Short- to Medium-term Outcomes of Radial Head Replacement Arthroplasty in Posttraumatic Unstable Elbows: 20 to 70 Months Follow-up

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Background: The radial head is considered the main stabilizer of the elbow when the medial collateral ligament and lateral ulnar collateral ligament have been compromised. Radial head replacement (RHR) is indicated for patients with irreparable or non-united radial head fractures associated with elbow stiffness or instability. The present study aimed to analyze the clinical results after treatment with titanium radial head prostheses, repair of torn soft tissue constraints, and early mobilization of the elbow.

Methods: From 2002 to 2008, 13 patients with radial head fractures were included. RHR arthroplasty was performed primarily for irreparable fractures in 10 patients and secondarily for radial head fracture nonunion in 3. All patients were followed-up clinically and radiographically for a mean of 38 months (range, 20 to 70 months).

Results: On the basis of Mayo Elbow Performance Scores, 8 patients had excellent results; 3, good results; and 2, fair results. No patient had elbow instability after RHR. Two patients had elbow stiffness 6 months after RHR and underwent surgical intervention for contracture release. None of the prostheses were removed because of loosening or infection.

Conclusion: Treatment of irreparable radial head fractures with a modular titanium radial head prosthesis and soft-tissue reconstruction yields satisfactory results. Early mobilization of the elbow is important for the restoration of elbow range of motion and function.

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Key words: irreparable radial head fracture, radial head replacement, posttraumatic unstable elbows

The joint between the radial head and the capitellum is an important stabilizer for axial and valgus loading of the forearm.[1] Fractures of the radial head constitute approximately 1.7% to 5.4% of all adult fractures.[2] Approximately 33% of fractures of the elbow may be associated with radial head fractures.[3] Approximately 85% of radial head fractures occur in young and active people.[4]

According to studies conducted at the Mayo Foundation, the medial collateral ligament is the pri-

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mary constraint and the radial head is the secondary constraint of the ulnohumeral joint in resisting valgus stress.[5] Biomechanically, the radial head is considered the main stabilizer if the coronoid process is fractured, the medial collateral ligament is incompetent, or the lateral ulnar collateral ligament is disrupted.[6] The critical role played by the radial head in overall stability of the elbow and forearm has motivated many orthopedic surgeons to preserve the radial head during fracture treatment. Treatment options for radial head fracture include splinting, open reduction and internal fixation (ORIF), early or delayed radial head excision, and radial head replacement (RHR).[7]

Mason Type III radial head fractures include comminuted fractures that are considered unreconstructible.[3] Surgical management includes radial head excision with or without RHR arthroplasty.[8] Recent studies have revealed altered kinematics and stability of the elbow after radial head excision alone. With RHR, the kinematics and stability of the elbow are equal to those of a native radial head.[9] RHR offers better results than radial head excision alone.

This study aimed to analyze the clinical results after treatment of complex elbow injuries with titanium radial head prostheses, along with ligament repair and fracture fixation to facilitate early mobilization of the elbow.

METHODS

We retrospectively reviewed 47 elbows with posttraumatic instability in 47 patients who had received surgical treatment between 2002 and 2008 at our hospital. Among these, 13 patients underwent RHR. The indications for RHR included comminuted and irreparable radial head fracture with elbow dislocation or comminuted radial head fracture with disruption of the medial collateral ligament (MCL), lateral ulnar collateral ligament (LUCL), or forearm interosseous ligament, non-united radial head fracture with elbow stiffness or instability.

Information on gender, age, injury mechanism and side, and radial head fracture classification with associated injuries was recorded for these 13 patients (Table 1). All 13 patients had Mason type III fractures of the radial head. Ten patients with an unreconstructible Mason type III fracture of the radial head had prosthesis replacement with a metal radial head implant (Evolve modular, Wright, TN, U.S.A.) with or without repair of soft tissue constraints primarily by the same surgeon (ACC) (Fig. 1).[3,10] The other 3 patients received ORIF with Leibinger plates primarily because of intra-operative findings of possible fracture fixation. Two patients had radial head

Table 1. Patient Data

No	Sex	Age	Injury	Side	Fx type*	Associated injury
1	F	16	Fell	R	III	Annular ligament
2	M	47	Fell	L	III	ULCL, coronoid
3	F	60	Fell	L	III	MCL
4	M	32	Fell	R	III	MCL
5	M	42	Fell	R	III	Ulnar fracture
6	F	63	Fell	R	III	ULCL
7	M	43	MVA	R	III	ULCL, coronoid, olecranon
8	M	34	Fell	L	III	ULCL
9	M	46	Fell	L	III	ULCL, coronoid
10	M	24	Judo	L	III	ULCL
11	M	27	Fell	R	III	ULCL
12	M	31	Fell	R	III	ULCL, coronoid
13	F	37	Fell	L	III	MCL

Abbreviations: ULCL: ulnar lateral collateral ligament; MCL: medial collateral ligament; MVA: motor vehicle accident. *: Mason classification.

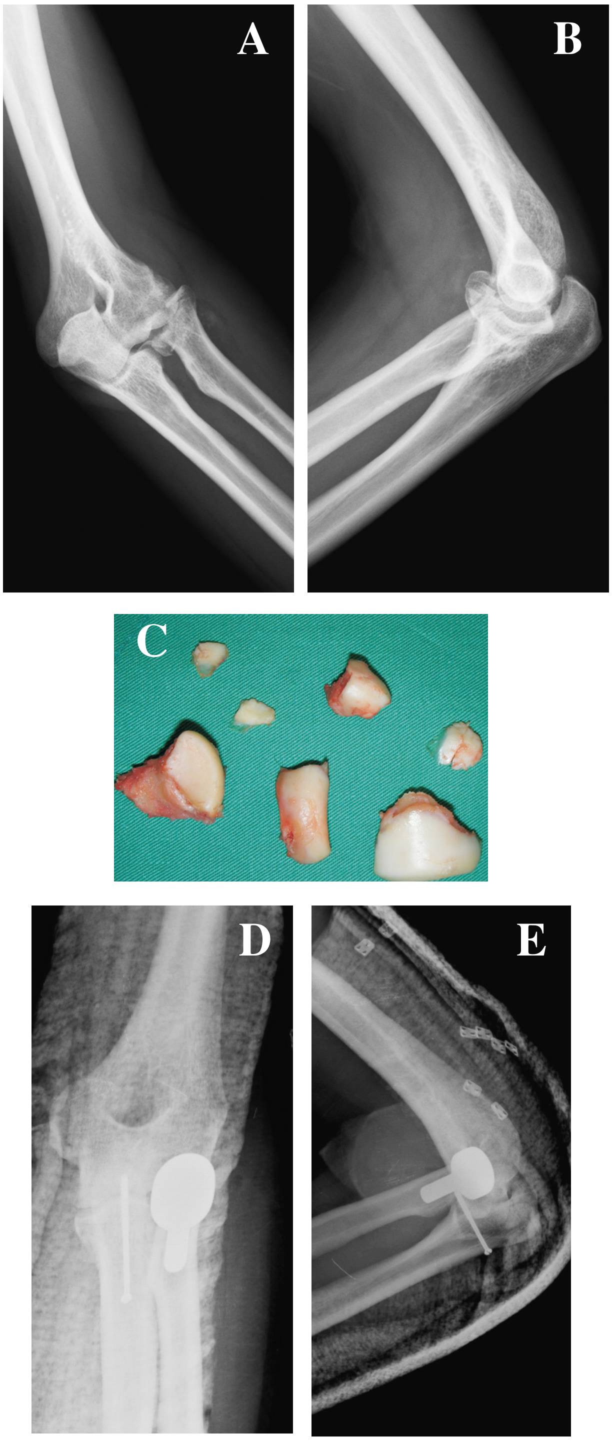

Fig. 1 (A, B) Comminuted radial head fracture with coronoid process fracture. (C) Intra-operative photograph showing severe, irreparable radial head fracture. (D, E) After radial head prosthesis implantation and open reduction and internal fixation for coronoid process with a cannulated screw.

fracture non-union with elbow stiffness and the other had radial head fracture nonunion with valgus instability. RHR arthroplasty with contracture release or collateral ligament repair was performed for these 3 patients (Fig. 2).

Surgical data, including surgical procedures, elbow stiffness and instability before RHR arthroplasty, and duration of follow-up, were also documented (Table 2). Table 3 lists the post-RHR range of motion, functional arc, stiffness and instability of the elbow.

Surgical procedure

All the implants were placed through a lateral Kocher approach,with a skin incision over either the lateral or posterior elbow.[11] We choose a lateral skin incision if we did not anticipate repair of the MCL or fixation of the olecranon or coronoid. A posterior approach was preferred for patients with elbow valgus instability or fracture of the olecranon or coronoid. We began a lateral elbow incision superior to the lateral epicondyle and extended it distally approximately 6 cm across the joint in the interval between the extensor carpi ulnaris and the anconeus. We started the incision for a posterior elbow approach at the level of the olecranon fossa and extended it distally to the proximal ulna. We then dissected between the triceps muscle posteriorly and between the brachioradialis and extensor carpi radialis longus muscles anteriorly to expose the lateral condyle and the capsule over the lateral surface of the radial head. The annular ligament was incised transversely. Then we could classify the radial head fracture as reperable or irreparable. We performed ORIF for reparable radial head fractures and RHR arthroplasty for irreparable fractures.

We used modular radial head implants (Wright). It was important to retrieve all the fragments of the radial head, even if radiographic intervention was required. The radial head fragments were recouped to assist in selecting the implant size. We compared the height of the radial head fragments with the trial prosthesis to select the thickness of the prosthetic head. A sizing disc was used to select the diameter of the implant. A slightly undersized diameter and thickness were preferred for the prosthesis so the radial head prosthesis articulated congruently with the capitellum.

During surgery, we observed the relationship

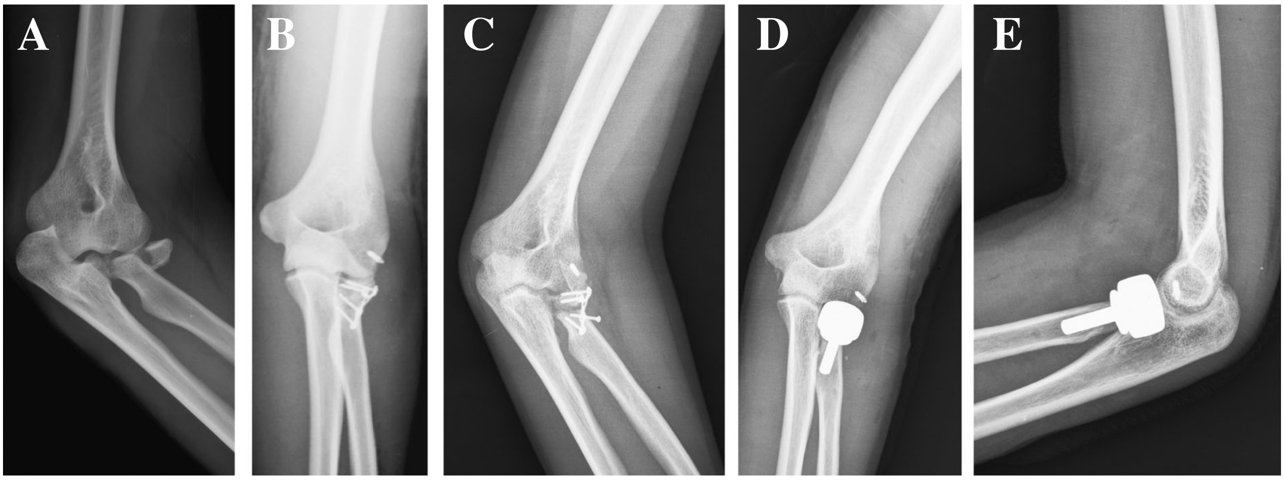

Fig. 2 (A) Elbow dislocation with displaced radial head fracture. (B) After open reduction and internal fixation for radial head with Leibinger plate and repair of lateral ulnar collateral ligament with suture anchor. (C) Displaced radial head fracture fragments with non-union. (D, E) Congruent articulation between the metal radial head implant and the capitellum 2 years after implantation.

Table 2. Surgical Data

No	1st op	Radial head non-union	Elbow stiffness (after 1st op)	Elbow instability (after 1st op)	2nd op	Follow-up (m)
1	RHR repair	–	nil	nil	–	70
2	RHR ORIF repair	–	nil	nil	–	52
3	RHR repair	–	nil	nil	–	34
4	RHR repair	–	nil	nil	–	36
5	ORIF	+	+	nil	RHR release	29
6	ORIF repair	+	nil	+	RHR,	27
7	RHR ORIF repair	–	nil	nil	–	32
8	RHR repair	–	nil	nil	–	42
9	RHR ORIF repair	–	nil	nil	–	20
10	ORIF repair	+	+	nil	RHR, release	33
11	RHR repair	–	nil	nil	–	40
12	RHR ORIF repair	–	nil	nil	–	39
13	RHR repair	–	nil	nil	–	42

Abbreviations: RHR: radial head replacement; ORIF: open reduction and internal fixation; op: operation.

between the capitellum and the implant in the anteroposterior and lateral projections by carrying the forearm through the range of flexion, extension, and rotation to ensure satisfactory contact between the capitellum and the prosthesis and a good fit in the radial medullary canal. If the patient had coexistent LUCL injury, we held the torn LUCL reduced to its isometric point with the ulnohumeral joint, and then reattached it and the other lateral capsular structures by making drill holes or using a suture anchor at the capitellar rotation center.

In patients with radial head fracture non-union and stiff elbows, an anterior and posterior capsulectomy, removal of scarring and heterotopic tissue and contracture release were performed first. All radial head fragments were removed. We resected the

Table 3. Post-Radial Head Replacement Data

No	Flexion/ extension (°)	Supination/ pronation (°)	Arc of flexion-extension (°)	Elbow rotation (°)	Elbow stiffness	Elbow instability
1	125/20	75/70	105	145	nil	nil
2	110/10	70/70	100	140	nil	nil
3	140/0	85/90	140	175	nil	nil
4	125/5	85/85	120	170	nil	nil
5	110/20	65/60	90	125	+	nil
6	135/0	85/90	135	175	nil	nil
7	135/0	85/90	135	175	nil	nil
8	130/5	80/85	125	165	nil	nil
9	125/5	70/70	120	140	nil	nil
10	95/15	70/80	80	150	+	nil
11	140/0	85/85	140	170	nil	nil
12	140/0	85/90	140	175	nil	nil
13	135/0	85/90	135	175	nil	nil

remaining radial head at the level of the radial neck fracture, perpendicular to the neck. About 60% of the native radial neck was needed for contact with the implant.

Postoperative care

After the procedure, a long-arm splint at 90 degrees of flexion was applied for all patients. When a patient had associated lateral-side ligament injuries, the forearm was splinted in maximal pronation at 90° of elbow flexion for the first 6 weeks. When there were associated medial-side ligament injuries, the forearm was splinted in maximal supination at 90° of elbow flexion for the first 6 weeks. If both medial and lateral-sided ligament injuries were present, the forearm was splinted in neutral rotation at 90° of elbow flexion. Active flexion and extension exercises were performed within a "safe" arc of motion as dictated by the associated osseous and soft-tissue injuries. Forearm pronation and supination exercises were performed actively with the elbow in 90° of flexion or as dictated by the degree of ligament stability. After 6 to 8 weeks, active and passive stretching and strengthening exercises were initiated.[12]

Outcome measures

All patients were followed-up clinically and radiographically for a mean of 38 months (range from 20 to 70 months) by the same surgeon. The clinical evaluation was performed using the Mayo Elbow Performance Score (MEPS).[13] The assessment included a record of the patient's pain level, range of movement at the elbow, elbow stability, and functional level. Each patient's affected range of movement was compared with the contralateral elbow. The MEPS results were classified as excellent (> 90), good (75–89), fair (60–74), or poor (< 60) (Table 4).

Radiographs, including anteroposterior and lateral views of each elbow, were evaluated postoperatively, at 1 month, 6 months, and 1 year and at the time of final outpatient department follow-up. The radiographs were reviewed for congruity of the radial head with the capitellum, evidence of capitellar osteopenia and erosion, size of prosthesis, periprosthetic loosening, heterotopic ossification, joint incongruity, and osteoarthritis. The size of the prosthesis was evaluated by comparing the widths of the medial and lateral ulnohumeral joint spaces of each patient's operatively treated and uninvolved elbow on follow-up anteroposterior radiographs.[14] If the width of the lateral ulnohumeral joint space was increased relative to that in the contralateral elbow or if the medial ulnohumeral joint space was not parallel and was wider laterally (Fig. 3), the prosthesis was considered too thick (overstuffing). We defined radiolucency as any discrete 1-mm region of decreased bone density around the prosthesis.[15] Periprosthetic lucency around the stem (Fig. 4) was graded as none, mild, moderate, or severe on the basis of the number of involved zones, using a modification of the Gruen classification for the hip,[16] and the amount of lucency was noted in millimeters. Heterotopic ossification was graded with use of the Hastings and Graham classification.[17] The degree of degenerative change was graded with the system outlined by Broberg and Morrey.[18]

Table 4. Explanation of Mayo Elbow Performance Score

Function	Definition	Points	Score classification
Pain	None	45	Excellent > 90
	Mild	30	
	Moderate	15	
	Severe	0	
Motion	Arc > 100	20	Good, 75–89
	Arc 50–100	15	
	Arc < 50	5	
Stability	Stable	10	Fair, 60–74
	Moderate instability	5	
	Gross instability	0	
Function	Comb hair	5	Poor < 60
	Feed	5	
	Hygiene	5	
	Shirt	5	
	Shoe	5	
Total		100	

RESULTS

The outcomes of 13 radial head arthroplasties in 13 patients were reviewed. The patients' median age was 37 years (range, 16–63 years). The mean duration of follow-up was 38.3 ± 12.4 months (range, 20-70 months). Eleven patients were injured in falls, one patient was injured by being dragged while participating in judo, and the other patient was injured in a motor vehicle accident (Table 1). RHR arthroplasty was performed primarily for irreparable fractures in 10 patients and secondarily (more than 6 months after injury) for nonunion in 3 patients.

Clinical results

Biomechanical study shows that activities of daily living can be accomplished without discomfort within a functional arc of motion of elbow flexion-extension of 100°, and forearm rotation of about 100° (pronation 50° to supination 50°).[19] Therefore we defined elbow stiffness as a functional arc of flexion-extension less than 100° and forearm rotation

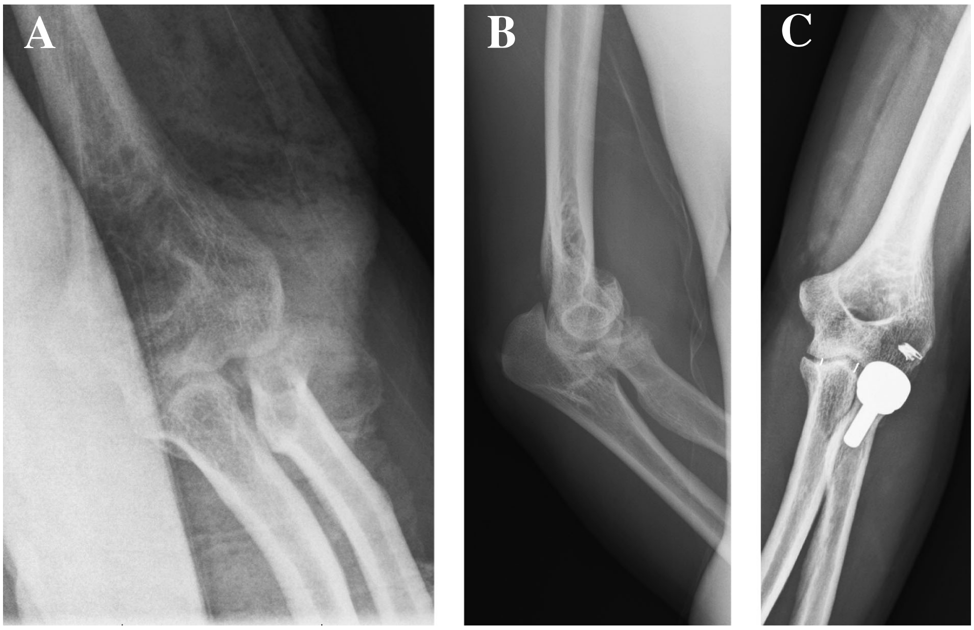

Fig. 3 (A, B) Subcapital irreparable radial head fracture and coronoid process avulsion fracture. (C) Radial head prosthesis with a non-parallel and laterally wider medial ulnohumeral joint space, indicating prosthesis overstuffing.

Fig. 4 (A, B) Comminuted irreparable radial head fracture. (C, D) After radial head prosthesis implantation. (E, F) Periprosthetic radiolucency around the stem, 8 months postoperatively.

less than 100°. The range of motion (ROM) of the elbow of the 13 patients after RHR was as follows (Table 3): mean flexion was 126.5° (95° to 140°) mean extension was 6.2° (0° to 20°), mean pronation was 78.8° (65° to 85°) and mean supination was 81.2° (60° to 90°). The mean arc of flexion-extension was 120.4° (80° to 140°) and mean arc of rotation was 160° (125° to 175°). None of the prostheses needed removal because of loosening or infection.

Radiologic results

Implant overstuffing was noted in 3 patients (23%). One patient (7%) patient had radiolucency. There were no instances of capitellar osteopenia, heterotopic ossification, or degenerative changes.

Functional results measured by MEPS

On the basis of MEPS, 8 patients had excellent results, 3 patients had good results, and the remaining 2 patients had fair results (Table 5).

Table 5. Mayo Elbow Perfomance Scores (MEPS) for all Patients

No.	Pain	ROM	Stability	Function	MEPS
1	30	20	10	20	80
2	45	20	5	25	95
3	45	20	10	25	100
4	45	20	10	25	100
5	15	15	10	20	60
6	45	20	5	25	95
7	45	20	5	20	90
8	15	20	5	20	60
9	45	15	10	25	90
10	45	20	5	25	95
11	30	20	10	25	85
12	45	20	10	25	100
13	30	20	5	25	80

Abbreviation: ROM: range of motion.

Complications

No patients had elbow instability after RHR. Two patients had elbow stiffness 6 months after RHR (Table 3). One patient had been treated surgically with both RHR and ORIF with placement of a dynamic compression plate for an olecranon fracture. He had limited range of motion of the involved elbow, and radiography revealed a screw protrusion at the dynamic compression plate. He underwent surgery for implant removal 21 months after RHR and regained full ROM of his elbow. The second patient had received a RHR and developed elbow stiffness two months later. He underwent two surgeries for contracture release and regained full elbow ROM. No patients had infection or neurovascular injury.

DISCUSSION

The management of comminuted Mason type-III radial head fractures with associated ligament disruption remains controversial.[3] Several surgical options have been advocated for these complex injuries, including ORIF, excision of the radial head, and RHR.[20]

Anatomically, the proximal radial epiphysis is contained wholly within the joint capsule. When the skeleton is immature, very few blood vessels cross the physis. The vascular supply to the proximal radial epiphysis is limited to a few small intraarticular vessels coursing along the radial neck and a few intraosseous vessels, resulting in a scanty vascular supply to the radial head.[21] Yamaguchi also observed that the radial head was supplied primarily by intraosseous vessels. One vessel supplies the radial head directly, entering through the nonarticular anterolateral surface. Consequently, fracture of the radial head is likely to disrupt its vascular supply.[22] In addition, ORIF of a comminuted radial head is often technically difficult. Therefore, ORIF is not reliable for comminuted fractures because of possible osteonecrosis, nonunion, or displaced fragments.[23,24]

Simple excision of the radial head in patients with associated interosseous membrane disruption or a medial collateral ligament injury yields poor results, with wrist or elbow instability a frequent outcome. Mikic et al. reported poor results in 50% of patients after excision of the radial head.[25] Josefsson et al. revealed that excision of the radial head may lead to stiffness, weakness and pain.[26] Leppilahti et al. also pointed out that radial head excision was associated with stiffness and a high complication rate.[27] Hall et al. treated 42 dislocated elbows with concomitant radial head fracture by excision of the radial head. Posterolateral rotatory instability occurred in 17% of their cases.[28] Recent reports in the literature have demonstrated that radial head excision is contraindicated for patients with an incompetent medial collateral ligament, disrupted forearm interosseous ligament, or elbow dislocation.[29-31] Radial head excision has fallen out of favor as a result of complications such as valgus elbow instability, elbow stiffness and proximal migration of the radius.[25]

Radial head arthroplasty is indicated for displaced comminuted radial head fractures that cannot be managed reliably with ORIF and have an associated elbow dislocation.[32] Replacement is also indicated in patients with comminuted radial head fractures that have or are likely to have a disruption of the medial collateral, lateral collateral, or interosseous ligaments.[33] In patients with non-united radial head fractures, articular injury to the capitellum and radial notch of the ulna may occur and lead to elbow arthrosis.[7] Prosthesis replacement can better restore the stability, flexion and extension of the elbow, and the rotational motion of the forearm.[34]

Various prosthetic materials, including silicone rubber,[35] acrylic,[36] cobalt-chromium,[37] vatallium,[38] and titanium,[39] have been employed. Silicone implants can fragment, cause synovitis, and restore axial and valgus stability of the elbow poorly.[40] Biomechanical studies have demonstrated that metallic implants restore elbow stability to a level similar to that of the native radial head when a fracture of the radial head occurs in combination with dislocation of the elbow, rupture of the medial collateral ligament, fracture of the proximal ulna, or fracture of the coronoid process.[41] New modular designs have improved sizing to better reproduce the anatomy of the proximal radius, and they are easier to insert intraoperatively.

Historically, monoblock and bipolar metallic radial head prostheses have been advocated. The size matching of monoblock implants is often imperfect and they are difficult to insert because of the need to subluxate the elbow.[42] A malarticulating implant with a well-fixed stem causes high contact pressure on the opposing articular cartilage, leading to early failure. Bipolar design may improve articular tracking, but the issues of polyethylene wear and debris area a real concern. Bipolar implants also have a tendency to become angulated under load, decreasing the stabilizing effect in the ligament-disrupted elbow.[43] The modular prosthesis that was used in this study has a smooth polished stem, implanted with a loose press-fit into the radial neck. The implant acts as a spacer, allowing soft tissue and ligaments to heal and has enough mobility to adapt to the anatomy of elbow.[44]

If the LUCL is intact, prosthetic insertion might be difficult. We might downsize 2 full stem sizes to facilitate insertion of the prosthesis or place a retractor under the radial neck and lever the proximal part of the radius anteriorly and laterally away from the capitellum. A retractor should never be placed over the anterior aspect of the proximal end of the radius to avoid injury to the posterior interosseous nerve. If there is coexistent LUCL injury, it may lead to prosthesis overstuffing as result of inserting a prosthesis that is too large. This error should be noted and avoided.[45]

This study was limited by its retrospective nature. In addition, the number of patients included was limited and the duration of follow-up was short.

Conclusions

Treatment of irreparable radial head fractures with a modular titanium radial head prosthesis and soft-tissue reconstruction yields satisfactory results. Early mobilization of the elbow is important for the restoration of elbow range of motion and function. Studies with a control group and long-term follow-up are needed for further evaluation.

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使用橈骨頭置換手術治療外傷後肘關節不穩定之短至中期結果 20 至 70 個月追蹤

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背 景： 當手肘的軟組織約束器受損後，橈骨頭就成爲主要穩定器，橈骨頭置換術適用於無法修補的橈骨頭骨折並且合併外傷後肘關節不穩定。本篇研究以回溯性研究方式，評估橈骨頭骨折患者在接受橈骨頭置換合併肘關節側韌帶修補手術，及早期活動的治療成效。

方 法： 本研究分析自 2002 年至 2008 年至林口長庚醫院求診之橈骨頭骨折患者共 13 名，以病歷回溯方式研究病患受傷機轉、骨折分類 (Mason classification)、橈骨頭置換術時間 (acute or delayed)、肘關節活動度 (flexion/extension, pronation/supination)、術後併發症 (stiffness, radiolucency)，並以 Mayo Elbow Performance Score 作評估。

結 果： 根據 Mayo Elbow Performance Score，61% 病患有極好的結果；23% 病患有好結果；16% 接受延遲橈骨頭置換手術的病患則屬於尚可接受的組別。鈦合金橈骨頭置換術後手肘彎曲平均是 126.5° (95° to 140°)，伸展平均是 6.2° (0° to 20°)，前臂旋前平均是 78.8° (65° to 85°)，前臂旋後平均是 81.2° (60° to 90°)，手肘彎曲伸展弧度平均是 120.4° (80° to 140 °)，前臂旋轉弧度平均是 160° (125° to 175°)。所有病患在接受鈦合金橈骨頭置換術後均沒有手肘不穩定的情形，其中兩位病患因手肘攣縮而接受放鬆手術。橈骨頭置入物都沒有因爲鬆脫或感染而遭到拔除。

結 論： 用鈦合金橈骨頭置換術以及軟組織重建手術治療粉碎而無法修補的橈骨頭骨折，有令人滿意的結果。儘快進行復健運動對於手肘的活動度和功能的恢復是相當重要的。

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關鍵詞： 不能修復的橈骨頭骨折，鈦合金橈骨頭置換術，創傷後肘關節不穩定

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