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Shoulder arthrodesis with plate fixation

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Objective: The aim of this study was to evaluate the long-term outcome of shoulder arthrodesis with plate fixation and primary autogenous grafting in terms of pain, functional status and arthrodesis position.

Methods: The study included 8 patients (7 males and 1 female; mean age: 39.3 years; range: 22 to 68 years) who underwent arthrodesis with plate fixation and primary autogenous grafting. Mean follow-up period was 66.6 (range: 47 to 96) months. Five cases had traumatic brachial plexus palsy, 2 polio sequela and 1 sequela of an operated proximal humerus fracture due to a falling injury. One of the traumatic palsy cases was accompanied with a humerus shaft fracture. Arthrodesis was performed in all cases according to AO principles with plate fixation and primary autogenous grafting. Five of the paralytic patients also underwent Steindler flexorplasty. Follow-up assessments included monthly radiologic control for union, the visual analog scale (VAS) for pain and the Oxford shoulder score (OSS) for functional status.

Results: Radiological fusion was seen in all cases in an average of 16 (range: 12 to 18) weeks, and arthrodesis was stable at physical examination. The accompanying humerus shaft fracture was also fixed with plate. One patient with traumatic palsy experienced a humerus fracture distal to the arthrodesis plate at the 8th postoperative month. An additional traumatic palsy case had flexion deformity at the wrist in the second year of follow-up and a wrist arthrodesis with dorsal plate was performed. One patient (12.5%) had a donor site infection on the tenth day after surgery. The target positions of 30° of abduction, 30° of forward flexion, and 30° of internal rotation were achieved with an average deviation of 7°. Mean active abduction was 68.1° (range: 55° to 90°), flexion was 67.5° (range: 60° to 85°), and internal rotation was at the level of trochanter major. The mean OSS was 35.9 (range: 32 to 40), and the mean VAS score was 2.9 (range: 1 to 7).

Conclusion: Our findings show that AO reconstruction plate and primary autogenous bone grafting is a safe and effective arthrodesis method that can also be used as a salvage procedure.

Key words: Arthrodesis; brachial plexus palsy; plate; shoulder.

Shoulder arthrodesis is described as the fusion of the humeral head to the glenoid fossa. Although it has been performed as a salvage procedure during the last century for many conditions, the indication of arthrodesis has been now limited due to advances in shoulder arthroplasty. Historical indications included shoulder tuberculosis, polio involvement in upper extremities, irreparable rotator cuff tears, osteoarthritis and romatoid arthritis.[1-4] At present, shoulder arthrodesis is indicated for congenital and traumatic brachial plexus palsies, inefficiency of deltoid and rotator cuff muscles, chronic infection, failed revision arthroplasty, severe refractory instability, and bone loss due to tumor resection from the proximal

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humerus.[1-3,5,6] Multiple external and internal techniques have been described for fixation during arthrodesis. Use of compression screw fixation is an acceptable method; however, it requires extended postoperative immobilization.[5]

A combined use of compression screws and plates is associated with a decreased need for postoperative immobilization and the reduced risk of non-union.[5,6] Some surgeons usually employ a spica cast following fixation with a single 4.5 mm dynamic compression plate,[6,7] while others do not.[8] Stark et al. found that only one out of 15 patients lost position following fixation with a DCP plate, and attributed this to inadequate fixation.[8]

Local skin irritation may also occur. In some cases, these screws should be removed. Stark et al. observed skin irritation in 4 of their 15 patients, which they were able to treat through the surgical removal of some of the screws.[8] A combination of plate and compression screws is routinely used by many surgeons.

External fixation can also be used in shoulder arthrodesis[5,9] and is usually indicated for injuries to the joint secondary to arthritis associated with tuberculosis.[9] Additional fixation can be achieved using a postoperative immobilization with a spica cast.[9] Some series have reported external fixation combined with compression screws,[10,11] after which no additional fixation such as casting was needed. Common complications of external fixation include pin tract infection and fracture following screw removal.[5,9-11]

The currently used approach is internal fixation with a plate, and a significant reduction is observed in the non-union rate with primary autogenous bone grafting.

The objective of the present study was to evaluate the long-term outcome in patients who underwent shoulder arthrodesis with plate fixation and primary autogenous bone grafting, in terms of pain, functional status and arthrodesis position.

Patients and methods

A total of 8 patients, seven men and one woman, underwent shoulder arthrodesis between 1999 and 2008 (Table 1). The mean age was 39.3 (range: 22 to 68) years, and mean follow-up period was 66.6 (range: 47 to 96) months. Arthrodesis was performed on the left shoulder in five patients, and the right shoulder in three patients. Six patients had traumatic injuries while two had upper limb paralysis secondary to polio.

Table 1. The demographic data of patients and complications.

No	Age	Sex	Mechanism	Neurological involvement and additional pathology	Additional surgery	Follow-up period (months)	Postoperative motion (forward elevation/ abduction/ internal rotation) (degree)	Oxford score during last exam	Arthrodesis position (flexion/abduction/ internal rotation) (degree)
1	29	Male	Traffic accident	Total brachial plexus injury. Fragmented fracture and dislocation of the proximal humerus. Fragmented fracture of the glenoid	Surgical intervention at proximal humerus and glenoid, shoulder arthrodesis, grafting for brachial plexus, wrist arthrodesis after one year	47	60/65/tr. major	36	35/35/30
2	34	Male	Traffic accident	C5, C6, C7	-	51	65/60/tr. major	35	30/25/40
3	51	Male	Traffic accident	C5, C6, C7	-	59	60/55/tr. major	35	30/35/30
4	47	Male	Traffic accident	C5, C6	-	63	65/55/tr. major	37	35/25/35
5	38	Male	Traffic accident	C5, C6	-	68	60/55/tr. major	32	30/30/30
6	22	Male	Poliomyelitis	Upper truncus	Steindler flexorplasty	72	80/90/tr. major	40	35/35/35
7	25	Male	Poliomyelitis	Upper truncus	Steindler flexorplasty	77	85/90/tr. major	40	40/30/35
8	68	Female	Fracture sequela	Axillary nerve injury, fragmented fracture and dislocation of the proximal humerus, malunion	Infection	96	65/75/tr. major	32	25/25/35

Five of the cases with traumatic paralysis were the result of a motorbike accident. One had a concurrent total brachial plexus injury. Four patients had upper root or truncus lesions. In all of these patients, the trapezius and levator scapula muscles on the same side had full strength. Function of the serratus anterior muscle was good in all patients, except one with total brachial plexus palsy. None of the patients had preoperative active motion of the shoulder and were only able to perform a shrugging motion of their shoulders. None of the active motions was transmitted from thoracoscapular muscles to the upper extremities.

The other traumatic case following a falling injury had undergone arthrodesis for non-union of the comminuted fracture of the proximal humerus, which had been treated with internal fixation using a plate-screw in another center. This patient also had axillary nerve injury.

One of the cases with traumatic brachial plexus injury had a concurrent comminuted fracture-dislocation of the proximal humerus and comminuted fracture of the glenoid. He initially underwent open reduction with the use of plate and screws for fixation. During follow-up, the Hand Surgery Department of the Medical Faculty of Istanbul University was consulted. Nerve grafting was found to be an appropriate solution for the brachial plexus. Shoulder arthrodesis was performed first due to the presence of irregular articular surfaces and brachial plexus palsy. Following arthrodesis, sural nerve grafting was performed on the C6 and C7 root. At the 4th postoperative month, a fracture was detected below the plate. Thus, another incision was made in the anterior and a long plate was applied without disturbing the previous one. The fractured area was grafted with autografts. At the end of postoperative Year 2, the patient achieved a functional elbow range of motion. A wrist arthrodesis was also performed to improve hand function.

The patients with a sequela of poliomyelitis had remarkable deltoid atrophy (Figs. 1a-d). At presenta-

Fig 1. Shoulder movements of a patient who underwent arthrodesis for sequela of poliomyelitis. **(a)** Forward elevation, **(b)** hand-to-mouth movement, **(c)** hand-to-neck movement, **(d)** abduction. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

tion, none of our patients had an active shoulder range of motion, but they had good periscapular muscle strength. Both cases had additional complaints of neck and shoulder pain. Furthermore, no tendon transfer was considered because of insufficient strength of the latissimus dorsi and teres major muscles. Thus, we decided to perform shoulder arthrodesis, where it was carried out using plate-screw fixation with the AO surgical technique and primary autogenous bone grafting.

The surgery was performed with the patient under general anesthesia in a semi-sitting position. The incision was initiated over the spina scapulae, with a forward inclination, and then directed toward the anterolateral corner of the acromion and further directed until proximal 1/3 of its course, to the point where the deltoid is attached to the humerus along the lateral side of the forearm. The deltopectoral groove was identified and intervened. The deltoid muscle was separated from the lateral clavicle, the anterior and lateral acromion, and moved distally and laterally, leaving it suspended on the neurovascular structures. The anterior and superior fibers of the rotator cuff were resected. The cartilaginous tissue was then removed by eroding the lower surfaces of the humeral head, glenoid and acromion. The humeral head was positioned to come into contact with the glenoid fossa and lower surface of the acromion. As the scapula is mobile, the body trunk, long axis of the humerus and long axis of the arm were defined as reference points for calculation of the angle during positioning. To obtain the target position of 30° of abduction, 30° of forward flexion and 30° of internal rotation, a temporary fixation was made using two Steinmann pins. Following fixation, hand-to-mouth and hand-to-head movements were tested. An aluminum template was used in order to contour the position of the fusion properly, selecting an appropriate AO reconstruction plate. The plate was placed on the spina scapulae, the lateral surface of the acromion and the proximal surface of the humerus. Two cancellous screws were first directed from the humeral head to the glenoid fossa over the plate to achieve horizontal compression. One 6.5-mm cancellous screw was directed from the acromion into the neck of the scapula again over the plate, passing approximately 1 cm medial to the glenoid surface. A minimum of four cortical screws were directed from the acromion into the glenoid and scapula and humeral shaft over the plate. The grafts harvested from the iliac crest were then placed into the gaps between the glenoid fossa and lower aspect of the acromion and the humeral head. Available subscapularis tendon was reattached to the humeral head. Then, the deltoid was sutured to the clavicle and lateral of the acromion with sutures placed through the bone. A sling was used for 6 to 8 weeks postoperatively. Active range of motion exercises of the hand, wrist, and elbow were started on the first postoperative day.

Patients were followed up monthly with radiological examination until union was achieved at the site of arthrodesis. In the long-term, patients were evaluated for pain, functional status and target position of arthrodesis. Pain and functional status were evaluated using the visual analog scale (VAS) and Oxford shoulder score (OSS),[2] respectively (Table 2).

Results

The demographic data of patients and complications are outlined in Table 1. All patients achieved a radiological fusion at the site of arthrodesis by postoperative Week 16 (range: 12 to 18 weeks) and the arthrodesis was stable at physical examination.

Patients reported a twinge of pain on their shoulder prior to surgery. The discomfort and pain were eliminated in all patients after the arthrodesis. No patient reported scapulothoracic or glenohumeral pain during follow-up.

One patient with traumatic paralysis developed a fracture of the humeral shaft below the arthrodesis plate at the 4th postoperative month, which was fixed with a second plate without removal of the arthrodesis plate. Union was achieved within four months (Figs. 2, 3 and 4a-c). The patient with axillary nerve injury who failed to achieve union of the comminuted fracture of the proximal humerus with plate fixation underwent shoulder arthrodesis 10 months after this surgery. He developed a wound on the 10th postoperative day and was treated with irrigation and debridement. The infection was eliminated with appropriate parenteral antibiotics based on the postoperative cultures and antibiogram.

The target position of 30° of abduction, 30° of forward flexion and 30° of internal rotation was clinically achieved in all patients with a mean deviation of 7 degrees. Measurements were performed using a goniometer, with the arm axis and body axis as reference points. The average active abduction was

Table 2. The Oxford shoulder score consists of 12 questions. Each question has five answers, i.e., a score range of 1 to 5 where 1 indicates "the mildest difficulty", and 5 "severe difficulty". Therefore, a total score of 12 indicates presence of less difficulty, while 60 means extreme difficulty.

During the past 4 weeks;	Points
1. *How would you describe your shoulder pain?*	
None	1
Mild	2
Moderate	3
Severe	4
Unbearable	5
2. *Have you had any trouble dressing yourself because of your shoulder?*	
No trouble at all	1
Little trouble	2
Moderate trouble	3
Extreme difficulty	4
Impossible to do	5
3. *Have you had any trouble getting in and out of a car or using public transport because of your shoulder?*	
No trouble at all	1
Little trouble	2
Moderate trouble	3
Extreme difficulty	4
Impossible to do	5
4. *Have you been able to use a knife and fork at the same time?*	
Yes, easily	1
With little difficulty	2
With moderate difficulty	3
With extreme difficulty	4
No, impossible	5
5. *Could you do the household shopping on your own?*	
Yes, easily	1
With little difficulty	2
With moderate difficulty	3
With extreme difficulty	4
No, impossible	5
6. *Could you carry a tray containing a plate of food across a room?*	
Yes, easily	1
With little difficulty	2
With moderate difficulty	3
With extreme difficulty	4
No, impossible	5
7. *Could you brush/comb your hair with the affected arm?*	
Yes, easily	1
With little difficulty	2
With moderate difficulty	3
With extreme difficulty	4
No, impossible	5
8. *How would you describe the pain you usually had from your shoulder?*	
None	1
Very mild	2
Mild	3
Moderate	4
Severe	5
9. *Could you hang your clothes up in a wardrobe, using the affected arm? (whichever you tend to use)*	
Yes, easily	1
With little difficulty	2
With moderate difficulty	3
With great difficulty	4
No, impossible	5
10. *Have you been able to wash and dry yourself using both arms?*	
Yes, easily	1
With little difficulty	2
With moderate difficulty	3
With extreme difficulty	4
No, impossible	5
11. *How much has pain from your shoulder interfered with your usual work (including housework)?*	
None	1
A little bit	2
Moderately	3
Greatly	4
Totally	5
12. *Have you been troubled by pain from your shoulder in bed at night?*	
No nights	1
Only 1 or 2 nights	2
Some nights	3
Most nights	4
Every night	5

Fig 2. Humerus fracture to the distal of the plate at the 4th postoperative month, following the arthrodesis performed due to traumatic brachial plexus palsy.

Fig 3. A second plate was anteriorly inserted without removing the arthrodesis plate. The patient achieved union during follow-up.

68.1 (range: 55 to 90), forward flexion was 67.5 (range: 60 to 85) degrees, and internal rotation was at the level of the trochanter major. All patients were able to do hand-to-mouth, hand-to-opposite shoulder, and to-anterior perineal region movements.

During the average follow-up period of 66.6 (range: 47 to 96) months, the mean OSS was 35.9 (range: 32 to 40) (original score range is 0 to 48), and the mean VAS score was 2.9 (range: 1 to 7) (original scale range is 0 to 10; where 0: no pain, 10: severe pain). Four patients had periodical pain independent of their daily activities.

Discussion

At present, the eradication of polio, a more successful fight against infections and advances in arthroplasty have resulted in the limitation of the indications for shoulder arthrodesis. Historical indications of arthrodesis for osteoarthritis, rheumatoid arthritis, irreparable rotator cuff tear, shoulder tuberculosis, and sequela of polio have been decreased in incidence or been replaced with arthroplasty.

Although the incidence of polio has been reduced, two patients in our series had sequelae resultant of polio. The mean age of these patients was 23.5 years. Their parascapular muscles were relatively well-protected. They underwent a Steindler flexorplasty in addition to arthrodesis. They reported that their upper extremity was stronger and more comfortable to use. None of the patients retained the preoperative pain and discomfort they felt over the shoulder area. They were able to do hand-to-head and hand-to-back pocket tasks. Daily functions such as dressing and face washing became possible. Neither showed scapular elevation.

The majority of our patients (5 patients; 62.5%) received treatment for a traumatic brachial plexus injury. The mean age of these patients was 57.6 years. In literature, the most common cause of brachial plexus injury is traffic accidents, which predominately affect young adults (90%). When the deltoid muscle and rotator cuff are not cured, neurolysis, nerve grafting and muscle transfer are required to restore shoulder functions.[5,6] As the trapezius muscles and levator scapulae muscles are almost always intact following traumatic brachial plexus injuries, active arm abduction is carried out through the scapulothoracic articulation. Serratus anterior function occurs with the forward elevation of the arm through scapular rotation.[5,6]

Shoulder arthrodesis is indicated for cases with extremely limited passive shoulder movements,

notable loss of bone or failed previous reconstructive surgery. Arthrodesis is also indicated for serious humeral or glenoid bone loss, dysfunction of deltoid and rotator cuff, and presence of persistent instability.[5,6] One of our patients had a non-smooth articular surface and non-union due to the fragmented fracture of the proximal humerus. Arthrodesis was considered for this patient who had concurrent axillary nerve paralysis.

The quality of remaining bone and soft tissue is an import factor in determining the suitability of prosthesis or arthrodesis following limb sparing surgery for bone tumors. Frequently, tissue loss is severe and arthrodesis is the only valid option. Such cases require vascularized fibula or abundant bone graft in order to achieve arthrodesis.[5,6,12]

Prosthesis is contraindicated when the septic event continues in patients with painful articular degeneration secondary to infection. In such cases, surgical debridement and glenohumeral fusion provide a painless and stable joint in many patients.[5,6]

The key indication is the presence of an irreparable deficiency of the deltoid muscle along with an irreparable rotator cuff tear. Fusion is usually recommended for young patients.[5] Multiple surgical techniques and fixation methods have been described for arthrodesis.[3,13] Intra-articular arthrodesis is carried out in the glenohumeral joint while extra-articular arthrodesis, which was mainly used for shoulder tuberculosis, is performed between the acromion and the humeral head. Currently, combined intra-articular and extra-articular fixation with one or two plates using of the AO technique has been reported to be the most common method.[1,2] In recent years, the need for postoperative casting or external fixation has been reduced with the use of dynamic compression plates.[3,13] We achieved sufficient stability with AO reconstruction plates in our patients, and union was observed in all patients during follow-up. It is very important to insert a minimum of 2 screws from the humeral head into the glenoid, one screw from the acromion into the neck of glenoid, and 4 screws into the humerus and scapula in order to achieve stability.[1-3]

For a better functional outcome with arthrodesis, the trapezius, levator scapula, serratus anterior and rhomboid muscles need to be functional.[1,6-8] Glenohumeral arthrodesis is contraindicated in patients without functional scapulothoracic movement.[10] Paralysis of the trapezius, levator scapula, and

Fig 4. Patient's movements. **(a)** Hand-to-mouth movement, **(b)** forward elevation, **(c)** rotation is seen. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

serratus anterior muscles may be the cause of such a loss of function. Shoulder arthrodesis is a less favorable option in patients with a risk of pseudarthrosis, such as Charcot arthropathy. Bilateral shoulder arthrodesis is not recommended for patients with bilateral shoulder disease as it will not allow for daily activities.[10] Shoulder arthrodesis does not provide satisfying results in patients with progressive neurological diseases or elderly patients.[10] In the current study, the periscapular muscles of all patients were intact.

Numerous studies have been conducted to establish the optimum positioning for arthrodesis, although no consensus has been reached until now. One of the discrepancies on the ideal position results from differences used in the reference points. These reference points can be the arm axis and vertebral border of the scapula or the lateral border of the scapula or the body trunk.[3,6-8] In the present study, the angle between the arm axis and the body axis was measured with a goniometer. It has been reported that the most critical complication following arthrodesis is the malposition of the extremity and chronic pain as a secondary consequence.[1] It is known that this leads to extreme abduction and malrotation of the flexion and winging scapula (scapula alata). Furthermore, extreme abduction may lead to traction neuritis in the brachial plexus, predominately the suprascapular nerve.[1,2] Although reference points may vary, historically less abduction and forward flexion and more internal rotation has been preferred. For our series of 8 patients our target position was 30° of abduction, 30° of forward flexion and 30° of internal rotation. With this position, patients reported satisfaction with both postoperative appearance and function. No patient complained of postoperative pain or discomfort.

The incidence of soft tissue problems and infections following arthrodesis has been reported to vary between 0 and 14 percent.[1,14] In the treatment of infection, irrigation and debridement are recommended along with appropriate antibiotics while keeping the plate-screw in place. An infection secondary to hematoma may develop at the donor site after harvesting the graft, and hematoma requires drainage and frequently parenteral antibiotics. In the present study, only one patient (12.5%) developed a wound infection associated with hematoma at the donor site and was treated with drainage and appropriate antibiotherapy.

Non-union is one of the most common complications following arthrodesis.[1,2,11] It should be considered in cases with a lack of radiological consolidation at a mean postoperative period of 24 weeks and the presence of chronic pain. Patient's age, presence of comorbidities, and a history of smoking or surgical procedures are among the factors in non-union. At present, fixation with an AO reconstruction plate provides sufficient stability. All of the patients in the current study underwent primary autogenous bone grafting and none experienced non-union.

Humeral shaft fractures below the arthrodesis plate occur in approximately 10% of patients. Loss of range of motion in the glenohumeral joint results in the application of force to the weak humeral shaft distal to the plate.[5,12,14] Most patients reported satisfactory results with bracing and immobilization of the humeral shaft fracture. If articular fusion is achieved, early rehabilitation without the need for immobilization can be obtained through the removal of the arthrodesis plate and fracture fixation. Cofield and Briggs favored external fixation in patients with fracture developing after arthrodesis fracture.[14] Most of these fractures develop in paralytic patients. External fixation can be used for treatment.[5,14] However, if the fracture is displaced and unstable, internal fixation is required.[14] In the present study, one patient developed a humeral shaft fracture distal to the arthrodesis plate at postoperative Month 4. Radiographs showed advanced porosis in the humerus, and thus a long plate was anteriorly inserted into the humerus without removing the arthrodesis plate. Union was achieved after 4 months. This patient had local osteopenia, particularly in paralytic cases. Therefore, there was no need to remove the plate.[5] The plate may be removed after the radiological evidence bony union, in patients with no obvious osteoporosis.

With the advances in the shoulder arthroplasty, the current indications for shoulder arthrodesis has been reduced. We preferred shoulder arthrodesis for patients with brachial plexus lesion, axillary nerve lesion and sequela of the poliomyelitis. Periscapular muscles were spared in these patients and shoulder arthrodesis is contraindicated when periscapular muscles are weak or paralyzed.

During arthrodesis extreme positions should be avoided in order to eliminate scapular elevation and shoulder pain. Therefore, we attempted to obtain an arthrodesis with a shoulder position of 30° in flexion, 30° in abduction and 30° of internal rotation. With this target position the patient is able to perform daily hygiene and personal care.

In conclusion, arthrodesis with fixation using an AO reconstruction plate and primary autogenous bone grafting is a reliable and safe method that can also be used as a salvage procedure.

Conflicts of Interest: No conflicts declared.

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