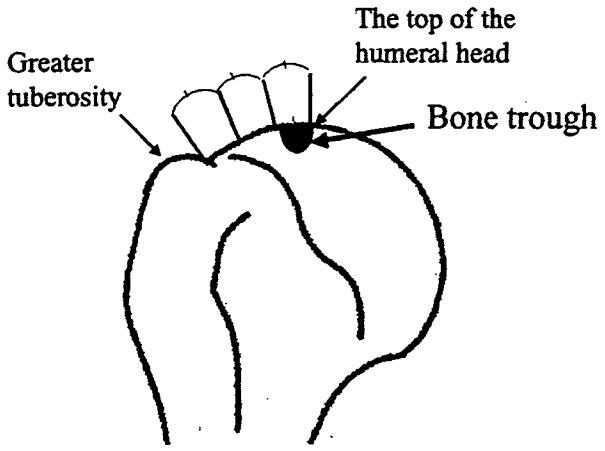

Figure 1 Bone trough just on lateral side of top of humeral head. The distance between the top of the humeral head and the greater tuberosity is equally divided into 3 sections, and the bone trough is made in the section nearest the top of the humeral head.

supraspinatus, infraspinatus, and subscapularis in 1. The symptoms occurred after an episode of trauma in 10 shoulders. The mean follow-up period was 50 months (range, 24 to 80 months).

Operative technique and rehabilitation protocol

The patient was placed in the beach-chair position. The deltoid was split between the anterior and middle thirds, and care was taken to preserve the origin. However, a part of the anterior or middle fibers (or both) was detached from its origin when greater exposure was necessary. The indication for decompression of the coracoacromial arch or resection arthroplasty of the acromioclavicular joint was decided depending on the preoperative examination, which included physical examination and systematic block tests by use of local anesthesia in the subacromial bursa, subcoracoid space, acromioclavicular joint, and glenohumeral joint.[19,20] As a result, an acromioplasty[12] and resection of the coracoacromial ligament were performed in all shoulders, and a coracoplasty was added in 10 shoulders. Resection arthroplasty of the acromioclavicular joint was performed in 2 shoulders. The torn tendon was pulled out with No. 2 nonabsorbable sutures running through the edge of the tendon. The adhesions with the surrounding tissues were severe in all cases; therefore, careful and sufficient extraarticular and intraarticular releases were performed to obtain enough mobility of the tendon to pull it out for the repair. Extraarticular releases included blunt and sharp dissection of adhesions of the cuff tendon with the bursa and capsule and excision of the coracohumeral ligament at the insertion to the coracoid process. If necessary, blunt and sharp intraarticular releases of the cuff tendon and the capsule from the superior to anterior labrum were performed. After sufficient releases and debridement of the tendon edge, the tendon was pulled out. If the edge reached beyond the top of the humeral head with the arm at the side, McLaughlin's procedure was performed. If the tendon could not reach over the top of the humeral head, a teres minor tendon transfer or latissimus dorsi muscle transfer was selected. A bone trough was made until cancellous bone was exposed. The tendon was sutured with No. 2 nonabsorbable sutures into the trough by a pullout technique. In addition, suture anchors were placed near the distal edge of the bone trough in 18 later patients (Figure 2). Suture anchors were used to augment the suture site and enlarge the contact area of the tendon on the bony surface. After the absence of impingement at the coracoacromial arch was confirmed, the deltoid was repaired to the acromion through drill holes.

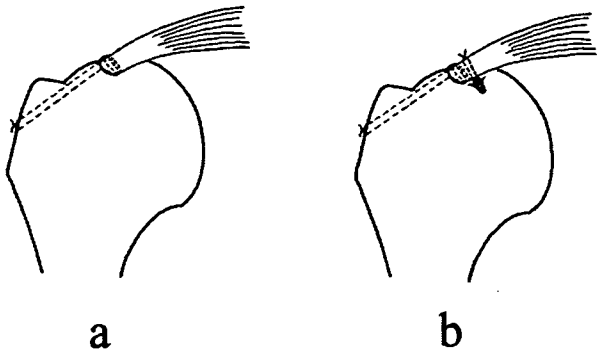

Figure 2 Methods of tendon suturing. The pullout method was used in 9 shoulders (**A**), and suture anchors were used in addition to the pullout method in 16 (**B**).

An abduction brace was used for 6 to 8 weeks postoperatively. A systematic postoperative rehabilitation program was carried out, with passive range-of-motion (ROM) exercises from 1 to 2 weeks after surgery, active ROM exercises from 8 to 10 weeks, and isometric cuff exercises from 10 to 12 weeks. Heavy work or sports were permitted after 6 months postoperatively, in principle, by assessing recovery of muscle strength and ROM.

Clinical and radiographic assessments

The clinical results were evaluated with the University of California, Los Angeles (UCLA) Shoulder Scoring System preoperatively and at the final follow-up examination. The UCLA scale consists of a total score of 35 points comprising scores for pain (10 points), function (10 points), ROM of forward flexion (5 points), strength of forward flexion (5 points), and patient satisfaction (5 points). The total score was classified as excellent (34-35 points), good (29-33 points), or poor (≤28 points). The ROM of active forward flexion, external rotation, and internal rotation was also evaluated preoperatively and at the final follow-up.

Radiographic evaluation was performed in all shoulders with anteroposterior radiographs obtained preoperatively and at the final follow-up to investigate the progression of OA of the glenohumeral joint and upper migration of the humeral head. OA was classified into 4 grades (Figure 3): grade 0, no obvious osteoarthritic change; grade I, formation of osteophytes at the humeral head or glenoid; grade II, narrowing of the glenohumeral joint space; and grade III, disappearance of the glenohumeral joint space. Upper migration of the humeral head was also classified into 5 grades (Figure 4). The inferior half of the glenoid was divided into 3 zones, and the grade was defined by the level of the inferior border of the articular surface of the

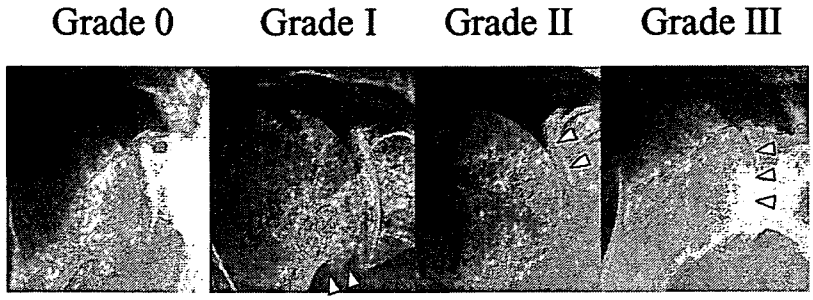

Figure 3 Grading of OA of glenohumeral joint: grade 0, no obvious osteoarthritic change; grade I, formation of osteophytes at humeral head or glenoid; grade II, narrowing of glenohumeral joint space; and grade III, disappearance of glenohumeral joint space.

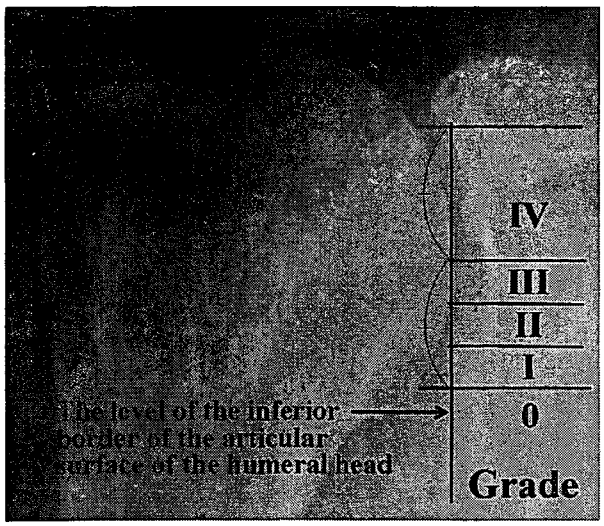

Figure 4 Grading of upper migration of humeral head. The inferior half of the glenoid is divided into 3 zones. The grade is defined by the position of the inferior border of the articular surface of the humeral head in the following zones: grade 0, the inferior border of the articular surface of the humeral head is below the lower glenoid rim; grades I, II, and III, the inferior border of the articular surface of the humeral head is in each zone; and grade IV, the inferior border of the articular surface of the humeral head is above zone III.

humeral head in those zones as follows: grade 0, the inferior border of the articular surface of the humeral head is below the lower glenoid rim; grades I, II, and III, the inferior border of the articular surface of the humeral head is in each zone; and grade IV, the inferior border of the articular surface of the humeral head is above zone III.

Statistical analysis

Preoperative and postoperative UCLA scores were statistically compared by use of the Wilcoxon signed ranks test. The correlation between the radiographic findings and the clinical results were statistically analyzed by the analysis of variance test. The correlation between the follow-up period and progression of OA was evaluated by the Mann-Whitney *U* test. The significance was set at $P < .05$.

RESULTS

The clinical and radiographic results are shown in Table I. Although postoperative heterotopic ossification at the coracoacromial space occurred in 2 shoulders (cases 23 and 25), no surgical treatment was required. There were no other complications. One shoulder, however, underwent a second surgery (coracoplasty) 28 months after the first surgery, because of restriction of movement resulting from residual pain.

The mean preoperative total UCLA score was 10.9 points (range, 4 to 19 points), and the mean postoperative score was 31.8 points (range, 23 to 35 points). The postoperative results of 11 shoulders were classified as excellent, 11 as good, and 3 as poor. The total UCLA score was significantly improved postoperatively ($P < .001$). Within the subscores, the pain score increased from 2.2 to 8.7 points ($P < .001$), the function score increased from 2.8 to 9.0 points ($P < .001$), the ROM score increased from 2.9 to 4.6 points ($P < .001$), and the strength score increased from 3.0 to 4.6 points ($P < .001$). Mean active flexion significantly improved, from 97.3° (range, 0° to 165°) to 146.6° (range, 120° to 170°) ($P < .001$), and external rotation also significantly improved, from 19.0° (range, −30° to 60°) to 41.2° (range, −10° to 75°) ($P < .001$). Preoperative internal rotation was from the lateral thigh to T5 preoperatively and from L4 to T4 postoperatively.

Preoperative OA of the glenohumeral joint was observed in 12 shoulders; all were classified as grade I. At final follow-up, OA had progressed from grade 0 to grade I in 4 shoulders and from grade I to grade II in 2. One shoulder, which was preoperatively graded as I, showed obvious enlargement of osteophytes, although the postoperative classification was still grade I. Therefore, in total, OA progressed in 7 shoulders (28%). The mean follow-up periods for the 7 shoulders that showed progression of OA and for the 18 shoulders that showed no progression were 52

Table I Patient demographics

No.	Age (y)	Sex	Torn tendons	Additional operation	Follow-up (mo)	UCLA score	
						Preoperative	Postoperative
1	74	M	SS, IS	CA	57	13	32
2	66	M	SS, IS	CA, C	68	8	29
3	67	F	SS, IS	CA	59	9	35
4	39	F	SS, IS	CA	36	15	29
5	69	F	SS, IS	CA	78	7	32
6	65	F	SS, IS	CA	68	16	23
7	48	M	SS, IS	CA	60	12	24
8	65	F	SS, IS	CA	52	13	30
9	61	M	SS, IS	CA	53	11	30
10	73	M	SS, IS, TM	CA	65	8	35
11	60	M	SS, IS, SUB	CA, C	21	4	34
12	64	F	SS, IS	CA	33	14	35
13	51	M	SS, IS	CA	80	4	35
14	59	M	SS, IS	CA, AC	45	19	35
15	58	M	SS, IS	CA, C	20	13	32
16	59	M	SS, IS, TM	CA, C, AC	21	16	35
17	62	F	SS, IS	CA	36	16	35
18	47	M	SS, IS	CA, C	60	5	35
19	51	F	SS, IS	CA, C	29	11	31
20	66	M	SS, IS	CA, C	56	10	35
21	66	M	SS, IS	CA	56	11	33
22	75	M	SS, IS	CA	60	13	31
23	70	F	SS, IS	CA, C	25	11	23
24	78	F	SS, IS	CA, C	52	10	34
25	61	M	SS, IS	CA, C	41	4	32

months (range, 25 to 78 months) and 48 months (range, 20 to 80 months), respectively. There was no correlation between the follow-up period and the progression of OA ($P = .525$). Upper migration of the humeral head was observed in 19 shoulders preoperatively; 18 shoulders were classified as grade I and 1 shoulder as grade II. At final follow-up, 2 shoulders showed progression from grade 0 to grade I and 4 shoulders from grade I to grade II. In total, upper migration progressed in 6 shoulders (24%). On the other hand, postoperative improvement of upper migration was observed in only 3 shoulders: from grade I to grade 0 in 2 shoulders and from grade II to grade 0 in 1 shoulder. The postoperative grade of OA and upper migration showed no significant correlation with the postoperative total UCLA score ($P = .959$ and $P = .903$, respectively).

DISCUSSION

For the surgical treatment of massive rotator cuff tears, different procedures have been reported, such as McLaughlin's procedure,[2,4,6,9-11,14,18] partial repairs,[3] muscle or tendon transfers,[1,4,5,7,16] muscle advancement, and grafting by various materials.[4,13,15] Because McLaughlin's procedure has provided stable, satisfactory results, it has been widely considered as a primary choice. In severe chronic massive rotator cuff tears, the torn tendon cannot be sutured at the original site because of the large defect, adhesion between the tendon and the surrounding soft tissues, and contracture of the cuff muscles. In such cases, suturing the tendon at the original insertion would produce excessive tension at the suture site and lead to reruptures[17] or residual symptoms. Therefore, medialization of the reinsertion of the tendon is often necessary in such cases, although the acceptable distance of the medialization will vary depending on the surgeon. Consequently, the important question is as follows: How much is the maximum distance of medialization? Liu et al[8] reported a cadaveric study that demonstrated that 17 mm of medial advancement of the insertion reduced the moment arm of the supraspinatus. However, as they mentioned in their article, the clinical maximum distance of advancement will be dictated by other clinical factors. We have attempted tendon-to-bone repair procedures with medialization of the reinsertion of cuff tendons as far as possible for severe massive cuff

Table I continued

Postoperative classification	OA grade			Upper migration grade			Complications
	Preoperative	Postoperative	Progress	Preoperative	Postoperative	Progress	
Good	1	1		1	1		
Good	1	2	+	1	1		
Excellent	1	1		1	1		
Good	0	0		1	1		
Good	0	1	+	1	1		
Poor	1	1	+	1	2	+	
Poor	0	0		0	0		
Good	0	0		1	1		
Good	0	0		1	0	Improvement	
Excellent	1	1		1	1		
Excellent	0	0		0	1	+	
Excellent	0	0		1	1		
Excellent	1	1		0	0		
Excellent	1	1		1	2	+	
Good	1	1		1	2	+	
Excellent	0	0		2	0	Improvement	
Excellent	1	1		0	1	+	
Excellent	0	0		0	0		
Good	0	1	+	1	1		
Excellent	1	1		1	1		
Good	0	1	+	1	2	+	
Good	0	0		1	1		
Poor	0	1	+	0	0		Heterotopic ossification
Excellent	1	1		1	1		
Good	1	2	+	1	0	Improvement	Heterotopic ossification

SS, Supraspinatus; *IS*, infraspinatus; *CA*, decompression of coracoacromial arch; *C*, coracoplasty; *TM*, teres minor; *sub*, subscapularis; *AC*, resection arthroplasty of acromioclavicular joint.

tears. However, we have set a limit on medialization, as the medial edge of the bone trough does not cross over the top of the humeral head in order to obtain sufficient muscle force, because the cuff muscles play an important role in stabilizing the humeral head toward the glenoid. There are no precise clinical studies in which the distance of medialization is specified or the tendon was sutured more medially than in our cases. There is concern about medialization of the reinsertion, such as restriction of movement of the glenohumeral joint as a result of impingement between the reinsertion and the rim of the glenoid or loss of the centripetal force of cuff tendons, as well as occurrence of OA of the glenohumeral joint. Therefore, we designed this study to evaluate the clinical and radiographic outcomes of a certain study group of massive cuff tears treated by McLaughlin's procedure. The previous reports of treatment for massive cuff tears showed satisfactory results in 76% to 93% cases of tendon-to-bone repair,[2,11,14,18] 56% cases of partial repair,[3] 35% to 85% cases of muscle or tendon transfers,[1,5,7,16] and 81% to 92% cases of grafting.[13,15] In our study, 22 of 25 shoulders (88%) obtained satisfactory results, which is comparable to or better than those results despite our inclusion of selected cases of severe massive cuff tears, although the difference in the severity of the cuff tears among those study groups should be taken into consideration. Our results suggest that, when adequate and sufficient mobilization is performed and the torn tendon can be sutured over the top of the humeral head, a satisfactory clinical result can be expected.

Our study showed excellent clinical results, whereas OA progressed in 28% of shoulders and upper migration of the humeral head progressed in 24%. The postoperative progression of OA in the massive cuff tear shoulders was reported in 13% to 42% of cases after latissimus dorsi muscle transfer[1,5] and 36% after debridement.[11] Moreover, in the debridement group, 28% of cases advanced toward cuff tear arthropathy.[11] In our study, the progression was comparatively mild, and no case progressed to either grade III or cuff tear arthropathy. The postoperative progression of upper migration of the humeral head was reported in 25% to 50% of cases after latissimus dorsi muscle transfer.[1,5] The progression rates of both OA and upper migration of the current study were comparable to or lower than those of other procedures in the midterm follow-up. Moreover, neither OA nor upper migration had correlation with the

clinical results. Nevertheless, because this procedure causes certain damage to the cartilage of the humeral head, further observation is necessary to determine the long-term results.

The advantages of McLaughlin's procedure for severe massive cuff tears are as follows: the operation is less invasive than other methods, there is no need to sacrifice other muscles, and there is no need to use foreign materials. On the other hand, one of the concerns with this procedure is that, as mentioned previously, the medialized reinsertion of the tendon could restrict rotation of the humeral head on the glenoid surface because of impingement between the reinsertion and the rim of the glenoid. However, the main mechanism of improvement of shoulder function with this procedure is considered to be the effect of restabilizing the humeral head against the glenoid so that the deltoid muscles can function effectively. In this situation, scapulothoracic motion will probably compensate, to a certain degree, for glenohumeral joint motion, which should be different from normal kinematics. Despite that, satisfactory ROM has been actually achieved in this series. It is also difficult to expect normal movement of the glenohumeral joint after any repair or reconstruction for severe massive cuff tears. The other concern is that, because the cuff tendons are attached on the humeral head, it would be difficult to replace the humeral head if OA progressed severely over time.

In conclusion, satisfactory clinical results were obtained with McLaughlin's procedure for severe massive cuff tears with medialization of the insertion on the top of the humeral head. Although OA of the glenohumeral joint and upper migration of the humeral head both have progressed postoperatively in some shoulders, the incidence rates were no higher than those of other procedures. Therefore, as a result of the efficient extraarticular and intraarticular mobilization of the tendon and the medialization of the reinsertion of the tendon up to the top of the humeral head, the indication of this tendon-to-bone repair procedure for massive cuff tears can be extended beyond the present indication.

REFERENCES

1. Aoki M, Okamura K, Fukushima S, Takahashi T, Ogino T. Transfer of latissimus dorsi for irreparable rotator-cuff tears. J Bone Joint Surg Br 1996;78:761-6.
2. Bigliani LU, Cordasco FA, McIlveen SJ, Musso ES. Operative repair of massive rotator cuff tears: long-term results. J Shoulder Elbow Surg 1992;1:120-30.
3. Burkhart SS, Nottage WM, Ogilvie-Harris DJ. Partial repair of massive rotator cuff tears: the evolution of a concept. Orthop Clin North Am 1997;28:125-32.
4. Cofield RH, Parvizi J, Hoffmeyer PJ, Lanzer WL, Ilstrup DM, Rowland CM. Surgical repair of chronic rotator cuff tears. J Bone Joint Surg Am 2001;83:71-7.
5. Gerber C. Latissimus dorsi transfer for the treatment of irreparable tears of the rotator cuff. Clin Orthop Relat Res 1992:152-60.
6. Hawkins RJ, Misamore GW, Hobeika PE. Surgery for fullthickness rotator-cuff tears. J Bone Joint Surg Am 1985;67:1349-55.
7. Karas SE, Giachello TL. Subscapularis transfer for reconstruction of massive tears of the rotator cuff. J Bone Joint Surg Am 1996; 78:239-45.
8. Liu J, Hughes RE, O'Driscoll SW, An KN. Biomechanical effect of medial advancement of the supraspinatus tendon. J Bone Joint Surg Am 1998;80:853-9.
9. McLaughlin HL. Lesions of the musculotendinous cuff of the shoulder. The exposure and treatment of tears with retraction. J Bone Joint Surg 1944;26:31-51.
10. McLaughlin HL. Repair of major cuff ruptures. Surg Clin North Am 1963;43:1535-40.
11. Melillo AS, Savoie FH, Field LD. Massive rotator cuff tears: debridement versus repair. Orthop Clin North Am 1997;28: 117-24.
12. Neer CS II. Anterior acromioplasty for the chronic impingement syndrome in the shoulder: a preliminary report. J Bone Joint Surg Am 1972;54:41-50.
13. Neviaser JS, Neviaser RJ, Neviaser TJ. The repair of chronic massive ruptures of the rotator cuff of the shoulder by use of a freeze-dried rotator cuff. J Bone Joint Surg Am 1978;60:681-4.
14. Nobuhara K, Hata Y, Komai M. Surgical procedure and results of repair of massive tears of the rotator cuff. Clin Orthop Relat Res 1994:54-9.
15. Ozaki J, Fujimoto S, Masuhara K, Tamai S, Yoshimoto S. Reconstruction of chronic massive rotator cuff tears with synthetic materials. Clin Orthop Relat Res 1986:173-83.
16. Paavolainen P, Slatis P, Bjorkenheim JM. Transfer of the tuberculum majus for massive ruptures of the rotator cuff. In: Post M, Morrey B, Hawkins R, editors. Surgery of the shoulder. St Louis: Mosby; 1990. p. 252-6.
17. Reilly P, Bull AMJ, Amis AA, Wallace AL, Richards A, Hill AM, et al. Passive tension and gap formation of rotator cuff repairs. J Shoulder Elbow Surg 2004;13:664-7.
18. Rokito AS, Cuomo F, Gallagher MA, Zuckerman JD. Long-term functional outcome of repair of large and massive chronic tears of the rotator cuff. J Bone Joint Surg Am 1999;81:991-7.
19. Suenaga N, Minami A, Iwasaki N, Kaneda K. Coracoacromial arch decompression in rotator cuff surgery. Int Orthop 2000;24: 212-6.
20. Suenaga N, Minami A, Fukuda K, Kaneda K. The correlation between bursoscopic and histologic findings of the acromion undersurface in patients with subacromial impingement syndrome. Arthroscopy 2002;18:16-20.