EDITOR'S CHOICE

The Unsalvageable Radial Head in Patients Aged 30 Years and Younger

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Purpose Concern exists regarding the use of radial head arthroplasty (RHA) in younger patients. This study assessed clinical, functional, and radiographic outcomes of RHA in patients aged 30 years and younger.

Methods A retrospective review identified 26 elbows that underwent a smooth stem modular RHA in patients aged 30 years and younger at a median follow-up of 3.3 years clinically and 2.9 years radiographically. The mean age was 24 ± 5 years. Indications were acute trauma in 13 patients and chronic pathologies in the remaining 13, and these 2 groups were evaluated separately. Patients underwent clinical, functional, and radiographic evaluation.

Results Average arc of motion was 137° ± 16° in the cohort with acute trauma and 120° ± 24° in the cohort with chronic pathologies. Mean Patient-Rated Elbow Evaluation scores were 23 ± 18 (acute) and 31 ± 19 (chronic). Mean Quick Disabilities of the Arm, Shoulder, and Hand scores were 18 ± 15 (acute) and 23 ± 20 (chronic). Average Mayo Elbow Performance Index scores were 90 ± 9 (acute) and 80 ± 13 (chronic). Severe capitellar erosion was present in 1 patient (4%) in the cohort with chronic pathologies. Radiographic stem lucency was seen in all cases with 10 of these (38%) graded as severe. Moderate-to-severe ulnohumeral arthritis developed in 4 patients (15%), 3 of whom were in the chronic reconstruction group. Two patients (8%) required reoperation, 1 for persistent instability and 1 for stiffness, both in the cohort with chronic pathologies.

Conclusions For acute trauma and challenging chronic conditions involving the radial head in patients aged 30 years and younger, a smooth stem modular RHA is an option. Although reoperation rates based on this series are low, osteoarthritis is common when used for post-traumatic conditions and severe radiographic stem lucency was seen in greater than one-third of patients. These concerning features warrant close follow-up, and further long-term outcomes are needed. *(J Hand Surg Am. 2021;46(11):989–997. Copyright © 2021 by the American Society for Surgery of the Hand. All rights reserved.)*

Type of study/level of evidence Therapeutic IV.

Key words Elbow trauma, radial head arthroplasty, radial head fracture, young patients.

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Indications for radial head arthroplasty (RHA) include acute irreparable fractures of the radial head, either in isolation or in the setting of complex elbow instability, as well as chronic symptomatic malunited or ununited radial head fractures.[1–4] Advances in implant design and surgical technique have led to improved outcomes following this procedure.[5] Recently reported midterm outcomes of a smooth stem modular implant suggest that favorable clinical results are maintained at an average of 8 years following surgery.[5]

There is a paucity of evidence reporting the outcomes of RHA performed in young patients, and the management of these diagnoses in this population is unclear.[6,7] For example, it is unknown whether these implants are as well tolerated in this group as in older patients and whether complication rates and implant longevity in this group are comparable to those reported in the published studies in older patients.

The purpose of this study was to assess the clinical, radiographic, and functional outcomes of RHA performed in patients aged 30 years and younger for either an acute or chronic indication. We aimed to describe these outcomes in this patient population and evaluate whether patients in this age group would show earlier signs of arthritis or implant failure secondary to higher activity demands.

MATERIALS AND METHODS

Following Western University institutional review board approval, our operative database was reviewed to identify all patients who underwent an RHA from 2006 to 2017. We identified patients who were 30 years of age or younger at the time of RHA. Patients were contacted via telephone for participation in the study and asked to return for reevaluation. For those unreachable via telephone, a letter was sent to their last known address. Written informed consent was obtained at the time of reassessment. Patients who were unable to return to the clinic were asked to complete patient-reported outcome assessments and send range of motion (ROM) photographs via secure email.[8] In cases where patients were no longer reachable, charts were reviewed to collect clinical and radiographic data from their last follow-up visit. Patients with less than 1 year of follow-up were excluded.

Figure 1 illustrates the patients who were included in the final analysis. Our review identified 33 patients who underwent RHA at ≤30 years of age. Eighteen patients were available for a comprehensive reassessment and 16 underwent repeat radiographic evaluation. Of the 15 patients who were not reachable via telephone or mail, 8 had follow-up visits and radiographs documented in the chart at least 1 year following surgery, and these were included for evaluation. Seven patients were thus excluded, leaving 26 patients for the final analysis.

All patients were treated with a modular, smooth-stemmed radial head implant (Evolve, Wright Medical Technology) performed by 1 of 5 fellowship-trained upper extremity surgeons at a single center. A detailed description of the surgical technique has been described in the literature.[3,9–11]

Outcome measures

Patient charts and initial injury images were reviewed to obtain demographic data, including age, sex, hand dominance, associated injuries, comorbidities, surgical indication, and complications. At the time of reassessment, patients were evaluated clinically, functionally, and radiographically. An independent assessor who was not involved in the participant's care obtained objective clinical measurements and administered the patient-reported questionnaires.

Objective clinical measures included elbow ROM and grip strength. Flexion, extension, pronation, and supination were measured in a standardized fashion by an independent assessor using a long-arm goniometer and were compared with that of the contralateral extremity. Grip strength was measured using a hand-held dynamometer and was compared with that of the contralateral extremity. A correction for limb dominance of 15% was used in the right-handed participants.

Functional outcomes were evaluated using standardized, validated outcome tools. The Patient-Rated Elbow Evaluation (PREE) and the Quick Disabilities of the Arm, Shoulder, and Hand (*Quick*DASH) questionnaires were used to assess patient-reported disability at the elbow and upper extremity, respectively. Using the patient's self-reported function in conjunction with clinical measurements, the Mayo Elbow Performance Index (MEPI) was calculated for each patient.

Standardized anteroposterior and lateral elbow radiographs were repeated at the time of reassessment. In patients who were unable to return for reassessment, the last available radiographs were reviewed. Two upper extremity fellowship-trained hand surgeons (L.A.S. and W.R.A.) independently evaluated all radiographs. Cases of disagreement were reconciled in discussion with a senior author (G.J.W.K.). Radiocapitellar alignment, prosthesis length, stem lucency, capitellar erosion, ulnohumeral degenerative

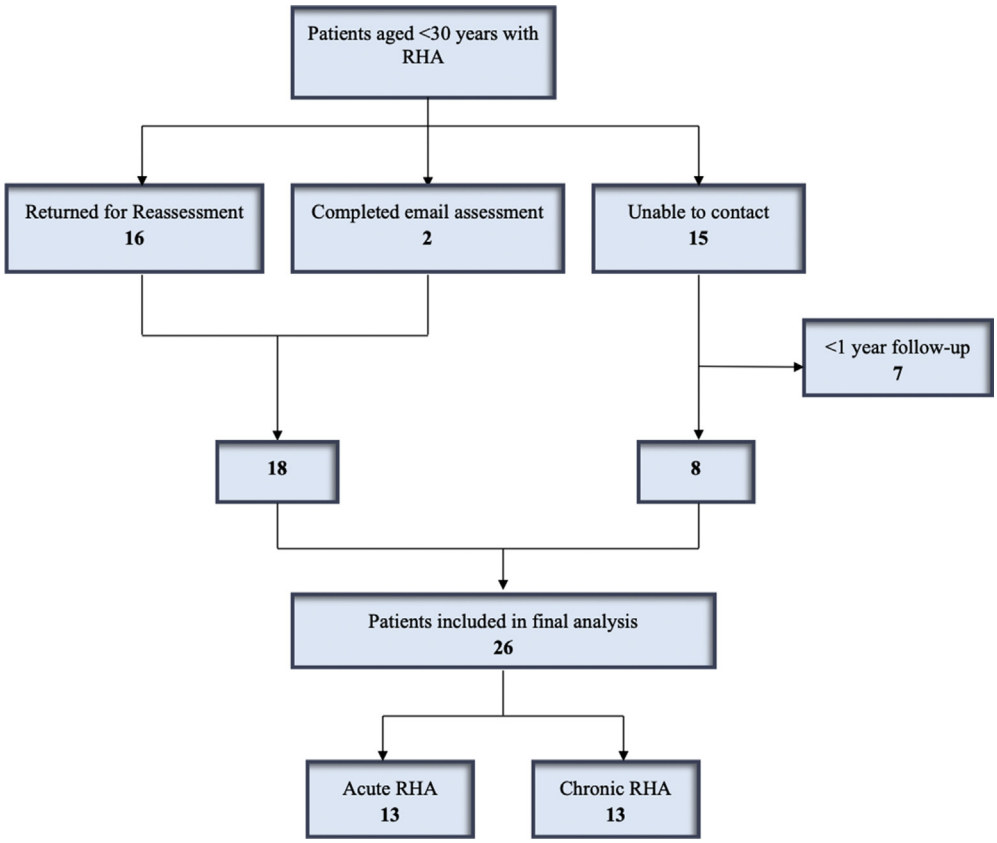

FIGURE 1: Patient selection.

changes, and the presence of heterotopic ossification were documented, as these have been used as radiographic outcome measures in previous literature.[5,9] Prosthesis length was graded as satisfactory, underlengthened, or overlengthened based on the alignment of the medial ulnohumeral joint as assessed on immediate postoperative radiographs.[12] A prosthesis was considered overlengthened if there was a lack of parallelism in the medial ulnohumeral joint.[5,10,12] Component stem lucencies were evaluated by modifying the classification by Gruen et al,[13] which has been previously applied to RHA.[1,5,9] This was graded as either none, mild, moderate, or severe based on the number of zones involved and the width of the luceny.[1,5,9] Capitellar erosion was assessed and graded as either none, mild, moderate, or severe.[1,5,9] Ulnohumeral arthritis was assessed using the Broberg and Morey classification system.[14,15] Finally, the presence of heterotopic ossification was assessed using the modified Brooker classification system.[16]

Patient and injury characteristics

The average patient age was 24 ± 5 years (range, 13−30 years; median, 26 years) with a median clinical follow-up of 3.3 years (range, 1−12.9 years) and median radiographic follow-up of 2.9 years (range, 1−9.6 years). Eleven patients were male and 15 were female. Thirteen RHAs were of the dominant extremity. Six patients had medical comorbidities at the time of injury. One patient had a workers' compensation claim. Thirteen patients underwent RHA for acute trauma and 13 underwent RHA for a chronic indication. Table 1 summarizes the injury characteristics in patients with acute trauma and chronic indications.

Of the patients with acute trauma, 10 had associated injuries. Most often these occurred in the ipsilateral elbow; however, 1 patient had an ipsilateral distal radius fracture and 1 had associated bilateral distal radius, bilateral scaphoid fractures, contralateral radial head fracture, ipsilateral triquetral fracture, and an L1 burst fracture. Indications for RHA in this group included an irreparable radial head fracture either in isolation or in the context of an elbow fracture dislocation. A radial head was deemed irreparable at the time of surgery if there was extensive articular commination or if an attempt to reduce and stabilize it was unsuccessful. In this age group, our preference was to fix the radial head when technically possible, and we did not limit fixation attempts to fractures with 3 or fewer fragments. The

TABLE 1. Injury Characteristics

Acute RHA	Number of Patients (%)	Chronic RHA	Number of Patients (%)
Associated injuries	10 (77%)	Indication	
		Radial head/neck malunion	6 (46%)
		Radial head/neck nonunion	3 (23%)
		Stiffness	3 (23%)
		Persistent instability	1 (7%)
Injury pattern		Previous ipsilateral elbow surgery	
Radial head/neck fracture	8 (62%)	Radial head/neck ORIF	
Terrible triad injury	3 (23%)	LCL repair	9 (69%)
Other elbow fracture dislocation	2 (15%)	Contracture release	3 (23%)
		Hardware removal	3 (23%)
		Coronoid ORIF	3 (23%)
			2 (15%)
Associated procedure		Associated procedure	
LCL repair	8 (62%)	Contracture release/removal heterotopic bone	10 (77%)
Coronoid ORIF	3 (23%)	LCL repair	5 (38%)
MCL repair	1 (7%)	Removal radioulnar synostosis	2 (15%)
Flexor pronator mass repair	1 (7%)	LCL reconstruction	1 (7%)
Triceps repair	1 (7%)	Capitellar marrow stimulation	1 (7%)
Capitellar marrow stimulation	1 (7%)	External fixator	1 (7%)

LCL, lateral collateral ligament; MCL, medial collateral ligament; ORIF, open reduction internal fixation.

decision to perform an RHA was made at the time of surgery. At the time of RHA, 10 patients underwent an associated ipsilateral elbow procedure (Table 1).

In the cohort with chronic indications, RHA was performed for radial head malunion or nonunion as part of a contracture release for posttraumatic stiffness with radiocapitellar arthritis and in 1 case, for ongoing elbow instability following radial head repair. All but 1 patient had undergone a previous ipsilateral elbow surgery (Table 1).

Statistical analysis

Descriptive statistics were calculated, and the cohorts with acute trauma and chronic indications were reported separately because these 2 groups were believed to be dissimilar in etiology and not homogeneous. Range of motion was compared with that of the unaffected side. Given the limited number of available patients meeting inclusion criteria, no further statistical analysis was performed.

RESULTS

Clinical outcomes

Range of motion outcomes were available in all 26 patients, 13 of whom were in the cohort with acute trauma and 13 in the cohort with chronic indications (Table 2). Average elbow ROM in the cohort with acute trauma was from 2° ± 14° to 140° ± 5°, with an average arc of motion of 137° ± 16°, 99% of the contralateral side. The average forearm rotation in the cohort with acute trauma was 75° ± 10° of pronation and 77° ± 7° of supination. In the cohort with chronic indications, average elbow ROM was from 14° ± 12° to 132° ± 14°, with an average arc of motion of 120° ± 24°, 88% of the contralateral side. The average forearm rotation in the cohort with chronic indications was 69° ± 15° of pronation and 69° ± 13° of supination.

Functional outcomes

Patient-Rated Elbow Evaluation and *Quick*DASH scores were available for 17 patients, 9 of whom were in the cohort with acute trauma and 8 in the cohort with chronic indications. These results have been characterized in Figure 2. The average PREE score in the patients with acute trauma was 23 ± 18 and that in the patients with chronic indications was 31 ± 19. The average *Quick*DASH score was 18 ± 15 in the cohort with acute trauma and 23 ± 20 in the cohort with chronic indications. Mayo Elbow Performance Index scores were available for 26 patients and have

TABLE 2. Clinical Outcomes

Clinical Measures	Total (n = 26)	Acute (n = 13)	Chronic (n = 13)
Extension	8°	2°	14°
Flexion	136°	140°	132°
ROM arc	128°	137°	120°
Percentage of contralateral arc	90%	99%	88%
Pronation	72°	75°	69°
Supination	72°	77°	69°
Grip strength*	81%	83%	80%

*Reported as percentage of the contralateral side with correction for right-hand dominance.

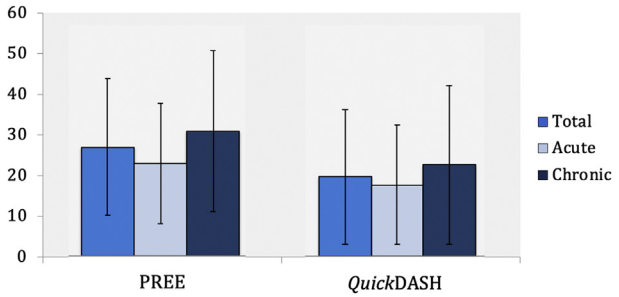

FIGURE 2: Patient-reported outcomes for total patients (n = 17), those with acute trauma (n = 9), and those with chronic indications (n = 8). Data represent mean values and standard deviations.

been shown in Figure 3. In the 13 patients with acute trauma, the average MEPI score was 90 ± 9, with 6 patients having excellent scores, 6 having good scores, and 1 having a fair score. The average MEPI score in the 13 patients with chronic indications was 80 ± 13, with 2 patients having excellent scores, 7 having good scores, 3 having fair scores, and 1 having a poor score.

Radiographic outcomes

Radiographic outcomes were available for all 26 patients and have been summarized in Table 3. In both cohorts, all implants were appropriately sized. As expected with this implant design, all patients had some amount of stem lucency. Ten patients (38%) were graded as severe. Of the patients graded as severe, 5 were in the cohort with acute trauma and 5 in the cohort with chronic indications. Capitellar erosions were seen in 9 patients (69%) with acute trauma and 7 patients (54%) with chronic indications. Of those with capitellar erosions, 1 patient (8%) with

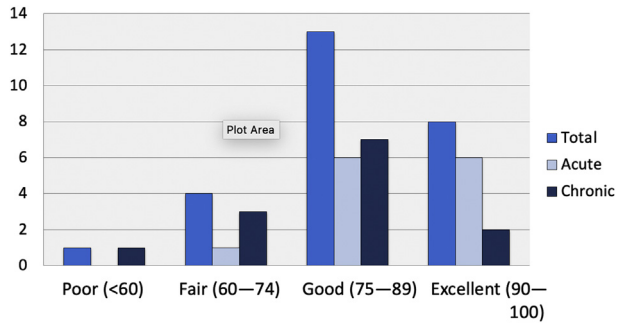

FIGURE 3: Mayo Elbow Performance Scores.

chronic indications was graded as severe (Fig. 4). Severe capitellar erosion did not develop in any of the patients with acute trauma. In the cohort with acute trauma, ulnohumeral arthritis developed in 7 patients (54%) at the final follow-up, with 1 graded as moderate and none graded as severe. In the cohort with chronic indications, ulnohumeral arthritis developed in 8 patients, with 2 graded as moderate and 1 graded as severe (Fig. 4). Of the patients in whom heterotopic ossification developed (7 in the cohort with acute trauma and 6 in the cohort with chronic indications), the majority were classified as mild and none required surgical intervention.

Complications and reoperations

At the final follow-up, 2 patients in the chronic group underwent reoperation. One patient (4%) required a revision RHA for persistent instability. This same patient also required a subsequent debridement for stiffness. Another patient underwent a contracture release for stiffness. No patient in the acute group underwent reoperation.

DISCUSSION

In this series, the use of RHA in patients aged 30 years and younger for a variety of indications resulted in adequate clinical and patient-reported function at a short-term follow-up (Fig. 5). Although revision and reoperation rates were low, loss to follow-up was high, which may have had an impact on this finding. Further, the incidence of radiographic arthritis and capitellar erosion was high, the long-term consequences of which remain unknown. Although our study reflects relatively short-term outcomes for young active patients who typically require heavier use of their elbow for a longer period of time, it is one of the few studies to date examining the role of RHA in this subset of patients.

Midterm results of RHA have been previously reported in the literature.[5,17–19] In a review of patients undergoing RHA with an average of 8 years of

TABLE 3. Radiographic Outcomes

Outcome	Total (%) (n = 26)	Acute (%) (n = 13)	Chronic (%) (n = 13)
Capitellar erosion	62	69	54
Severe capitellar erosions	4	0	8
Moderate-to-severe ulnohumeral arthritis	15	8	23
Implant lucency	100	100	100
Heterotopic ossification	50	54	46

follow-up, clinical, functional, and radiographic outcomes were found to be similar to the short-term outcomes, with no significant deterioration.[5] These authors evaluated all subjects with RHAs and reported a slightly greater ROM (11° ± 14° to 137° ± 15°) and higher average MEPI scores (91) than that of our cohort.[5] However, in our study, the final average ROM was within a functional range (127.7° ± 23.1°). The majority of patients had good to excellent outcomes, as indicated by the MEPI (average, 85 ± 12), though this score may lack responsiveness in a more active population. A considerable number of patients in our study developed concerning radiographic outcomes with respect to capitellar erosions (62%) and ulnohumeral arthritis (58%), with a small number graded as severe. These findings were more substantial than those reported by Marsh et al[5]; however, theirs was a cohort with acute injuries, whereas this study had a mixed group of patients with acute and chronic injuries.

The need for RHA in younger patients typically results from higher energy injuries and more commonly occurs in the context of elbow fracture dislocations. Although midterm outcomes for RHA, in general, are favorable, generalizing these results to a younger population requires an understanding of the role of RHA in complex elbow trauma.[5,17,18] This has been evaluated by Watters et al[20] who investigated the role of RHA in the management of terrible triad injuries. In their retrospective study of 39 patients at the 18-month follow-up, RHA was found to be superior compared with radial head fixation in maintaining elbow stability; however, RHA was associated with a higher incidence of arthritis, at 21%.[20] The overall revision rate in their study was 28%.[20] Although this study may better reflect our study population, the revision rate in our series was much lower.

Revision rates following RHA vary widely in the literature (0% to 32%).[1,9,18,21] In our study, we had a revision rate of 4% and a reoperation rate of 8%. A recent large database study of inpatients with radial head fractures identified an average revision burden of 11.7% for RHA for patients of all ages and indications.[22] In a study by Duckworth et al[23] looking specifically at complex radial head fractures, revision rates following RHA were reported to be 28% at an average follow-up of 6.7 years. These authors identified the age of younger patients and the use of silastic implants as risk factors for revision, recommending that young patients be counseled on the potentially increased need for future surgery.[23] Our series used only smooth-stemmed modular implants, which have good results reported in the literature, and did not include silastic implants; however, we also had a small sample size with a shorter duration of follow-up and high loss to follow-up rates. These factors may explain the lower reoperation rate of our study compared with these 2 studies. In a study of over 58,000 radial head fractures, Kupperman et al[24] reported a reoperation rate following RHA of 10.7% at 2 years, which more closely mirrors our findings. Although the authors of that study did not report which components were used and did not stratify results by age, they may have been better able to account for the loss to follow-up by identifying reoperations using billing codes.

In our study, patients with RHA performed for both acute and chronic indications were included. Although low numbers in each group limited our ability to compare them statistically, we observed a poorer arc of motion in the chronic group with fewer patients from this group reporting excellent functional outcomes. Patients in the chronic group also experienced a more frequent incidence of severe capitellar erosion, severe ulnohumeral arthritis, and revision surgery. Previous studies looking specifically at RHA performed for chronic indications mirror these findings, showing significantly less ROM compared with that of the contralateral side,

FIGURE 4: Radiographic complications. **A**, **B** A patient with severe capitellar erosions. Radial head arthroplasty was performed for a radial neck malunion and postoperative stiffness. Heterotopic bone, as seen in these images, developed following her first surgery (radial neck open reduction internal fixation) and has been stable on subsequent imaging. Capitellar erosions developed shortly after RHA but have been unchanged for the last year. Clinical follow-up in this patient was at 27.7 months. At the time of the last follow-up, some pain was reported (PREE pain score of 13); however, no revision surgery was required, and the patient was able to return to her former occupation. **C**, **D** A patient in whom severe arthritis developed, as graded by the Broberg−Morrey scale. He sustained a Monteggia variant injury as a child, with an elbow fracture dislocation and both bones forearm fracture. He subsequently developed a radial head nonunion, thus undergoing RHA. His elbow was unstable shortly following RHA, requiring revision RHA with an ulnar osteotomy, lateral collateral ligament repair, and external fixator. He subsequently underwent debridement for stiffness. Clinical follow-up in this patient was at 155 months. High pain scores were reported (PREE pain of 39); however, no further surgery was planned, and the patient was able to return to his former job as a carpenter.

similar average MEPI scores (83%), and higher rates of ulnohumeral arthritis (74%) at the 8-year follow-up.[2]

Two studies have reported on the use of RHA in young populations.[6,7] In a retrospective review of military patients undergoing RHA, Dunn et al[7] investigated outcomes in the young active patient population. Their review included patients aged 20−50 years with a mean age of 31 years and follow-up of 2 years.[7] Although they found that patients maintained excellent subjective outcome scores, they reported a high complication rate (47%).[7] Revision rates (3/19) were also higher in their study compared with that of our findings, which may represent differences between military and civilian populations or be related to radial head implant designs used in their study.[7] Additionally, it has been reported that a significant number of patients do not regain preinjury activity levels.[6,7] A study by Jung et al[6] reported on RHA in recreational athletes with an average age of 49 years (range, 18−79 years) and found that return to sport at 8 years following RHA was low (53%) and even fewer patients returned to their same level of activity. This suggests that although patients may

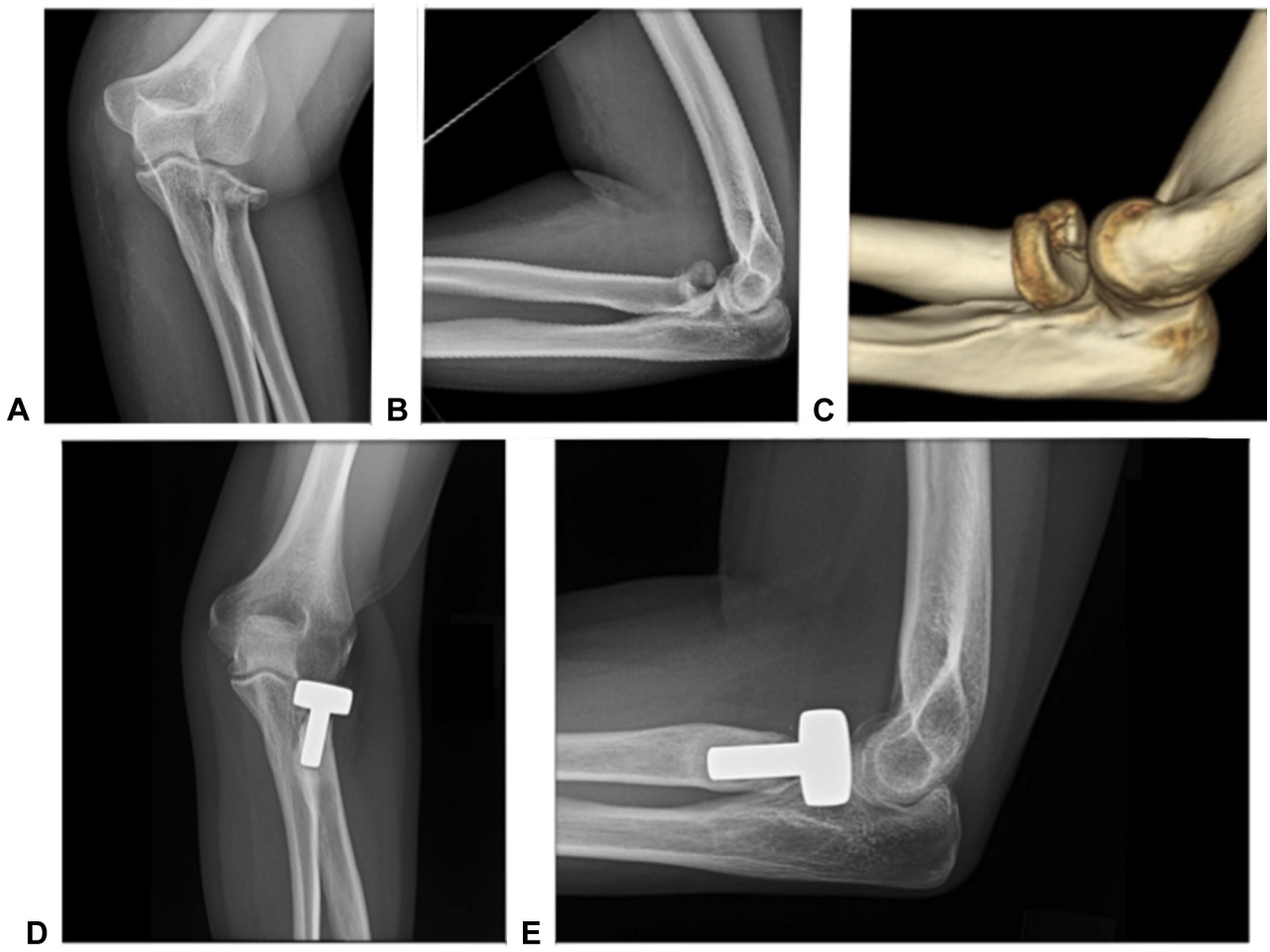

FIGURE 5: A case of a patient with an 8-year follow-up has been illustrated. **A-C** An irreparable radial head fracture. The patient underwent an RHA acutely for the irreparable radial head fracture. At the 8-year follow-up, she had a 150° arc of motion, a PREE score of 13, and a *Quick*DASH score of 11, and she returned to her previous occupation. **D**, **E** Radiographs showed some lucency surrounding the implant and mild ossification on the medial side.

obtain reasonable clinical and functional outcomes, return to prior activity in this more active population is less likely.[6]

Although our study represents one of the few studies investigating RHA in younger patients and is the only study, to our knowledge, to exclude all patients over the age of 30 years, we recognized several limitations. Given the rarity of this procedure in young patients, our cohort was small. Further, loss to follow-up in this young, mobile population limited the number of patient-reported functional outcome assessments that we were able to obtain. Second, the retrospective nature of our study is a limitation. For patients who were unable to return for a repeat follow-up, we relied on the information available in the charts, which may be subject to error or was incomplete in some cases. It is also possible that patients may have sought further treatment in a different center, resulting in a higher reoperation rate than what we were able to detect, perhaps explaining our lower revision rate compared with that of other studies involving younger patients. Low revision and reoperation rates as outcome measures do not necessarily indicate that patients are functioning well. Finally, our follow-up duration is probably inadequate to predict the long-term outcomes and complications in this young cohort who will require the functional use of their elbow for many more years. Future long-term prospective studies in this population would help address these shortcomings.

In cases of acute trauma with irreparable radial head fractures and in complex chronic conditions involving the radial head, RHA with a smooth stem modular implant is a viable option in patients aged 30 years and younger, demonstrating acceptable clinical, functional, and radiographic outcomes at an early follow-up in this series; however, the long-term outcomes remain uncertain. Concerning radiographic

features, particularly capitellar erosions and ulnohumeral arthritis, developed in a greater number of patients in our study compared with that in the literature, where RHA is performed in older patients. In general, RHA performed for chronic indications tended to have inferior outcomes compared with that performed for acute trauma. Further longer-term studies evaluating RHA in young patients are warranted to predict the longevity of this procedure in this patient population.

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