Proximal radial diaphyseal segment resection for posttraumatic proximal radioulnar synostosis: a prospective study of 15 cases

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\textbf{Background:} Proximal radioulnar synostosis is a complication after elbow injuries. Various treatment methods have been reported and are associated with unpredictable outcomes. In a prospective study, we evaluated the medium-term effects of proximal radial resection on wrist and elbow function and forearm rotation in 15 cases.

\textbf{Methods:} We treated 15 patients with posttraumatic proximal radioulnar synostosis by resection of 1 cm of the proximal radial diaphysis. On the preoperative examination and last follow-up, the Mayo Elbow Performance Score, grip force, visual analog scale for elbow and wrist score, radiographic ulnar variance changes, and elbow range of motion were measured. The Disabilities of the Arm, Shoulder, and Hand (QuickDASH) score and the general satisfaction of the patients were assessed at the final follow-up.

\textbf{Results:} The mean duration of follow-up was 31 ± 13 months. The mean active postoperative supination/pronation arc was 101° ± 45°. The mean increase measured in the ulnar variance at the final follow-up was 3.3 ± 1.5 mm ($P = .02$). The mean final QuickDASH score was 13.3 ± 12.1. The preoperative and final Mayo scores were 57 ± 10 and 91 ± 7, respectively ($P = .01$). The general satisfaction with the results of the operation was 86.6%.

\textbf{Conclusions:} We suggest that proximal radial resection for the treatment of posttraumatic proximal radioulnar synostosis shows acceptable results in adults regarding the recovery of range of motion and patient satisfaction. This technique might be considered as a salvage procedure, particularly in cases with previous failed heterotopic resection at the proximal radioulnar joint, resulting in disturbed anatomy.

\textbf{Level of evidence:} Level IV, Case Series, Treatment Study.

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\textbf{Keywords:} Proximal radioulnar joint; synostosis; heterotopic ossification; radial resection; QuickDASH score; Mayo Elbow Performance Score; ulnar variance; satisfaction
Posttraumatic proximal radioulnar synostosis is a rare but serious complication after severe elbow injuries that could lead to functional disability from a limitation of forearm rotation. Because of extensive anatomic distortion and the proximity of the neurovascular structures, treatment of proximal radioulnar synostosis is difficult and associated with unpredictable outcomes. Treatment methods have included excision of the synostosis with soft tissue or synthetic material interposition, excision of the proximal radius, screw insertion to distract the radius from the ulna, and rotational osteotomy of the radius. Reports of varying degrees of improvement in forearm rotation are inconclusive because of the small number of cases and different evaluation methods.

Kamineni et al reviewed 7 cases treated by proximal radial resection to create a new axis of forearm rotation. The aim of this prospective study was to evaluate the medium-term effects of proximal radial resection on wrist and elbow function and forearm rotation in cases with proximal radioulnar synostosis.

Materials and methods

Patients

In a prospective study between May 2007 and January 2012, we treated posttraumatic proximal radioulnar synostosis with a proximal radial diaphyseal segment resection in 19 patients (16 men and 3 women), including 10 patients with injuries on the left and 9 patients with injuries on the right forearm. Patients who had signs of distal radioulnar joint instability were excluded from this study. The dominant limb was involved in 10 of the patients. All of the patients presented with limited rotational forearm motion. The mean age of the patients was 31 ± 13 years (range, 12-56 years). Eleven cases were traffic accident injuries, and 8 were fall injuries. Seven patients underwent elbow contracture release surgery in a separate operation to improve the flexion arc. Six patients had a fracture-dislocation (1 had a concomitant scaphoid fracture), 3 had a radial head fracture, 5 had a proximal ulnar fracture, 4 had fractures of both forearm bones, and 1 had extensive soft tissue injury with a skin defect. The radial resection procedure was performed 31 ± 15 months (range, 5-55 months) after the initial injury.

Assessments

At the preoperative examination and last follow-up, the following assessments were conducted. The flexion/extension and supination/pronation range of motion were measured by a goniometer, and elbow stability was examined. All of the patients were assessed with the Mayo Elbow Performance Score and the visual analog scale (VAS) for the elbow and wrist; the grip force was measured by a grip dynamometer (Jamar device; Patterson Medical, Warrenville, IL, USA). At the final follow-up, the Disabilities of the Arm, Shoulder, and Hand (QuickDASH) score was calculated for all of the patients, and the patients’ general satisfaction was assessed. The ulnar variance changes were calculated from the preoperative and follow-up wrist radiographs. We defined synostosis recurrence as new heterotopic bone formation at the osteotomy site visible on the final elbow radiographs, bridging between proximal and distal stumps (resulting in fixed forearm rotation).

Figure 1  Case number 8. (A) Preoperative radiograph. (B) Preoperative axial computed tomography scan showing extensive synostosis. (C) Operative approach; asterisk indicates radial resection site. (D) Immediate postoperative radiograph.
Operative technique

The procedure was performed in the supine position under general anesthesia with the application of a tourniquet. The proximal radial shaft was exposed by the Thompson approach in all of the patients except 2, for whom the Kocher approach was used because of a previous surgical scar. With use of a power saw (without irrigation), 1 cm of the radial diaphysis was resected just distal to the synostosis. Bone wax and Gelfoam (Pfizer, New York, NY, USA) were used in all of the cases at the resection site after gentle manipulation. A suction drain was placed, and the wound was closed in layers (Fig. 1).

Postoperative rehabilitation program

No splinting was used postoperatively. Adjuvant 25 mg of indomethacin was administered twice a day for 6 weeks. Active and active assisted forearm range of motion began on the first postoperative day. The patient follow-up occurred at 3, 6, and 12 weeks and at 6 months and the last follow-up.

Statistical analysis

The statistical analysis was performed by SPSS software, version 18.0 (Statistical Product and Service Solutions, SPSS Inc, Chicago, IL, USA). The data are presented as the mean ± standard deviation and median. The Wilcoxon and Mann-Whitney U tests were used to compare the continuous variables. The paired t test was used to compare the quantitative variables before and after the radial resection procedure. P < .05 was considered statistically significant.

Results

We treated 19 cases; of these, 15 patients participated in the long-term follow-up study. The mean age of the observed patients was 29 ± 14 years. The results are presented in Online Supplementary Table I.

The mean preoperative arc of flexion/extension was 78° ± 31°, and the supination/pronation was fixed in all of the patients. The postoperative flexion/extension and supination/pronation arcs were 81° ± 33° and 101° ± 45° (range, 15°-180°), respectively. The mean duration of the follow-up was 31 ± 13 months (range, 6-48 months). At the time of the final follow-up, the final pronation was 50° ± 30° (range, 0°-90°); the data on the forearm range of motion of case number 11 were excluded because of an untreated recurrence. The mean increase measured in the ulnar variance at the final follow-up was 3.3 ± 1.5 mm (range, 0-7 mm; P = .02); however, none of the patients complained of wrist pain assessed with the VAS score.

The mean grip force was 25.9 ± 11.4 kg preoperatively and 26.3 ± 11.7 kg at the final follow-up. The mean final QuickDASH score was 13.3 ± 12.1. The preoperative and final Mayo scores were 57 ± 10 and 91 ± 7, respectively. The mean increase in the preoperative and final Mayo scores was 33 ± 8 (P = .01). The general satisfaction with the surgical results was 86.6%, and no preoperative factor

<table>
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<th>Table 1</th>
<th>Comparison of preoperative and final assessments</th>
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<td>Scores/measurements</td>
<td>Preoperative</td>
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<tr>
<td></td>
<td>Mean (SD)</td>
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<tr>
<td>Supination/pronation arc of motion, degrees</td>
<td>0 (0)</td>
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<tr>
<td>Mayo Elbow</td>
<td>57 (10)</td>
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<tr>
<td>Performance Score, points</td>
<td>25.9 (11.4)</td>
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<tr>
<td>Grip force, kg</td>
<td>-0.13 (1.4)</td>
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<td>QuickDASH score</td>
<td></td>
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<td>Ulnar variance, mm</td>
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SD, standard deviation.
was found predictive for higher satisfaction of the patients. Comparative results are presented in Table I.

Two patients had posterior interosseous nerve paralysis postoperatively; 1 resolved at 3 months, and 1 underwent a tendon transfer procedure for wrist extension at 3 months but resolved in 9 months. Four patients, including 2 adolescents, developed recurrence; 3 patients underwent reoperation, with 1 refusing surgery (Fig. 2). Except for 1 patient, who had a concomitant ipsilateral scaphoid fracture, all of the patients had full wrist range of motion at the final follow-up.

The site of the osteotomy was at the level of the bicipital tubercle in 8 cases and distal to the tubercle in 7 patients. We found no relationship between the ulnar variance changes and the site of resection, VAS score, and Quick-DASH score. None of our patients complained of instability of the proximal radial stump or of tardy radial nerve irritation; however, mild instability of the elbow was detected in 5 cases at the final follow-up.

Discussion

Little has been published about the therapeutic options for posttraumatic proximal radioulnar synostosis that have involved heterogeneous outcomes and high complication rates. Currently, the treatment preference is to excise the synostosis when the associated fractures are healed or when the process is radiographically static. Vince and Miller described 3 proximal radioulnar synostosis cases managed by synostosis resection, in which recurrence developed in 2 cases. Failla et al reported on a case series of 20 proximal radioulnar patients treated by synostosis resection; recurrence developed in 7 patients, and 13 patients had poor results. Jupiter and Ring presented good to excellent outcomes in a 17-patient case series with 1 recurrence. Their experience has not been repeated by other authors in the literature.

To reduce the risk of postoperative synostosis recurrence, synthetic and biologic materials have been used to fill the resection gap, including fat graft, vascularized fascio-fat graft, muscle, silicone, and Gelfoam and bone wax. Radiation therapy and adjuvant nonsteroidal anti-inflammatory medication have been suggested as prophylactic means to prevent recurrence. In this study, we used Gelfoam and bone wax for the surgical interposition.

In 1948, Bunnell suggested treating proximal radioulnar synostosis by bypassing the lesion, and this treatment is associated with fewer complications. Kelikian and Doumanian, in 1957, reported a modified method using a swivel prosthesis to replace the proximal part of the radius distal to the bicipital tuberosity with acceptable results. In 7 cases, Kamineni et al assessed a technique to improve the outcomes with proximal radial resection (distal to the synostosis location) to create a new axis of forearm rotation; good short-term results were reported. The effect of this procedure on the wrist and elbow functional outcomes was not reported. In this study, we applied a similar method with 15 patients. Because of the similarity between this method and the Sauvé-Kapandji surgery for distal radioulnar injuries, this method could theoretically be viewed as a reverse Sauvé-Kapandji technique.

In an English-language literature review of the proximal radial resection technique, we found the study of Kamineni et al to be the only case series that reported promising results with this method; our study differs in some aspects. Our study is a prospective study focused on the clinical outcomes and the effects of this procedure on the wrist and elbow separately. We performed release of the elbow when necessary in a separate operation with at least a 6-month interval, and we excluded the effects of any additional procedure in our study.

In our study, of the 15 patients whom we observed until the end of the study, the mean preoperative grip force was $25.9 \pm$
11.4 kg; at the final follow-up, it was 26.3 ± 11.7 kg ($P = .01$). This finding shows a slight increase in the grip force, which is statistically significant but clinically unimportant.

The active range of motion increased in all of our patients, except in the case with a recurrence. We did not include the passive range of motion of the forearm in our evaluations; however, all of our patients had almost full range of motion except for the patient with untreated recurrence (Fig. 3).

Radial displacement was another assessment in our study, and as we expected, this displacement increased the ulnar variance with an average of 3.3 ± 1.5 mm (range, 0-7 mm), which appears to be greater than the radial displacement in the radius head resection studies, reported to be 1.4 mm by Leppilaiti and Jalovaara and 1.9 mm by Morrey et al (Fig. 4). In these 15 cases, the radius excision site was located at the level of the bicipital tuberosity in 8 cases and below the tuberosity in 7 cases.

The relationship between the change in the ulnar variance and the site of osteotomy was reassessed, but there was no significant correlation. None of our patients complained of wrist pain (except 1 patient who had a concomitant ipsilateral scaphoid fracture).

Two of our patients were adolescents with open growth plates according to plain radiography. Both of them showed recurrence. One underwent a second operation and showed improvement of forearm supination/pronation to 70°/10°. This patient was not satisfied with the surgery and complained of pain at the surgery site and hand weakness.

We had 4 cases of recurrence, including those of the 2 adolescents. In all of the cases of recurrence, severe limitation of the range of motion was obvious in the second week, and heterotopic ossification was detected radiographically in the sixth week. Three of these 4 patients underwent similar surgery, and none of them developed recurrence after the second operation. The mean active forearm range of motion of these 3 cases was 88° ± 28°. Thus, considering the patient who underwent tendon transfer for nerve paralysis, 5 of the 15 followed-up patients needed additional major surgical procedures.

There were 2 cases of transient posterior interosseous nerve paralysis, which improved spontaneously in 3 and 9 months; however, none of our patients complained of tardy radial nerve palsy or irritation. None of the patients complained of postoperative elbow instability; but clinically, a mild valgus instability occurred in 5 of our cases. We compared the different prognostic factors with respect to the final clinical results evaluated by the QuickDASH score; none of the factors had an effect on the final result.

According to the results of our study, proximal radial resection for posttraumatic proximal radioulnar synostosis appears to give acceptable results in adults with respect to recovery of range of motion and patient satisfaction; however, in terms of the clinical scores, the results are varied. Although only 2 of our cases were adolescents, the outcomes of this method suggest that it is not appropriate before closure of the growth plate. The increase in ulnar variance is, on average, greater than in cases in which radius head resection is performed; however, this change in variance does not cause wrist pain. The results suggest that treatment of synostosis recurrence with repetition of the identical method is safe and effective. This surgery does not produce symptoms resulting from instability in the stump of the radius at the osteotomy site or delayed mid-term posterior interosseous nerve injury.

### Conclusion

Although we did not attempt to compare the reverse Sauvé-Kapandji technique with other techniques (particularly synostosis resection) in this study, we suggest this technique for the treatment of all cases of proximal radioulnar joint synostosis. It might be considered as a salvage procedure, particularly in cases with previous failed surgery, heterotopic ossification on the proximal forearm, or elbow with disturbed anatomy.

### Disclaimer

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Supplementary data

Supplementary data related to this article can be found online at http://dx.doi.org/10.1016/j.jse.2014.02.007.

References