Proximal Radial Resection for Posttraumatic Radioulnar Synostosis: A New Technique to Improve Forearm Rotation

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Background: Heterotopic ossification about the elbow joint can lead to considerable functional disability, including the loss of forearm rotation. Many procedures have been described for the treatment of proximal radioulnar synostosis. Varying degrees of success have been achieved with regard to the improvement of the flexion arc, but less success has been reported in terms of the restoration of forearm rotation. The success of treatment is associated with the extent of heterotopic ossification, soft-tissue scarring, and anatomical distortion. A new and simple technique to address the unresectable proximal radioulnar synostosis is described.

Methods: Seven patients were managed with a partial proximal radial resection distal to the synostosis and were followed for an average of eighty months (range, twenty-four to 144 months).

Results: Forearm rotation improved from an average fixed pronation of 5° to an average arc of 98° (range, 40° to 175°). The average functional score improved from 57 points preoperatively to 81 points at the time of the final review. Complications included reankylosis at the site of the resection and ulnar-nerve sensory neurapraxia in one patient each.

Conclusions: Resection of a 1-cm-thick section of the proximal part of the radial shaft provides a safe and reliable method of improving forearm rotation in patients with heterotopic ossification of the elbow. A single technical factor that seems to positively influence the result is the application of bone wax at the resection site. This simple procedure is ideally suited for patients who have a proximal radioulnar synostosis that (1) is too extensive to allow a safe and discrete resection, (2) involves the articular surface, and (3) is associated with an anatomical deformity.

The development of a synostosis in the proximal part of the forearm is an uncommon but potentially disabling condition. Heterotopic ossification around the elbow joint is often asymptomatic, allowing a range of movement that is compatible with 90% of the activities of daily living[1,2]. Heterotopic ossification can result from burns[3], genetic predisposition[4], trauma involving the central nervous system[5,6], distal biceps tendon repair[7,8], and crush and direct local soft-tissue injury[9,10], with operatively treated forearm fractures cited as the most common cause[11].

Synostoses between the radial head and the bicipital tuberosity are especially difficult to treat, often because of extensive anatomic distortion. Synostosis takedown procedures are often difficult, endanger local neurovascular structures[12], and are associated with unpredictable improvement in the arc of rotation of the forearm. In the present study, we present our experience in the treatment of this difficult condition with use of a technique that creates a new axis of forearm rotation.

Materials and Methods

We retrospectively reviewed the records of eighty-seven patients with heterotopic ossification of the elbow who had undergone surgical treatment between January 1988 and January 1998. All patients had presented with some restriction of the flexion-extension arc. Forty patients had had surgical intervention to improve the flexion arc, twenty-two had had intervention to improve both the flexion arc and the rotation arc (with use of discrete radioulnar synostectomies), and twenty-five had had intervention primarily to improve the rotation arc. Eighteen of the latter twenty-five patients had been treated with removal of a discrete lesion and were excluded from this study. The other seven patients had presented with a primary functional disability due to loss of forearm rotation resulting from an extensive posttraumatic radioulnar synostosis involving the proximal one-third of the forearm. The cause of the synostosis was a high-velocity motor-vehicle accident in two patients and a low-velocity injury due to a fall in the other five. Three patients had a fracture-dislocation, and one had an

TABLE I Data on the Patients

	Case 1	Case 2	Case 3
Age *(yr)*	28	30	44
Sex	M	F	M
Mechanism of injury	Fell down 24-ft (7.3-m) elevator shaft	Motor-vehicle accident	Helicopter crash
Injuries	Central acetabular fracture-dislocation, fracture-dislocation of elbow, fractures of radial head and coronoid	Lacerations of liver and spleen; fractures of pelvis, fifth lumbar vertebra, sacrum, ribs, ulna; ligamentous injury of knee; bilateral pneumothorax	Fractures of lumbar spine, cervical spine, mandible; fracture-dislocation of elbow; fracture of femur; bilateral open fracture of ankle
Previous treatment	Resection of radial head, open reduction and internal fixation of coronoid, removal ectopic bone	Above-the-elbow splint for 6 wk	Radial head replacement, capsular release, interposition arthroplasty, ulnar nerve transposition
Preop. flex./ext. *(deg)*	85°/–75°	100°/–90°	130°/–40°
Preop. pronat./supinat. *(deg)*	0°/0°	15°/–15°	20°/–20°
Preop. radiographic findings*†	Ulnohumeral degenerative changes ++, type-IIc synostosis (15 mm)	Ulnohumeral degenerative changes ++, comminuted proximal ulnar fracture, type-III synostosis (38 mm)	Deformed trochlea, irregular capitellum, previous radial head resection, type-IIC synostosis (33 mm)
Interval between injury and index op. *(mo)*	144	6	16
Procedures performed at index op.	10 mm of radius resected (distal to tuberosity)	8 mm of radius resected (distal to tuberosity), synostosis takedown, capsulotomy, excision of olecranon tip	7 mm of radius resected (distal to tuberosity), anterior capsulectomy, removal of metalwork
Interpositional material	Bone wax, Gelfoam	Bone wax, Gelfoam	Bone wax, Gelfoam, anconeus
Intraop. flex./ext.	85°/–75°	140°/–20°	130°/–10°
Intraop. pronat./supinat.	70°/30°	90°/30°	80°/70°
Continuous passive motion	Yes	Yes	No
Radiation	Yes	No	No
Indomethacin	No	No	No
Splint†	No	Yes	Yes
Durat. of follow-up *(yr)*	12	4.5	10
Final flex./ext.	90°/–75°	135°/–30°	130°/–30°
Final pronat./supinat.	90°/25°	90°/–30°	70°/45°
Complications	Examination under anesthesia at 1 mo	Ulnar nerve symptoms for 3 mo, examination under anesthesia at 1 mo	Slight weakness of elbow
Subjective result	Satisfactory	Satisfactory	Satisfactory
Preop./final Mayo elbow performance score *(points)*	50/75	50/60	55/100

*+ = mild, ++ = moderate, and +++ = severe. †The extent of the synostosis is given in parentheses. ‡Splint = block splint.

TABLE I *(continued)*

Case 4	Case 5	Case 6	Case 7	Average
46	58	52	56	45
M	M	M	F	
Fell onto elbow while rollerblading	Fell from 10-ft (3.0-m) scaffolding	Fell onto outstretched hand while playing basketball	Fell at age of 6 yr (50 yr before presentation)	
Fracture of radial head and neck	Open comminuted fracture of proximal olecranon, radial head, and coronoid	Fracture-dislocation of elbow	Fracture of elbow	
Open reduction and internal fixation of radial fracture	Radial head resection, open reduction and internal fixation of olecranon fracture	Open reduction and internal fixation, radial head resection	Plaster cast for 3 wk	
90°/–65°	125°/–30°	135°/–25°	90°/–30°	108°/–51°
5°/–5°	–70°/70°	50°/–50°	15°/–15°	5°/–5°
Ulnohumeral degenerative changes +, malunion of proximal radius and ulna, type-IIC synostosis (25 mm)	Radioulnar and radiocapitellar degenerative changes ++, type-IIC synostosis (35 mm)	Ulnohumeral degenerative changes +, type-IC synostosis (35 mm)	Ulnohumeral degenerative changes +++, marked valgus deformity, absent radial head, type-IIC synostosis (30 mm)	(30 mm)
24	8	60	600	123
10 mm of radius resected (distal to tuberosity), anterior capsulectomy	5 mm of radius resected (distal to tuberosity)	10 mm of radius resected (between head and tuberosity), ectopic bone excised anteriorly and posteriorly	5 mm of radius resected (distal to tuberosity)	
Bone wax	Bone wax	Gelfoam	Bone wax	
135°/–15°	125°/–15°	125°/20°	140°/–20°	126°/–19°
80°/70	70°/85°	80°/50°	60°/40°	76°/54°
Yes	No	Yes	No	
No	No	No	No	
No	Yes	No	Yes	
Yes	Yes	Yes	No	
3.5	2	10	5	80 mo
135°/–45°	130°/–20°	135°/–45°	100°/0°	122°/–35°
75°/30°	90°/85°	20°/20°	35°/45°	67°/31°
None	None	Reankylosis, examination under anesthesia at 1 month	Forearm ache	
Satisfactory	Satisfactory	Unsatisfactory	Satisfactory	
65/85	55/85	75/90	50/75	57/81

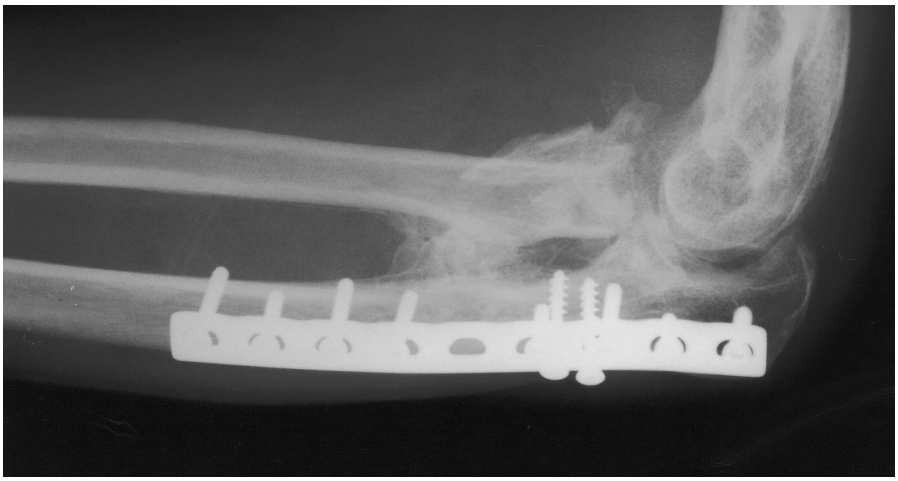

Fig. 1-A

Figs. 1-A, 1-B, and 1-C Case 5, a fifty-eight-year-old man (Case 5) with an extensive type-II synostosis. **Fig. 1-A** Radiograph made eight months after the injury.

open injury. Three patients had a fracture of both forearm bones, and four had a fracture of only one bone.

The office records, hospital charts, and radiographs were reviewed, and a final clinical and radiographic evaluation was performed for each patient at the time of the study. The mean time-interval between the original injury and the index operation was 123 months (range, six to 600 months). The preoperative radiographs were anatomically classified according to the system proposed by Viola and Hastings[13]. One patient had a type-I lesion (synostosis of the proximal radioulnar joint involving the intra-articular surfaces), five had a type-II lesion (synostosis of the proximal radioulnar joint extending distally to the bicipital tuberosity and involving the intra-articular surfaces) (Fig. 1-A), and one had a type-III lesion (synostosis distal to the proximal radioulnar joint and involving the neck and the bicipital tuberosity).

All seven patients were managed by the senior author (B.F.M.), and all were assessed with the modified Mayo elbow performance score[2]. Subjective data were collected at an average of approximately eighty months (range, twenty-four to 144 months) postoperatively.

Operative Technique

The procedure is performed with the patient under general anesthesia and in the supine position. A tourniquet is used. The arm is brought across the chest and stabilized by an assistant. A Thompson approach was utilized in the first patient but, because of the difficulties of this exposure, a Kocher approach was used in all six subsequent patients. Once the interval between the anconeus and the extensor carpi ulnaris is entered, the dissection is directed toward the ulnar shaft and the synostosis, which is followed to its distal margin by elevating the supinator from the radius. A 1-cm section of the radial shaft is then resected (Fig. 1-B). The resection is performed with use of a power saw either proximal or distal to the bicipital tuberosity, as dictated by the extent of the synostosis. In six of our seven patients, the resection was carried out distally. The range of forearm motion is examined at this stage, and a gentle manipu-

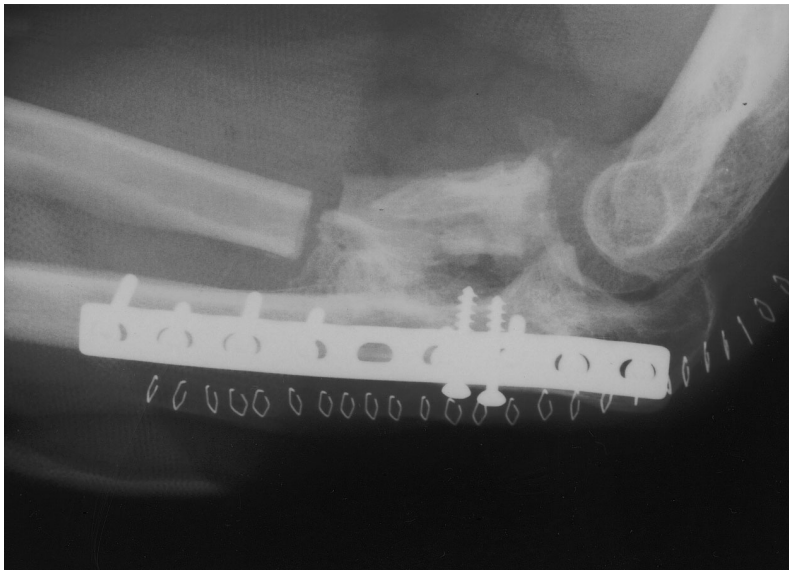

Fig. 1-B

Radiograph made immediately after resection of 5-mm-thick segment of the radial shaft distal to the bicipital tuberosity.

lation is performed, if needed, to mobilize the forearm. The transected bone ends are covered with bone wax, and the interval is bridged with Gelfoam (Upjohn, Kalamazoo, Michigan). The tourniquet is released, hemostasis is secured, and the exposure is closed in layers over a single suction drain.

The postoperative rehabilitation program consisted of continuous passive-motion therapy for forty-eight hours (four patients) and the use of static pronation-supination splints for three months (all patients). Static splinting was achieved with use of a two-component splint, with the first component spanning from the arm to the forearm and the second component consisting of an inner shell that wrapped the distal part of the forearm and the wrist like a gauntlet. A Velcro strap was used to rotate the forearm and wrist alternately to the maximum attainable amounts of pronation and supination. For the first three weeks, the program proceeds as follows: full supination at night, active and passive motion for one hour upon rising in the morning, full pronation until noon, removal of the splint for one hour at lunch, full supination until dinner, removal of the splint for one hour at dinner, full pronation during the evening, and removal of the splint for one hour before bedtime. After three weeks, the periods in which the splint is not worn progressively increase, depending on progress. The patient is assessed every three weeks, and the program is modified as needed. After three months, if further treatment is warranted, the splint is worn at night in the position in which it is most needed until no further progress is being made. The specific regimen varied from patient to patient. Two patients received indomethacin. Radiation therapy was offered to three patients, but only one accepted.

Results

Detailed results are presented in Table I. The mean preoperative arc of rotation was 0°, and the mean position of ankylosis was 5° of pronation. The mean total arc of rotation was 129° (range, 100° to 155°) intraoperatively and 98° (range, 40° to 175°) at the time of the final review. The mean improvement in the arc of pronation was 71° intraoperatively and 62° at the time of the final review. The mean improvement in the arc of supination was 59° intraoperatively and 36° at the time of the final review.

In six patients, the resected osseous surfaces had been sealed with bone wax; in four, Gelfoam had been placed between the resected bone ends; and in one, the anconeus muscle had been interposed between the bone ends. Only Gelfoam had been used in the patient who had a poor final arc of motion (Case 6), both bone wax and Gelfoam had been used in the patient with a fair arc (Case 2), and only bone wax had been used in the patient with a good arc (Case 7). Of the four patients who had excellent motion, two (Cases 4 and 5) had been treated with bone wax only, one (Case 1) had been treated with bone wax and Gelfoam, and one (Case 3) had been treated with bone wax, Gelfoam, and interposition of the anconeus. While these numbers are limited, Gelfoam in isolation seems to be inadequate to prevent reankylosis whereas bone wax appears to have more favorable properties in this respect.

Three patients (Cases 1, 2, and 6) demonstrated a marked loss of forearm rotation at one month postoperatively. Two of these patients (Cases 1 and 2) had a functional arc of motion on examination under anaesthesia, and one (Case 6) required a formal manipulation. In one of these patients (Case 6), the arc of rotation had measured 130° intraoperatively but decreased to only 40° by the time of the latest follow-up. In the other two patients, however, the final arcs of rotation were excellent (Case 1) and fair (Case 2). One patient (Case 2) had paresthesias in the distribution of the ulnar nerve, which resolved at three months postoperatively. No patient had a postoperative infection.

The mean resection gap, as measured on radiographs

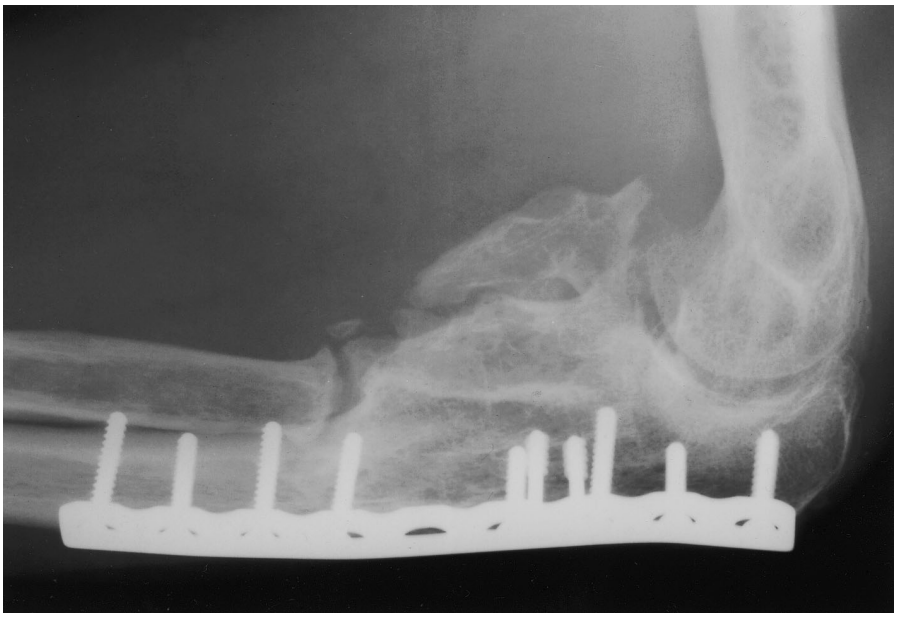

Fig. 1-C
Twenty-four months postoperatively, the synostosis had progressed, the resection site remained open, and function had been maintained.

with use of an electronic caliper, was 6.8 mm (range, 5.3 to 8.2 mm) postoperatively and 4.7 mm (range, 2.5 to 7.2 mm) at the time of the latest follow-up (Fig. 1-C). The mean angulation between the proximal and distal fragments at the time of the most recent follow-up was 3.4° (range, 1.5° to 4.5°).

At the time of the most recent follow-up, the functional result according to the Mayo elbow performance score was excellent in two patients, good in four, and fair in one. There was little difference between the preoperative and postoperative scores for pain and stability; however, there were substantial improvements in the scores for motion and activities of daily living. The average score for motion increased from 5 points (all patients) preoperatively to 18 points (range, 15 to 20 points) at the time of the final follow-up, and the average score for activities of daily living improved from 11 points (range, 0 to 20 points) preoperatively to 21 points (range, 15 to 25 points) at the time of the final follow-up. The overall functional score improved from an average of 57 points (range, 50 to 75 points) preoperatively to an average of 81 points (range, 60 to 100 points) at the time of the final review.

Discussion

Most reports on the treatment of heterotopic ossification about the elbow have involved small and heterogeneous groups of patients, with high complication rates and moderate outcomes[14,15]. Historically, late excision of the synostosis mass has been advocated because of the poor results of early excision[8,10,16,17], which has commonly been associated with recurrence[10]. However, more recent investigators have observed better results with fewer complications[1,18-20], with some reporting good results, after early excision of the synostosis mass[7,18,19].

Vince and Miller, in what we believe to have been the first detailed report of radioulnar cross-union, described a series of twenty-eight patients in whom a synostosis had developed after a fracture of the forearm[10]. Only three cross-unions involved the proximal radioulnar joint. All three patients were treated with excision of the synostosis, with recurrence developing in two. The third patient had had interposition of a silicone sheet at the site of the excision and did not have a recurrence of the cross-union.

Both synthetic and biological materials have been interposed between the bone surfaces at the site of excision of the synostosis, including bone wax[5,8], Gelfoam, polyethylene[8], cellophane membrane[21], silicone[8,22], muscle[23], vascularized anconeus pedicle graft[24], free fat graft[5,25], and free vascularized fascio-fat graft[26]. Other measures that have successfully prevented the recurrence of heterotopic bone formation have included indomethacin[27] and radiation therapy[16,19,28-32], although the majority of studies involving those measures have been related to total hip arthroplasty. These prophylactic and surgical interposition methods have been associated with varying degrees of success with respect to the prevention of the recurrence of heterotopic ossification. The risk factors that have been associated with recurrence have included the severity of the initial injury, the extent of the synostosis, and the failure of a previous takedown procedure[33,34]. Reoperation at the same site in the early postoperative period and a delay of postoperative mobilization by more than three days may also prevent a good result[8].

The most direct and common surgical approach for the treatment of proximal radioulnar synostosis involves resection of the synostosis. An alternate strategy that has been used to restore forearm rotation is to bypass the lesion and to create a pseudarthrosis of the radius distal to the synostosis. This possibility was suggested by Bunnell in 1948[35]. In 1957, Kelikian and Doumanian reported on two patients in whom a proximal radioulnar synostosis was treated with the insertion of a swivel prosthesis within the axis of the proximal part of the radius, distal to the biceps tuberosity[12]. Although the short-term results were promising, the long-term results were not described. Similarly, Proubasta and Lluch reported on one patient in whom a silicone radial head implant was inserted within the radial medullary cavity[36]. After ten years of follow-up, the patient had retained an improvement of 80° of supination and 20° of pronation. The radiographs suggested that the resected area included the bicipital tuberosity, but the authors provided no information on any subsequent assessment of elbow power in flexion or supination.

The operative technique described in the present study has not been reported previously, to our knowledge. This technique preserves the articular integrity proximal to the synostosis. In six of our patients, the resection was performed distal to the bicipital tuberosity. In five of our patients the synostosis involved the radial head and neck and the bicipital tuberosity, and in one patient it involved the bicipital tuberosity alone. In one patient (Case 6) in whom the synostosis involved only the radial head and neck, the resection was performed proximal to the bicipital tuberosity. The final range of motion in this patient was poor, and the clinical result was unsatisfactory. The average arc of forearm rotation was 129° intraoperatively and 98° at the time of the final review, representing a maintenance of 76% after an average duration of follow-up of eighty months (range, twenty-four months to twelve years). This represents a substantial improvement in the long-term maintenance of forearm rotation in comparison with previous results from our clinic[33]. Furthermore, the degree of synostosis and deformity in the current series was more extensive, making the outcome even more acceptable to both the patient and the surgeon. It should be emphasized that this technique is not considered an alternative to removal of the synostosis. When it is technically possible to cleanly excise a discrete bridge of bone, that method continues to be the treatment of choice. The technique described here addresses a pathologic process that is not amenable to resection of the synostosis.

The presence of a chronic Essex-Lopresti injury would preclude the use of this procedure. Therefore, the preoperative assessment should rule out the presence of distal radioulnar joint symptoms and signs. A mean reduction in the resection gap of 2.1 mm at the time of long-term follow-up does not appear to cause symptoms. Previous reports have suggested that as much as 2 mm[37,38] of radial shortening can

occur without the development of symptoms in the wrist or the distal radioulnar joint.

In conclusion, the technique that we have described in the present study is a relatively simple surgical procedure that reliably improves forearm rotation after the formation of an extensive proximal radioulnar synostosis that is not otherwise amenable to resection. ■

NOTE: The authors thank Sherry Koperski for her help during this study.

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The authors did not receive grants or outside funding in support of their research or preparation of this manuscript. They did not receive payments or other benefits or a commitment or agreement to provide such benefits from a commercial entity. No commercial entity paid or directed, or agreed to pay or direct, any benefits to any research fund, foundation, educational institution, or other charitable or nonprofit organization with which the authors are affiliated or associated.

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