft. Surgery was performed at 19.2 ± 41.2 months after injury (median, 7.6 months; range, 1.1-185.4 months). Several outcome scores were recorded pre- and postoperatively, including Disabilities of the Arm, Shoulder, and Hand (DASH), as well as visual analog scale (VAS) (range, 0-10; 0 = no pain) and Single Assessment Numeric Evaluation (SANE). Range of motion, Constant score, American Shoulder and Elbow Surgeons (ASES) score, Simple Shoulder Test score, and complications/reoperations were recorded postoperatively.

Results: Scores improved significantly for the DASH (preoperative, 34.9; postoperative, 8.0; $P < .001$) and VAS (preoperative, 5.0; postoperative, 1.5; $P = .011$). There was a trend toward improved SANE scores (preoperative, 15.0; postoperative, 80.0; $P = .097$), but the difference was not statistically significant, likely because of the small number of patients having preoperative SANE scores for review. Increased age was associated with higher VAS scores ($r = 0.628$, $P = .016$) and less forward flexion ($r = -0.502$, $P = .048$) and external rotation ($r = -0.654$, $P = .006$). Patients with workers' compensation had lower scores for 3 measures: SANE (75.8 vs 88.4, $P = .040$), Constant (86.7 vs 93.4, $P = .019$), and ASES (81.9 vs 97.4, $P = .016$). Operating on the dominant extremity resulted in lower Constant scores (87.8 vs 95.4, $P = .012$). A 2-head tendon tear (107.5° vs 123.3° , $P = .033$) and the use of >1 graft (105.0° vs 121.3° , $P = .040$) resulted in decreased abduction.

Conclusion: This was the first large series to observe patients with chronic or subacute PM tendon tears treated with dermal allograft reconstruction. PM tendon reconstruction with dermal allografts resulted in good objective and subjective patient-reported outcomes.

Keywords: pectoralis major; allograft; chronic rupture; reconstruction; clinical outcome

Pectoralis major (PM) tendon ruptures are a rare injury caused by an eccentric contraction leading to tendon avulsion from the humeral insertion.^{3,11,18,24} PM tendon ruptures most commonly occur during weight lifting but have been reported in other athletic activities, such as football, wrestling, rugby, and waterskiing.^{11,16,18} The primary role of the PM is adducting and internally rotating the humerus.⁶ PM tendon ruptures often peak among patients

between 20 and 40 years of age,^{6,11,18} and they occur almost exclusively in males.^{6,14,18} Steroid use increases the susceptibility of the PM tendon to injury.^{1,6,7,11,18,21,24} Ruptures of the PM tendon are occurring at an increasing incidence owing to higher awareness in fitness, including weight training.^{6,21} Patients often report hearing a pop, followed by immediate pain, deformity, weakness, and swelling.⁶ On examination, patients typically have a palpable defect, an asymmetric axillary fold, weakness in resisted shoulder adduction and internal rotation, and possibly ecchymosis.¹⁸ Diagnosis of a PM tendon tear is primarily clinical, but magnetic resonance imaging is the modality of choice to

The Orthopaedic Journal of Sports Medicine, 6(1), 2325967117745834

DOI: 10.1177/2325967117745834

© The Author(s) 2018

This open-access article is published and distributed under the Creative Commons Attribution - NonCommercial - No Derivatives License (<http://creativecommons.org/licenses/by-nc-nd/4.0/>), which permits the noncommercial use, distribution, and reproduction of the article in any medium, provided the original author and source are credited. You may not alter, transform, or build upon this article without the permission of the Author(s). For reprints and permission queries, please visit SAGE's website at <http://www.sagepub.com/journalsPermissions.nav>.

supplement findings obtained during the history and physical examination.^{6,18} PM injuries fall into 1 of 3 categories based on the Tietjen classification: contusion, partial tearing, and complete tearing.^{6,11,18}

With the exception of older sedentary patients or those who have proximal muscle belly tears, surgery is generally recommended.^{6,11,15,18} Indications for surgical intervention include complete tears, tears at the myotendinous junction, intratendinous tears, or tears at the tendinous insertion.^{6,11} Surgery has demonstrated superior outcomes to nonoperative management even if delayed. Multiple studies have shown that if treated nonoperatively, patients may report strength deficits that render them unable to return to competitive activities.^{7,8,12,17,24,27} Additionally, Bak and colleagues³ performed a meta-analysis demonstrating that 88% of patients who underwent surgical repair reported excellent or good results versus 27% treated nonoperatively.

There is no consensus on the definition of an acute versus a chronic PM tendon rupture.¹¹ Flint and colleagues¹⁰ defined the injuries based on the timing of surgical intervention. If the surgery is performed within 6 weeks from the date of injury, the rupture is classified as acute, whereas chronic ruptures are those in which surgery is performed after 6 weeks from the original injury. Regardless of the definition of acute versus chronic ruptures and although multiple studies have shown that delayed repair of PM tendon tears can yield good outcomes,^{6,21,28} other studies have indicated that surgically intervening sooner leads to better patient outcomes.^{1-3,7,18,27} Moreover, prognosis is not related to patient age or location of rupture but rather when the rupture is repaired.³

Unfortunately, it is not uncommon for PM tendon ruptures to be missed or misdiagnosed initially, which may result in delay in treatment.^{12,14,18} Additionally, patients may treat themselves for a presumed strain or sprain and further delay treatment.¹⁸ Patients may also sustain a rerupture of a previously repaired PM. Surgery for patients with chronic injury or a rerupture of a previously repaired PM is more technically difficult, as it requires increased surgical exposure and dissection, owing to muscle retraction, scarring, poor tissue quality, and adhesions.^{11,18} Chronic injuries, as well as subacute injuries where tissue quality may be poor, may necessitate an auto- or allograft because a direct repair may no longer be possible.^{6,11}

In addition to the challenges associated with repair of a chronically or subacutely torn PM, other anatomic factors make PM tendon repair difficult. One of these challenges is the short length of the sternal and clavicular tendons of the PM. This translates into difficulty in obtaining adequate fixation within the tendon itself, even if the PM injury is addressed in the acute setting. Thus, it is important to have a reliable method to treat chronically torn PM tendon or

subacute tears with poor tissue quality. One of the many advantages of using a dermal allograft, as used in this study, is that as a soft tissue augment, the graft increases the surface area of the repair through which suture can be passed. This means that the surgeon can place the graft over the muscle belly and then pass multiple sutures through the graft and native tissue without strangulating the muscle belly, since forces are adequately dispersed. Additionally, based on graft properties, dermal allografts may provide a favorable biological environment for soft tissue healing.

Despite the numerous surgical techniques described for repair of acute tears of the PM tendon,¹¹ only a handful of techniques have been described with grafts to augment the repair of a chronically torn PM tendon or a torn PM tendon with poor tissue quality.^{5,14,20,23,25,26} They include the use of a bone-patellar tendon autograft, hamstring autograft, Achilles tendon allograft, and fascia lata allograft. These are only case reports or small case series with limited objective outcomes. To our knowledge, only 1 case report examined dermal allograft for PM reconstruction.⁹ Thus, this is the first large series comprising patients with chronic PM tears or with subacute PM tears with poor tissue quality who were treated with a dermal allograft, which is approved by the United States Food and Drug Administration for use in augmentation of PM tendon repairs.

The primary aim of this study was to evaluate the clinical outcome of PM reconstruction with dermal allograft augmentation for chronic tears or subacute tears with poor tissue quality. The secondary aim was to determine patient and surgical factors affecting outcome.

METHODS

Participants

Institutional review board approval was obtained before this study was conducted (No. Pro00045088). Inclusion criteria were a full-thickness PM tendon tear detected on clinical examination and/or magnetic resonance imaging by the senior surgeon (J.M.I.), with a minimum of 4 weeks between the date of injury and the date of surgery and with a minimum follow-up of 6 months. These tears were considered either chronic PM tendon tears (>6 weeks between date of injury and date of surgery) with or without poor tendon quality or subacute PM tendon tears (4-6 weeks between date of injury and date of surgery) with poor tissue quality. From May 2012 to January 2016, a total of 19 consecutive patients (19 PM tendon ruptures) met the inclusion criteria. These 19 patients were 100% of the total number of patients who underwent surgery for a PM tendon repair during this period, as the senior surgeon is a consultant for complicated shoulder and elbow cases. The

*Address correspondence to Julie A. Neumann, MD, 614 13th Avenue, Salt Lake City, UT 84103, USA (email: Julie.Neumann.MD@gmail.com).

[†]Kerlan-Jobe Orthopaedic Clinic at White Memorial Medical Center, Cedars-Sinai Medical Center, Los Angeles, California, USA.

One or more of the authors has declared the following potential conflict of interest or source of funding: J.M.I. is a paid consultant for Acumed and Arthrex; is a paid speaker for Acumed, Arthrex, and Tornier; receives research support from Acumed; and receives royalties from Tornier.

Ethical approval for this study was received from the Cedars-Sinai Office of Research Compliance and Quality Improvement (Institutional Review Board No. Pro00045088).

patients in this study received a dermal allograft with either an ArthroFLEX Decellularized Dermal Allograft (Arthrex) or GraftJacket (Wright Medical Technology) for rupture of the PM tendon. The senior surgeon performed all surgical procedures with the technique described here.

Outcomes

Final follow-up data were collected during routine postoperative visits at 26.4 ± 16.0 months postsurgery. Of the 19 patients, 11 had follow-up ≥ 24 months. Subjective outcome measures included Disabilities of the Arm, Shoulder, and Hand (DASH), visual analog scale (VAS) for pain (0-10, 0 = no pain), Single Assessment Numeric Evaluation (SANE), Constant score, American Shoulder and Elbow Surgeons (ASES) score, and Simple Shoulder Test. Objective outcome measures included active range of motion (ROM) measured by goniometer for forward flexion, abduction in the scapular plane (scaption), external rotation at 0° of abduction, and internal rotation at the side. Complications and reoperations were recorded.

Surgical Technique

Patients received a preoperative interscalene nerve block by the anesthesia team. The procedure was performed under general anesthesia, and patients were placed in the supine position. A deltopectoral approach was utilized. The sternal and clavicular heads of the PM were identified. If only 1 head was torn, the following steps apply only to that head. If both heads were torn, each head underwent the following steps. The abnormal PM tendon was debrided, leaving a stable tendon stump capable of retaining sutures. A rip-stop suture was then placed into the native tendon to control the tendon. The tendon was evaluated specifically for retraction, type of tearing, and excursion. At this point, if the tendon stump was not able to be mobilized to its insertion on the humerus or if the stump was too frayed to adequately retain sutures, an allograft was utilized. Given the chronic nature of the tears, the PM tendon and the muscle belly were wrapped with an appropriately sized dermal allograft and then sutured in a Krackow pattern with 2 No. 5 FiberWire sutures through both graft and underlying native PM tendon and muscle (Figure 1). Two allografts were used in 7 cases (36.8%) of severe retraction and where the sternal and clavicular heads were completely torn. Including the rip-stop suture, a total of 4 to 6 suture strands came from each PM head.

Lateral to the bicipital groove, the PM tendon footprint was exposed and roughened up with a Midas Rex (Medtronic) until bleeding cortical bone was achieved. The PM tendon repair was performed with cortical buttons (Pec Button; Arthrex) for 8 patients (42.1%), 4.75-mm Biocomposite SwiveLocks or 5.5-mm Biocomposite FT suture anchor (Arthrex) for 9 patients (47.4%), or a combination thereof for 2 patients (10.5%). The fixation devices were staggered on the humerus to prevent stress risers. The arm was abducted and externally rotated to optimize the tension of the PM tendon repair. When appropriate tension had been achieved, the fixation devices were placed. In the

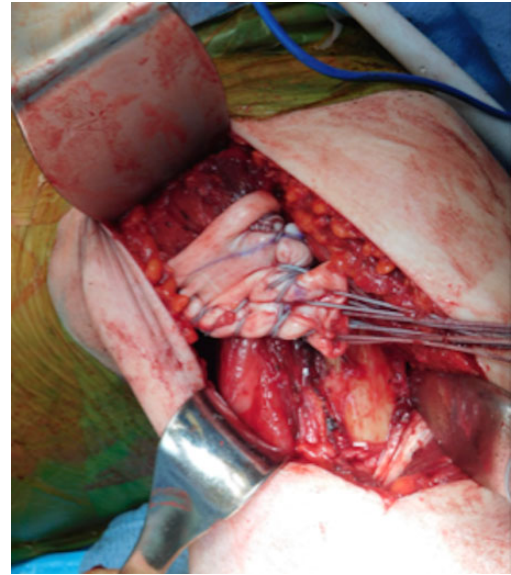


Figure 1. An intraoperative photograph of a left pectoralis major, as visualized through the deltopectoral approach. A rip-stop suture was used to gain control of the clavicular head of the pectoralis major. The clavicular head, including its tendon, was wrapped with an appropriately sized dermal allograft, and 2 No. 5 FiberWire sutures were passed in Krackow pattern through the graft and the native muscle and tendon.

patients for which pectoralis buttons were utilized, the buttons were inserted unicortically, and the sutures were toggled until the tendon was completely reduced to the bone (Figure 2). The sutures from each button were tied to each other. Once tied down, the sutures were then passed back through the dermal allograft and tied to each other again to achieve additional fixation.

Additionally, stem cells were applied to the surgical site at the conclusion of the repair for 9 patients (47.4%). The stem cells utilized (BioDFactor; Derma Sciences) were a morselized tissue allograft derived from human placental tissues. The senior author utilized stem cells to improve healing potential as well as to decrease scar formation about the PM, in turn improving postoperative subjective and objective outcomes.

The wound was copiously irrigated, and Tisseel (Baxter International Inc) was used for hemostasis. A layered closure was performed over a drain. Sterile dressing was applied and the patient placed in a shoulder sling. A postoperative radiograph was obtained in the postanesthesia recovery room (Figure 3).

Rehabilitation

For the first 6 weeks, patients were instructed to remain immobilized in the shoulder sling at all times. Physical therapy began on postoperative week 6 and consisted of 4 phases. For postoperative weeks 6 through 12, phase 1 focused on pain-free passive ROM and active-assisted ROM combined with scapular stabilization exercises. There was



Figure 2. This left-sided pectoralis major tendon repair was performed with the use of pectoralis cortical buttons. This intraoperative photograph was taken with the arm abducted and externally rotated after the final construct had been tensioned.

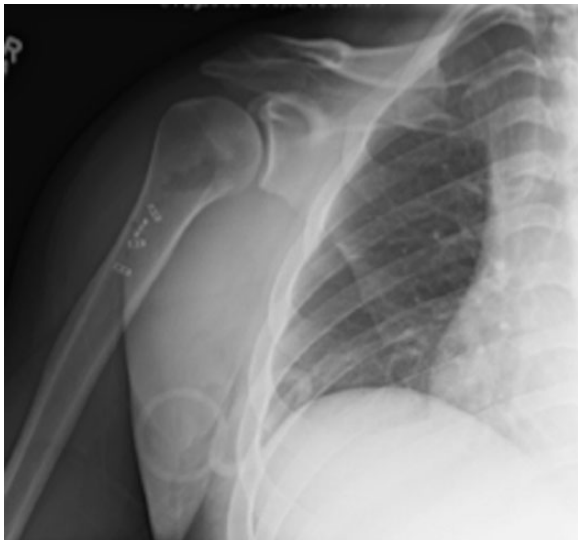


Figure 3. An anterior-to-posterior postoperative radiograph obtained in the postanesthesia recovery room to verify placement of the pectoralis buttons within the canal of the right proximal humerus.

no resisted internal rotation or adduction during phase 1. Phase 2 included weeks 12 to 16, and it focused on progressive return to full active ROM. Patients were allowed to begin cycling and running. Phase 3 began at 16 weeks with more aggressive scapular stabilization as well as eccentric strengthening. With the goal of maintaining ROM, patients were allowed to begin plyometrics as well as a throwing

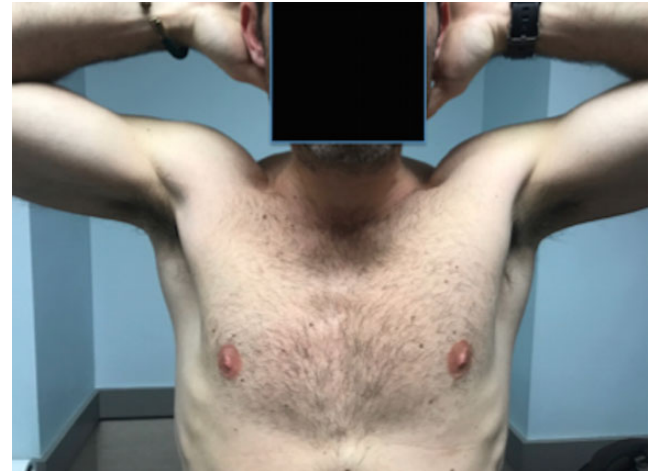


Figure 4. This patient returned to clinic 32 months after his right pectoralis major tendon repair with an augmenting dermal allograft. He returned to workouts with no difficulty and was satisfied with his repair.

program. Phase 4, the final phase, began 5 months postoperatively. The goal of phase 4 was slow return to full activities as tolerated. Figure 4 shows a patient who had his follow-up appointment 32 months after his right PM tendon repair with dermal allograft. He returned to workouts with no difficulty and was satisfied with the repair.

Statistical Analysis

Descriptive statistics, including mean, range, and standard deviation, were calculated for all continuous variables. Ratios and percentages were calculated for the nominal variables. A paired *t* test was used to compare the DASH, VAS, and SANE scores pre- and postoperatively. An independent samples *t* test or analysis of variance with post hoc Tukey tested the influence of age, workers' compensation status, hand dominance, tear pattern, number of grafts used, revision surgery, fixation method, and addition of stem cells on the continuous outcomes at final follow-up. The chi-square test or Fisher exact test determined the influence of age, workers' compensation status, hand dominance, number of tendon heads torn, number of grafts used, revision surgery, fixation method, and addition of stem cells on the nominal outcomes at final follow-up. A Pearson correlation coefficient was used to examine the relationship between time from injury to surgery and outcomes at final follow-up. The *P* value for statistical significance was set at .05. Data processing and analysis were performed with SPSS (v 24; IBM).

RESULTS

Patient characteristics were as follows (mean \pm SD): age, 39.1 ± 8.4 years; height, 184.6 ± 7.7 cm; weight, 102.7 ± 9.6 kg; body mass index, 30.2 ± 3.6 ; time between injury and surgery, 19.2 ± 41.2 months (median, 7.6 months; range, 1.1-185.4 months). All 19 patients (100%) in this study were

TABLE 1
Pre- and Postoperative Objective and Patient-Reported Outcome Measures^a

	Preoperative	Postoperative	P Value
DASH	34.9 ± 18.1	8.0 ± 12.2	<.001 ^b
Visual analog scale	5.0 ± 2.2	1.5 ± 2.1	.011 ^b
SANE	15.0 ± 7.1	80.0 ± 7.1	.097
Constant		90.1 ± 4.9	
ASES		90.3 ± 12.3	
Simple Shoulder Test		11.8 ± 0.7	
Range of motion, deg			
Forward flexion		169.1 ± 20.0	
Abduction		114.3 ± 15.0	
External rotation		61.3 ± 13.1	

^aData are presented as mean ± SD scores or degrees (where indicated). ASES, American Shoulder and Elbow Surgeons; DASH, Disabilities of the Arm, Shoulder, and Hand; SANE, Single Assessment Numeric Evaluation.

^bStatistically significant difference ($P < .05$).

male and right-hand dominant. Of the 19 surgical procedures, 5 (26.3%) were performed for nondominant (left) PM tendon ruptures. Injury mechanisms were as follows: bench pressing or other workout ($n = 7$), work related (8), skiing (2), cliff jumping (1), and bar fight (1). Of the 8 injuries (42.1%) that occurred at work, occupations included law enforcement ($n = 5$), firefighter (1), construction worker (1), and airline technician (1). One head of the tendon (sternal or clavicular) was involved in 9 cases (47.4%). Every time that only 1 head of the tendon was involved, it was always the sternal head. Both heads were torn in the remaining 10 cases (52.6%). For 4 patients (21.1%), the procedure involved a revision surgery.

Table 1 displays the pre- and postoperative objective and patient-reported outcome measures. Scores for DASH (from 34.9 to 8.0, $P < .001$) and VAS (from 5.0 to 1.5, $P = .011$) improved significantly pre- to postoperatively. There was a trend toward improved SANE scores (from 15.0 to 80.0, $P = .097$) but the difference was not significant, likely because of the small number of patients having preoperative SANE scores for review. Internal rotation at the side at final follow-up was as follows: to T5 for 3 patients (15.8%), T7 for 3 (15.8%), T10 for 2 (10.5%), T12 for 6 (31.6%), L3 for 1 (5.3%), and the sacroiliac joint for 1 (5.3%). It was not recorded for 3 patients (15.8%).

Age ≥ 40 years was associated with an inferior outcome with regard to external rotation only (Table 2). In terms of age on a continuous scale, an increased age was associated with a higher postoperative VAS score ($r = 0.628$, $P = .016$) and less forward flexion ($r = -0.502$, $P = .048$) and external rotation ($r = -0.654$, $P = .006$) at final follow-up.

Table 3 displays the effect of workers' compensation status on the outcome after surgery. Table 4 presents the effect of arm dominance on the outcomes after surgery. Tables 5 and 6 show the difference in outcome between 1- and 2-head tendon tears and 1- and 2-graft repairs, respectively.

There was no difference in any of the outcome measures at final follow-up between those patients undergoing

TABLE 2
Difference in Objective and Patient-Reported Outcome Measures at Final Follow-up Between Patients <40 and ≥ 40 Years Old^a

	Age, y		P Value
	<40 ($n = 10$)	≥ 40 ($n = 9$)	
DASH	9.2 ± 12.5	9.2 ± 9.2	.960
Visual analog scale	0.5 ± 0.8	2.0 ± 2.4	.170
SANE	82.5 ± 9.4	82.7 ± 13.6	.975
Constant	90.6 ± 3.1	89.4 ± 7.4	.725
ASES	94.4 ± 5.3	86.7 ± 15.7	.274
Simple Shoulder Test	12.0 ± 0.0	11.3 ± 1.2	.220
Range of motion, deg			
Forward flexion	172.3 ± 9.7	164.3 ± 28.8	.419
Abduction	111.1 ± 13.0	120.0 ± 18.7	.308
External rotation	67.8 ± 9.7	52.9 ± 12.5	.018 ^b

^aData are presented as mean ± SD scores or degrees (where indicated). ASES, American Shoulder and Elbow Surgeons; DASH, Disabilities of the Arm, Shoulder, and Hand; SANE, Single Assessment Numeric Evaluation.

^bStatistically significant difference ($P < .05$).

TABLE 3
Difference in Objective and Patient-Reported Outcome Measures at Final Follow-up Between Patients With and Without Workers' Compensation Injury Status^a

	No Workers' Compensation ($n = 11$)	Workers' Compensation ($n = 8$)	P Value
DASH	9.1 ± 12.5	9.8 ± 9.1	.894
Visual analog scale	0.9 ± 2.1	2.0 ± 1.8	.313
SANE	88.4 ± 9.7	75.8 ± 9.7	.040 ^b
Constant	93.4 ± 3.8	86.7 ± 3.4	.019 ^b
ASES	97.4 ± 4.3	81.9 ± 13.7	.016 ^b
Simple Shoulder Test	12.0 ± 0.0	11.3 ± 1.2	.220
Range of motion, deg			
Forward flexion	165.0 ± 26.2	174.3 ± 5.3	.375
Abduction	110.0 ± 14.1	118.6 ± 15.7	.305
External rotation	60.0 ± 13.9	62.9 ± 12.9	.680

^aData are presented as mean ± SD scores or degrees (where indicated). ASES, American Shoulder and Elbow Surgeons; DASH, Disabilities of the Arm, Shoulder, and Hand; SANE, Single Assessment Numeric Evaluation.

^bStatistically significant difference ($P < .05$).

primary and revision surgery. The type of fixation used and the additional use of stem cells did not influence outcomes. A longer delay between injury and surgery was associated with a lower postoperative Constant score ($r = 0.680$, $P = .031$). Additionally, no effects on patient outcomes were found in the comparison of tears fixed <6 weeks to 3 months to 6 months after injury.

There were no complications, including deformity or rerupture of the PM tendon, humeral fracture, hematoma,

TABLE 4
Difference in Objective and Patient-Reported Outcome Measures at Final Follow-up Between Patients Receiving Surgery on Their Dominant and Nondominant Arms^a

	Nondominant Arm (n = 5)	Dominant Arm (n = 14)	P Value
DASH	13.9 ± 13.7	7.5 ± 9.7	.295
Visual analog scale	0.8 ± 1.0	1.6 ± 2.3	.491
SANE	84.8 ± 18.9	81.7 ± 7.5	.671
Constant	95.4 ± 3.8	87.8 ± 3.3	.012 ^b
ASES	90.4 ± 12.7	90.2 ± 13.9	.977
Simple Shoulder Test	12.0 ± 0.0	11.6 ± 0.9	.482
Range of motion, deg			
Forward flexion	171.0 ± 12.4	168.2 ± 23.2	.874
Abduction	112.0 ± 13.0	115.6 ± 16.7	.689
External rotation	58.0 ± 4.5	62.7 ± 15.6	.522

^aData are presented as mean ± SD scores or degrees (where indicated). ASES, American Shoulder and Elbow Surgeons; DASH, Disabilities of the Arm, Shoulder, and Hand; SANE, Single Assessment Numeric Evaluation.

^bStatistically significant difference ($P < .05$).

TABLE 5
Difference in Objective and Patient-Reported Outcome Measures at Final Follow-up Between Patients With a 1- and 2-Head Tendon Tear^a

	1-Tendon Tear (n = 9)	2-Tendon Tear (n = 10)	P Value
DASH	14.7 ± 13.7	4.6 ± 4.6	.054
Visual analog scale	2.0 ± 2.3	0.7 ± 1.5	.240
SANE	80.8 ± 12.0	84.1 ± 11.5	.622
Constant	87.3 ± 3.3	91.2 ± 5.2	.278
ASES	87.2 ± 13.4	92.9 ± 11.7	.435
Simple Shoulder Test	12.0 ± 0.0	11.7 ± 0.8	.363
Range of motion, deg			
Forward flexion	162.5 ± 27.1	175.6 ± 5.0	.200
Abduction	123.3 ± 8.2	107.5 ± 15.8	.033 ^b
External rotation	61.9 ± 17.1	60.6 ± 8.6	.856

^aData are presented as mean ± SD scores or degrees (where indicated). ASES, American Shoulder and Elbow Surgeons; DASH, Disabilities of the Arm, Shoulder, and Hand; SANE, Single Assessment Numeric Evaluation.

^bStatistically significant difference ($P < .05$).

infection, or heterotopic ossification. There were no reoperations among any patients in this study.

DISCUSSION

This is the largest case series to date following patients with chronic or subacute PM tears treated with dermal allograft reconstruction. The most important finding of the present study is that PM reconstruction with dermal allograft has a good outcome without significant

TABLE 6
Difference in Objective and Patient-Reported Outcome Measures at Final Follow-up Between Patients With a 1- and 2-Graft Repair^a

	1 Graft Used (n = 14)	2 Grafts Used (n = 7)	P Value
DASH	11.8 ± 12.7	5.0 ± 4.9	.233
Visual analog scale	1.9 ± 2.2	0.7 ± 1.6	.276
SANE	80.7 ± 11.0	84.8 ± 12.4	.538
Constant	89.2 ± 4.6	90.6 ± 5.5	.682
ASES	87.4 ± 12.2	93.6 ± 12.7	.386
Simple Shoulder Test	12.0 ± 0.0	11.6 ± 0.9	.482
Range of motion, deg			
Forward flexion	165.5 ± 24.8	175.0 ± 5.5	.376
Abduction	121.3 ± 8.3	105.0 ± 17.6	.040 ^b
External rotation	63.0 ± 15.7	58.3 ± 7.5	.609

^aData are presented as mean ± SD scores or degrees (where indicated). ASES, American Shoulder and Elbow Surgeons; DASH, Disabilities of the Arm, Shoulder, and Hand; SANE, Single Assessment Numeric Evaluation.

^bStatistically significant difference ($P < .05$).

complication in the setting of chronic tears or subacute tears with poor tissue quality. At 26.4 ± 16.0 months of follow-up, DASH and VAS scores improved significantly pre- to postoperatively, and there was a trend toward improved SANE scores. To our knowledge, this is the first study reporting subjective and objective outcome data following reconstruction of chronic or subacute PM repairs augmented with dermal allograft.

Generally, there is a lack of high-quality trials in the operative management of PM tendon ruptures.¹⁶ This is especially the case with outcomes after management of PM tendon ruptures requiring graft placement. Based on the limited availability of data, the decision was made to compare the results of this study with those of prior studies consisting predominantly of primary repairs of the PM. Consistent with this study, multiple studies showed that patients who sustained PM ruptures were males, the most common sporting injury was weight lifting, and there was a higher frequency of PM rupture in the dominant extremity.^{3,4,7} Patients in this study were slightly older (39.1 ± 8.4 years) than those in most other studies (28, 30.5, and 31.2 years).^{3,4,7} This study also found that older age is associated with worse VAS score, forward flexion, and external rotation. In 2000, Bak and colleagues³ performed a meta-analysis on 108 cases of PM ruptures and, similar to this study, found that younger patients were more likely to have an excellent outcome (mean age, 27.2 ± 6.3 years) compared with good outcomes (age, 35.9 ± 12.5 years, $P = .08$) or fair outcomes (age, 32.0 ± 9.9 years, $P = .07$).

In the present study, the final Constant score decreased when there was a longer time between injury and surgery. Similarly, Bak et al³ found that surgery within 8 weeks of injury led to significantly improved outcomes when compared with conservative treatment or delayed repair of the PM. Specifically, Bak et al³ demonstrated that the delay to

surgery was least for patients with excellent (2.3 ± 4.3 weeks) or good (10.5 ± 15.7 weeks; $P = .14$) results, whereas those with a fair result had had their surgery after 13.4 ± 20.6 weeks ($P = .28$). In other studies, PM injuries that were repaired acutely had improved outcomes versus PM ruptures that were repaired with delay.^{1,2,7,18,27}

There were no apparent complications among the patients in the present study, but in 2016, Balazs and colleagues⁴ reported on 291 active-duty military personnel and showed that white race ($P = .03$) and surgery >6 weeks from the injury ($P = .02$) were both significant risk factors for a postoperative complication. In 2014, de Castro Pochini and colleagues⁷ performed a prospective cohort study of 60 patients and, similar to this study, demonstrated that fixation method (anchor vs button) had no statistically significant effect on patient outcome. This is also supported by cadaveric studies demonstrating no statistically significant biomechanical differences among transosseous repair, suture anchor, and pectoralis cortical button.^{19,22}

To our knowledge, no prior studies have assessed the effect of workers' compensation status, primary versus revision surgery, a 2-tendon tear, the use of more than 1 graft for the reconstruction, or the effect of stem cells on prognosis after PM repair.

To date, although graft choices aside from dermal allografts have been described, no case series have evaluated subjective and objective outcomes after any type of graft placement in the setting of chronic or subacute PM tendon ruptures. Dehler and colleagues⁹ reported a case in which a 30-year-old entertainment wrestler underwent chronic PM reconstruction with a dermal allograft 2 years after his injury. At 17 months postoperatively, he was pain free with full ROM and improvement in the deformity of his PM muscle.

This study does have several limitations. Most notably, the patients in this series were not compared with patients with chronic tears or subacute tears with poor tissue quality who underwent other surgical techniques described in the literature, such as primary repair without dermal allograft, as data for that cohort were not available. Also, this study is a retrospective case series. Additionally, although final follow-up data were collected at 26.4 ± 16.0 months postsurgery, only 11 of the 19 patients had follow-up ≥ 24 months. Other limitations of this study include observation bias, as the primary surgeon measured the postoperative active ROM and determined the intraoperative tissue quality. Also, most patients in this study had no preoperative ROM, owing to a lack of preoperative documentation. Although multiple biomechanical studies have found no difference in outcome between fixation methods,^{13,19,22} lack of fixation standardization may have made a difference in patient-reported outcomes.

CONCLUSION

PM tendon reconstruction with dermal allografts resulted in good objective and improved patient-reported outcomes at 26.4 months of follow-up. Increased age, workers'

compensation-related injuries, involvement of multiple heads of the tendon, the need for multiple grafts, and an increased time between the injury and surgery all negatively affected the outcome. In conclusion, reconstruction of chronic or subacute PM tendon ruptures with a dermal allograft augment resulted in improved VAS and DASH scores at a mean of 26.4 months postoperatively. Additionally, at final follow-up, patients had excellent postoperative mean SANE, Constant, ASES, and Simple Shoulder Test scores, as well as active ROM, including forward flexion, abduction in the scapular plane, external rotation at 0° of abduction, and internal rotation. Moreover, patients in this study did not have any postoperative complications or reoperations.

ACKNOWLEDGMENT

The authors thank Elly Nagata for her aid in facilitating the data collection required for this investigation.

REFERENCES

1. Aarimaa V, Rantanen J, Heikkilä J, Helttula I, Orava S. Rupture of the pectoralis major muscle. *Am J Sports Med.* 2004;32(5):1256-1262.
2. Antosh IJ, Grassbaugh JA, Parada SA, Arrington ED. Pectoralis major tendon repairs in the active-duty population. *Am J Orthop (Belle Mead NJ).* 2009;38(1):26-30.
3. Bak K, Cameron EA, Henderson IJ. Rupture of the pectoralis major: a meta-analysis of 112 cases. *Knee Surg Sports Traumatol Arthrosc.* 2000;8(2):113-119.
4. Balazs GC, Brelin AM, Donohue MA, et al. Incidence rate and results of the surgical treatment of pectoralis major tendon ruptures in active-duty military personnel. *Am J Sports Med.* 2016;44(7):1837-1843.
5. Baverel L, Messedi K, Pietu G, Crenn V, Gouin F. Pectoralis major tear with retracted tendon: how to fill the gap? Reconstruction with hamstring autograft and fixation with an interference screw. *Case Rep Orthop.* 2017;2017:2095407.
6. Butt U, Mehta S, Funk L, Monga P. Pectoralis major ruptures: a review of current management. *J Shoulder Elbow Surg.* 2015;24(4):655-662.
7. de Castro Pochini A, Andreoli CV, Belangero PS, et al. Clinical considerations for the surgical treatment of pectoralis major muscle ruptures based on 60 cases: a prospective study and literature review. *Am J Sports Med.* 2014;42(1):95-102.
8. de Castro Pochini A, Eijnisman B, Andreoli CV, et al. Pectoralis major muscle rupture in athletes: a prospective study. *Am J Sports Med.* 2010;38(1):92-98.
9. Dehler T, Pennings AL, ElMaraghy AW. Dermal allograft reconstruction of a chronic pectoralis major tear. *J Shoulder Elbow Surg.* 2013; 22(10):e18-e22.
10. Flint JH, Wade AM, Giuliani J, Rue JP. Defining the terms acute and chronic in orthopaedic sports injuries: a systematic review. *Am J Sports Med.* 2014;42(1):235-241.
11. Haley CA, Zacchilli MA. Pectoralis major injuries: evaluation and treatment. *Clin Sports Med.* 2014;33(4):739-756.
12. Hanna CM, Glenny AB, Stanley SN, Caughey MA. Pectoralis major tears: comparison of surgical and conservative treatment. *Br J Sports Med.* 2001;35(3):202-206.
13. Hart ND, Lindsey DP, McAdams TR. Pectoralis major tendon rupture: a biomechanical analysis of repair techniques. *J Orthop Res.* 2011; 29(11):1783-1787.
14. Joseph TA, DeFranco MJ, Weiker GG. Delayed repair of a pectoralis major tendon rupture with allograft: a case report. *J Shoulder Elbow Surg.* 2003;12(1):101-104.
15. Kircher J, Ziskoven C, Patzer T, Zaps D, Bittersohl B, Krauspe R. Surgical and nonsurgical treatment of total rupture of the pectoralis

- major muscle in athletes: update and critical appraisal. *Open Access J Sports Med.* 2010;1:201-205.
16. Mooers BR, Westermann RW, Wolf BR. Outcomes following suture-anchor repair of pectoralis major tears: a case series and review of the literature. *Iowa Orthop J.* 2015;35:8-12.
 17. Nute DW, Kusnezov N, Dunn JC, Waterman BR. Return to function, complication, and reoperation rates following primary pectoralis major tendon repair in military service members. *J Bone Joint Surg Am.* 2017;99(1):25-32.
 18. Park JY, Espiniella JL. Rupture of pectoralis major muscle: a case report and review of literature. *J Bone Joint Surg Am.* 1970;52(3):577-581.
 19. Petilon J, Carr DR, Sekiya JK, Unger DV. Pectoralis major muscle injuries: evaluation and management. *J Am Acad Orthop Surg.* 2005;13(1):59-68.
 20. Rabuck SJ, Lynch JL, Guo X, et al. Biomechanical comparison of 3 methods to repair pectoralis major ruptures. *Am J Sports Med.* 2012;40(7):1635-1640.
 21. Schachter AK, White BJ, Namkoong S, Sherman O. Revision reconstruction of a pectoralis major tendon rupture using hamstring autograft: a case report. *Am J Sports Med.* 2006;34(2):295-298.
 22. Schepsis AA, Grafe MW, Jones HP, Lemos MJ. Rupture of the pectoralis major muscle: outcome after repair of acute and chronic injuries. *Am J Sports Med.* 2000;28(1):9-15.
 23. Sherman SL, Lin EC, Verma NN, et al. Biomechanical analysis of the pectoralis major tendon and comparison of techniques for tendosseous repair. *Am J Sports Med.* 2012;40(8):1887-1894.
 24. Sikka RS, Neault M, Guanche CA. Reconstruction of the pectoralis major tendon with fascia lata allograft. *Orthopedics.* 2005;28(10):1199-1201.
 25. Wolfe SW, Wickiewicz TL, Cavanaugh JT. Ruptures of the pectoralis major muscle: an anatomic and clinical analysis. *Am J Sports Med.* 1992;20(5):587-593.
 26. Zaccchilli MA, Fowler JT, Owens BD. Allograft reconstruction of chronic pectoralis major tendon ruptures. *J Surg Orthop Adv.* 2013;22(1):95-102.
 27. Zafra M, Munoz F, Carpintero P. Chronic rupture of the pectoralis major muscle: report of two cases. *Acta Orthop Belg.* 2005;71(1):107-110.
 28. Zeman SC, Rosenfeld RT, Lipscomb PR. Tears of the pectoralis major muscle. *Am J Sports Med.* 1979;7(6):343-347.