International Orthopaedics (SICOT) (2015) 39:73–79
DOI 10.1007/s00264-014-2594-5

ORIGINAL PAPER

Comparative study of radial head resection and prosthetic replacement in surgical release of stiff elbows

Shi-yang Yu · He-de Yan · Hong-jiang Ruan · Wei Wang · Cun-yi Fan

Received: 21 September 2014 / Accepted: 1 November 2014 / Published online: 16 November 2014

Abstract
Purpose Elbow trauma can compromise the arc of elbow flexion and forearm rotation. This study aimed at comparing the outcomes of radial head resection and prosthetic replacement in the surgical release of post traumatic elbow stiffness and associated restriction in forearm rotation.
Methods We retrospectively reviewed the data of patients who underwent open arthrolysis with radial head resection (n = 15; resection group) or radial head replacement (n = 19; replacement group). The pre- and postoperative measurements of the elbow range of motion (ROM) were recorded. Elbow function was evaluated by the Broberg and Morrey Evaluation System; the Mayo Elbow Performance Index (MEPI); and the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire.
Results Over a mean follow-up duration of 22 months, the improvement in the arc of flexion and extension was 79° (range, 45–125°) and 82° (range, 10–110°), while that in the ROM for forearm rotation was 96° (range, 40–150°) and 102° (range, 15–150°) in the resection and replacement groups, respectively. There were no significant intergroup differences in the elbow ROM measured at the last follow up. The Broberg and Morrey, MEPI, and Dash scores in the two groups were comparable.
Conclusions Both resection and prosthetic replacement of the radial head with open arthrolysis of post traumatic elbow stiffness were feasible in treating the associated restriction of forearm rotation. We recommend that if the elbow is stable after complete release, radial head resection is preferable to prosthetic replacement because it is technically less demanding.

Keywords Elbow stiffness · Radial head · Resection · Prosthetic replacement · Arthrolysis

Introduction

Stiffness of the elbow joint is a common complication of elbow trauma [1, 2]. Difficulty in elbow movement secondary to trauma can be attributed to several factors, such as fibrosis of the capsule, heterotopic ossification (HO), and malunions or nonunions of elbow fractures. The restriction in the degree of elbow flexion or rotation hinders the execution of daily activities. Surgical treatment of elbow stiffness has proved to be effective in restoring elbow motion [3–5], which significantly improves the patients' quality of life, particularly when post traumatic elbow function is low [6].

Several surgical techniques have been introduced for the correction of elbow stiffness [2, 3, 7–13], but only a few studies have addressed the manipulation of a rotation-restricted elbow. Open arthrolysis with prosthetic replacement of the radial head has been shown to be an effective strategy for the correction of limited forearm rotation [14]. However, to the best of our knowledge, no studies have been published on the comparison between the outcomes of radial head resection and replacement in treating elbow contracture. The purpose of this study was to compare the results of radial head resection and prosthetic replacement in open arthrolysis for the correction of elbow stiffness and forearm rotation restriction and accordingly establish criteria for the selection of the appropriate treatment strategy.

Shi-yang Yu and He-de Yan contributed equally to this work.

S.-y. Yu · H.-d. Yan · H.-j. Ruan · W. Wang · C.-y. Fan (✉)
Department of Orthopaedics, Shanghai Jiaotong University Affiliated Sixth People's Hospital, Shanghai 200233, People's Republic of China
e-mail: fancunyisjtu@126.com

Materials and methods

Patients and materials

This investigation was designed as a retrospective study. The study protocol was approved by the ethical committee of Shanghai Jiao Tong University Affiliated Sixth People's Hospital East Campus. We retrospectively reviewed the data of patients who underwent open elbow arthrolysis at our institution between January 2010 and January 2013. The criteria for inclusion were as follows: (1) skeletally mature, (2) post traumatic elbow stiffness with total arc of flexion and extension less than 100° and total range of motion (ROM) for forearm rotation less than 90°, and (3) radial head excision or radial head replacement was performed to treat rotation limitation. The exclusion criteria were as follows: (1) severe burn injuries, (2) associated central nervous system injuries, (3) prior elbow release, and (4) active infection. During the three-year study period, 221 patients underwent surgery for elbow stiffness at our institution. Of the patients, 39 met the inclusion and the exclusion criteria; then, five of the 39 patients were excluded because their follow-up data were available for less than six months from the most recent surgery and they could not be contacted. Among the remaining 34 patients, 15 underwent open release and radial head excision (resection group), and 19 patients underwent open release with prosthetic replacement of the radial head (replacement group). Table 1 shows the patient demographics. The injury patterns included the terrible triad of the elbow, radial head fracture, distal humerus fracture and Monteggia fracture. The initial injury patterns and the treatment protocols for the same are summarized in Table 2.

All patients underwent radiologic evaluation before surgery and laboratory tests. The laboratory test results, including the levels of serum phosphate, blood calcium, and blood alkaline phosphate, were normal for all patients. All the surgeries had been performed by the same surgeon (Cun-yi Fan). The indications for radial head resection included nonunion or malunion of the radial head, cartilage damage in the capitellum, and severe adhesions of the radial head limiting forearm rotation or flexion and extension of the elbow. If the risk of valgus instability was thought to be high after removal of the radial head, replacement with a radial head prosthesis was considered.

Surgical technique

Surgery was performed in the supine position under brachial plexus block. A sterile tourniquet was applied. The site of incision was determined on the basis of the incision made in the previous surgery, the location of the heterotopic bone, and the presence of neuropathy. Surgical exposure was achieved through combined lateral and medial incisions in 28 patients, a lateral incision in two patients, and a posterior midline incision in four patients in both groups. The internal fixations were removed depending on the patient's willingness and whether solid union of the fracture had occurred. All metal implants of the previous surgery were removed in six patients in the resection group and 11 patients in the replacement group.

The extended Kocher approach was used for the lateral incision. The space between the anconeus and the extensor carpi ulnaris was widened to expose the radial head and neck. This was followed by the dissection of the annular ligament and removal of the bridging heterotopic ossification between the radius and ulna. Next, the biceps tuberosity was identified, and at a level of 5 mm above this tuberosity, the neck of the proximal end of the radius was resected. Then, complete anterior capsulectomy was performed, and the ulnohumeral joint was exposed; any osteophytes or heterotopic bones present in the coronoid fossa were then resected. The medial approach was used for the release of the posterior aspect of the elbow joint. The ulnar nerve was identified and preserved. The margins of the triceps tendon were then split and reflected off the distal humerus to expose the posterior aspect of the elbow. Subsequently, the posterior band of the medial collateral ligament (MCL) and posterior capsule were released, and bony impediments or scar tissues present within the olecranon fossa were removed under direct visualization.

For the patients in the replacement group, the same procedure described above was followed with the addition of the prosthetic replacement of the radial head after satisfactory exposure of the surgical area was achieved. A Tornier cement stem and a bipolar radial prothesis (Edina, MN, USA) were implanted for the arthroplasty. The annular ligament was then repaired by placing nonabsorbable sutures.

The contracture release was considered satisfactory if a flexion/extension arc of 130°/10° and a pronation/supination arc of 50°/50° were achieved. Elbow stability was assessed after complete arthrolysis. If the elbow showed valgus or varus instability, repair of the lateral collateral ligament (LCL) or the MCL was performed with the use of osseous suture anchors. One and three patients required LCL repair, while three and five patients required both LCL and MCL repair in the resection group and replacement group, respectively. MCL repair was required for two patients of the replacement group. After reexamining the ROM, a unilateral hinged external fixator (Orthofix, Verona, Italy) was applied to the elbow to provide additional stability and enable early elbow joint mobilization in a controlled manner. Ulnar nerve neurolysis was performed for all patients at the final stage of the surgery. Five and four patients in the resection group and the replacement group underwent subcutaneous anterior transposition of the ulnar nerve, respectively. A drainage tube was left in place, and the wound was closed in layers.

Table 1 Demographics and preoperative comparison between groups

Characteristic	Resection group	Replacement group
No. of elbows	15	19
Gender (F/M)	13/2	15/4
Age (years)	31.2 (range, 16–56)	34.1 (range, 16–54)
Dominant arm	11	10
Initial pathology		
Terrible triad of the elbow	4	7
Radial head fracture	7	10
Distal humeral fracture	3	1
Monteggia fracture	1	1
Time from injury (months)	14 (range, 3–36)	10 (range, 3–30)
Pre-operative flexion and extension arc	37° (range, 5–70°)	34° (range, 0–90°)
Flexion	82° (range, 40–115°)	78° (range, 30–130°)
Flexion contracture	46° (range, 20–80°)	44° (range, 0–85°)
Pre-operative forearm rotation ROM	14° (range, 0–80°)	16° (range, 0–80°)
Pronation	9° (range, 0–75°)	4° (range, 0–30°)
Supination	5° (0–50°)	11° (0–70°)
Pre-operative ulnar neuropathy	5	3
Duration of surgery (h)	2.8 (range, 1.5–4.5)	3.3 (range, 2.1–4.6)
Total inpatient cost (RMB)	35,819	61,028

F female, *M* male, *ROM* range of motion

Postoperative management

Patients were prescribed 25 mg of indomethacin thrice daily for approximately four to six weeks after the surgery to prevent HO. Patients were instructed to perform cycle exercises, which included active, active-assisted, and passive elbow motion, starting from the first postoperative day. The exercises were performed for half-hour sessions three or four times daily during the first postoperative week; the length of the individual sessions was gradually increased to one hour in the subsequent weeks. The progressive exercise program was continued for as long as three months after the surgery. The hinged external fixator was removed six to eight weeks after surgery as an outpatient procedure.

Table 2 Comparison of initial injury patterns and treatment in the groups

Characteristic	Resection group	Replacement group
Terrible triad of the elbow		
ORIF	1	1
ORIF and casting	2	4
Radial head resection and casting	0	2
Casting	1	0
Radial head fracture		
ORIF	1	3
ORIF and casting	4	4
Radial head resection and casting	0	1
Casting	2	2
Distal humerus fracture		
ORIF	1	0
ORIF and casting	2	1
Monteggia fracture		
ORIF and casting	1	1

ORIF open reduction and internal fixation

Intergroup comparison

The two treatment groups did not show any significant differences in terms of age ($P=0.88$), gender ($P=0.67$), dominant arms involved ($P=0.30$), the initial fracture patterns ($P=0.67$), the interval between the initial injury and our intervention ($P=0.10$), the presence of ulnar neuropathy ($P=0.42$), or the mean surgical time ($P=0.27$). Similarly, no significant intergroup differences were noted with respect to the arc of flexion and extension ($P=0.16$) and the ROM for forearm rotation ($P=0.97$). The total inpatient cost was RMB 35,819 (equivalent to USD 5,777) in the resection group and RMB 61,028 (equivalent to USD 9,843) in the replacement group ($P<0.01$). The data obtained for the two groups are compared in Table 1.

Evaluation

Follow-up evaluation was done at six to eight weeks (removal of external fixator), at three months, and then every six months after the surgery. Patients whose follow-up data were inadequate were invited for a free clinical evaluation and

radiological examination. Standard anteroposterior and lateral radiographs were obtained for detection of HO and assessment of arthritis grade and implant stability. The elbow arthritis was graded according to the criteria described by Broberg and Morrey [15]. Clinical evaluation at follow up included assessment of the ROM of the elbow, elbow pain, instability, and ulnar neuropathy. The final elbow ROM was measured using a goniometer. Elbow function was assessed using the Broberg and Morrey Evaluation System [16] score, the Mayo Elbow Performance Index [17] (MEPI), and the Disabilities of the Arm, Shoulder, and Hand questionnaire [18] (DASH) score. Elbow pain was evaluated using a visual analogue scale (VAS) in the range of 0 to 10, with 0 representing no pain and 10 representing the most severe pain. In addition, patients were asked to rate their general satisfaction (as very satisfied, satisfied, or not satisfied) with the treatment at the final follow up.

Statistical analysis

Continuous variables, such as elbow ROM and clinical function scores, were analysed using the unpaired *t*-test, whereas dichotomous variables were compared by Fisher's exact test. A *P* value of 0.05 or less was considered statistically significant. All the statistical analyses were performed using IBM Corp., release 2010, SPSS Statistics for Windows, version 19.0 (IBM Corp., Armonk, NY).

Results

The mean follow-up duration in this study was 22 months (range, 13–34 months). The results of the data obtained at the final follow up are summarized in Table 3. The mean flexion degree after treatment was slightly greater in the resection group than in the replacement group ($P<0.05$), but the intergroup differences were not significant in terms of the final arc of flexion and extension ($P=0.09$) and the ROM for forearm rotation ($P=0.57$). Figures 1 and 2 show images of the elbow and its motion in one patient each in the resection group and replacement group, respectively. No significant differences were noted between the two groups with respect to the Broberg and Morrey scores, MEPI, DASH scores, arthritis grade, and patient satisfaction rate recorded at the final follow up.

The postoperative complications evaluated were pain, infection, HO, and ulnar neuropathy. Three and six patients in the resection group and replacement group reported having occasional and mild pain at the final follow-up visit, with the VAS score being 2 (range, 1–3) and 2.8 (range, 2–4), respectively. One patient in each group developed superficial pin-tract infection, which was treated with the removal of the pins and wound care. Two patients in the resection group and three in the replacement group had recurrence of HO, but the elbow motion was not affected. Two and one patient had persistent ulnar nerve palsy, while one and two patients had new signs of ulnar neuropathy without a pre-existing ulnar nerve dysfunction in the resection and replacement groups, respectively. Elbow instability was absent in both groups at the latest follow up. There were no intergroup differences in terms of the frequency of complications ($P>0.05$).

Discussion

Elbow trauma can severely compromise the motion of the elbow. Limitation of forearm rotation occurs frequently with elbow trauma, especially when the radial head is involved. In our case series, 30 out of 34 patients had fracture or dislocation of the radial head during the initial injury, and the average ROM of forearm rotation was 15° (range, 0–80°). The causes for the limitation in the rotation are malunions or nonunions of the radial head fracture, prolonged immobilization, soft tissue contracture, and HO around the proximal radioulnar joint.

Primary radial head resection has been considered as the treatment of choice for displaced and comminuted fractures of the radial head [19, 20]. Resection of the radial head following trauma affords satisfactory long-term results. Goldberg et al. [21] conducted a retrospective study of patients with Mason type II and type III fractures of the radial head who underwent the excision procedure and reported that the patient satisfaction rate was 92%, over an average follow-up period of 16.4 years. Secondary radial head resection is a common procedure adopted for the open release of stiff elbows [22, 23]. In this study, all patients who underwent open arthrolysis with radial head resection reported postoperative improvement in the execution of daily activities and occupational work. Only three of our patients who underwent radial head excision reported occasional and mild pain at the end of the follow-up period, and no complications of instability or recurrence of elbow stiffness were observed during the study period; these findings verify the safety of this procedure.

For elbows with severe stiffness, the collateral ligaments may be ossified and may, therefore, be excised during complete arthrolysis; this results in instability of the elbow. Therefore, prosthetic replacement should be carefully considered if the radial head cannot be preserved, in order to correct the rotatory restriction, especially in the cases of associated ligament disruption or elbow dislocation occurring with the initial trauma or high risk of postoperative valgus instability. According to Morrey et al. [24], the radial head, as the secondary constraint of the elbow joint, plays an important role in preventing valgus instability, especially when the anterior band of the MCL (the primary constraint) is divided.

Table 3 Comparison of treatment outcomes in the resection and replacement groups

Parameter	Resection group		Replacement group		
	Mean±SD	Range	Mean±SD	Range	*P* Value
Flexion	127°±13°	110–150°	125° ±8°	110–140°	< 0.05[a]
Flexion contracture	11° ±14°	0–45°	9° ±8°	0–25°	0.14[a]
Flexion and extension arc	116° ±21°	80–150°	116° ±13°	90–140°	0.09[a]
Improvement in flexion and extension arc	79° ±23°	45–125°	82° ±27°	10–110°	0.53[a]
Pronation	36° ±20°	0–70°	43° ±20°	15–70°	0.95[a]
Supination	75° ±16°	45–90°	74° ±27°	0–100°	0.27[a]
Forearm rotation ROM	110° ±27°	75–150°	118° ±38°	30–160°	0.57[a]
Improvement in forearm rotation ROM	96° ±30°	45–150°	102° ±42°	15–150°	0.20[a]
B & M score	89±6	76–97	88±7	72–99	0.64[a]
MEPI	95±7	80–100	94±7	80–100	0.24[a]
DASH score	11±7	2–25	9±8	1–28	0.91[a]
B & M categorical rating	2 excellent, 11 good, 2 fair		3 excellent, 15 good, 1 fair		0.84[b]
MEPI categorical rating	12 excellent, 3 good		13 excellent, 6 good		0.70[b]
Arthritis grade[c]	Grade I, 9; Grade II, 5; Grade III, 1		Grade I, 10; Grade II, 6; Grade III, 3		0.79[b]
Satisfaction rating	Very satisfied, 13; Satisfied, 2		Very satisfied, 16; Satisfied, 3		1.00[b]

ROM range of motion, *B & M* Broberg and Morrey, *MEPS* Mayo Elbow Performance Index, *DASH* Disabilities of the Arm Shoulder and Hand questionnaire

[a] Unpaired *t*-test[b] Fisher's exact test[c] Grade 0, normal joint; Grade 1, slight joint space narrowing with minimum osteophyte formation; Grade 2, moderate joint space narrowing with moderate osteophyte formation; and Grade 3, severe degenerative changes with gross destruction of the joint

Biomechanical studies have also shown the importance of the radial head in varus and posterolateral stability of the elbow [25–28]. In the presence of a torn MCL, obvious valgus instability, and associated lesions of the LCL and coronoid process on the affected limb, radial head replacement arthroplasty should be performed to provide stability to the elbow [29]. History of resection of the radial head and lesions of the interosseous membrane are other indications for the prosthetic replacement of the radial head [30]. In this study, three patients in the replacement group had undergone improper radial head resection in their previous surgeries and had laxity under valgus stress after the surgical release of the elbow. However, the patients were not aware of these problems before surgery because of the restricted motion of the elbow. As mentioned by Faldini et al. [31], elbow instability might be more relevant in the case of heavy workers or athletes after the removal of the radial head; therefore, prosthetic replacement is a better option in such cases.

Oversizing and overstuffing of the prosthesis are main reasons that mandate the revision of radial head replacement [32, 33]; therefore, the size and height of the implant need to be carefully determined during the operation, which further increases the procedural difficulty. In our study, the operation time in the resection group was slightly, but not significantly, lesser than that in the replacement group. However, the inpatient cost was significantly higher for patients treated with

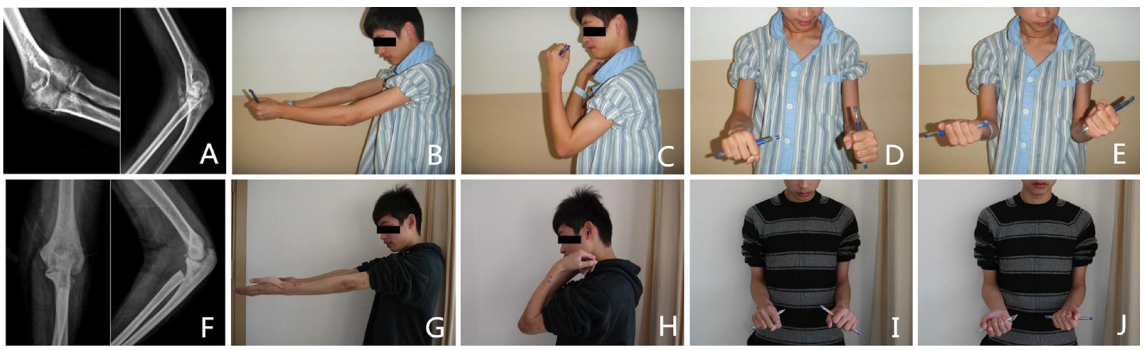

Fig. 1 (**a**) The anteroposterior and lateral radiographs of a 22-year-old man with elbow stiffness after initial trauma. The range of (**b**) extension, (**c**) flexion, (**d**) pronation, and (**e**) supination of the elbow was limited. (**f**) Postoperative anteroposterior and lateral radiographs show radial head resection. At a follow-up examination 36 months after surgery, the range of (**g**) extension, (**h**) flexion, (**i**) pronation, and (**j**) supination of the elbow was satisfactory

Fig. 2 (**a**) The anteroposterior and lateral radiographs of a 48-year-old man show elbow stiffness after open reduction and internal fixation of radial head fracture. The range of (**b**) extension, (**c**) flexion, (**d**) pronation, and (**e**) supination of the elbow was limited. (**f**) Postoperative anteroposterior and lateral radiographs show radial head replacement and some heterotopic ossification (HO) around the elbow joint at 24 months after surgery. The range of the (**g**) extension, (**h**) flexion, (**i**) pronation, and (**j**) supination of the elbow was satisfactory

replacement arthroplasty. Since there were no significant differences between the radial head resection and prosthetic replacement with regard to the postoperative elbow motion and function, we recommend that the resection procedure would be preferable if no instability is detected during the surgery, since it is technically less demanding and cheaper.

Several issues in the operative procedure of the surgical release of the stiff elbow need to be highlighted. The lateral ulnar collateral ligament and the anterior bundle of the MCL should be carefully preserved during the arthrolysis, since they are the principal constraints of the elbow joint against posterolateral rotatory instability and valgus forces [34, 35]. After complete arthrolysis of the elbow is performed and satisfactory ROM is achieved, it is important to check for valgus and varus stress stability. Repair of the collateral ligament can be performed by using nonabsorbable sutures or suture anchors, if necessary. The hinged external fixator provides stability after extensive arthrolysis and creates ideal conditions for the recovery of muscles and ligaments; moreover, it maintains and improves the arc of motion as a contracture splint, which is very helpful for postoperative rehabilitation [5, 13]. Considering that the recurrence of HO affects the final ROM of the elbow and correlates with the time of postoperative immobilization [36], we believe that the use of the external fixator promotes early rehabilitation and thereby contributes to good outcomes in the management of elbow stiffness.

Since the current study is retrospective in nature, the results would not be as reliable as those of a prospective randomized controlled study on the topic. The choice of whether the patient required resection or replacement of the radial head with arthrolysis was left to the surgeon's discretion. However, the demographics and preoperative status of the patients in both groups in our study were comparable, which minimizes the influence of selection bias to some extent. Other limitations are the small number of patients and short follow-up duration. Previous studies have shown that the results one year after arthrolysis can be applied for the mid-term follow-up period [11, 23].

Conclusions

Our study indicates that both resection and prosthetic replacement of the radial head for the surgical correction of elbow stiffness are feasible in the management of the associated restriction of forearm rotation. The two treatment methods did not show any significant difference with respect to the ROM and postoperative function of the elbow. Radial head resection is preferable if the elbow is stable after complete arthrolysis because it is technically less demanding; in other cases, prosthetic replacement is recommended to ensure the stability of the elbow. The long-term outcomes of arthrolysis with radial head resection and replacement need to be compared in a well-designed, prospective, randomized trial with a larger sample size.

Conflict of interest None.

Ethical committee approval The study protocol was approved by the ethical committee of Shanghai Jiao Tong University Affiliated Sixth People's Hospital East Campus with study number DYLL-2014004.

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