Distal Humeral Hemiarthroplasty Versus Total Elbow Arthroplasty for Acute Distal Humeral Fractures

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abstract

For acute distal humeral fractures not amenable to open reduction and internal fixation, total elbow arthroplasty has become an established alternative. However, lifelong activity restrictions designed to prevent early mechanical failure make this a poor option for some patients. This has led to a renewed interest in distal humeral hemiarthroplasty. Using modern implants and techniques, distal humeral hemiarthroplasty has shown outcomes comparable to those of total elbow arthroplasty at short- to mid-term follow-up, with an overall higher but different complication rate. Long-term data are needed, but the available literature suggests that distal humeral hemiarthroplasty be considered as another option on the treatment spectrum in select patient populations. [Orthopedics. 2017; 40(1):13-23.]

Adult distal humeral fractures are relatively rare injuries, comprising 2% to 5% of all fractures and 30% of all elbow fractures. A bimodal age and sex distribution has been reported consisting of high-energy injuries in younger males and low-energy falls in elderly females with osteoporosis. The majority of these fractures have a reconstructable intra-articular component (AO/OTA type 13-B or 13-C), making open reduction and internal fixation (ORIF) the treatment of choice. The success of ORIF is dependent on the surgeon’s ability to anatomically reconstruct the articular surface with a rigid fixation construct that is durable enough to allow early mobilization. If the fracture is multifragmentary or the articular surface is extensively comminuted, anatomic reconstruction may be impossible. Likewise, if bone quality is poor, as with osteoporosis or inflammatory arthritis, reconstruction may lack the stable fixation necessary for early motion. In these situations, arthroplasty should be considered. Similar to hemiarthroplasty and total joint arthroplasty, which are recognized treatment options for acute fractures about the hip or shoulder, distal humeral hemiarthroplasty and total elbow arthroplasty may be considered for acute distal humeral fractures.

Although hemiarthroplasty of the elbow has recently regained popularity, its use was first reported in the literature by Mellen and Phalen nearly 70 years ago. Their small case series and several others that followed described the use of different custom-made hemiarthroplasty implants in treating acute distal humeral fractures, fracture sequelae, tumors, and inflammatory arthritis. These were all uncemented designs made of a variety of materials, and although some initially provided pain relief and satisfactory range of motion, most eventually failed due to instability and inadequate fixation. In the 1970s and 1980s, with the advent and relative success of cemented, linked total elbow arthroplasty prostheses, in addition to improved knowledge of fracture fixa-
Indications for total elbow arthroplasty continued to expand, and its use as a primary treatment for nonrepairable acute intra-articular distal humeral fractures in elderly patients gained widespread acceptance when Cobb and Morrey first published their series in 1997. Total elbow arthroplasty has since become an established treatment alternative, with several recent studies finding equivalent or favorable outcomes when compared with nonoperative management or ORIF. Unfortunately, despite advancements in the understanding of the complex anatomy and kinematics of the elbow and continued improvements in implant design, total elbow arthroplasty continues to have relatively high complication and revision rates. Mechanical complications inherent to the linked articulation (ie, polyethylene or bushing wear, aseptic loosening of the ulnar component, peri-prosthetic osteolysis and fracture, implant fracture) are the most common causes of late failure requiring revision. To minimize risk and prolong implant survival, patients undergoing total elbow arthroplasty must adhere to lifelong activity restrictions, making it a poor choice for young, active patients or elderly, high-demand patients. The latter group includes not only older, active patients but also anyone who relies on upper body strength to get in and out of a chair or ambulate with assistive devices.

These limitations of total elbow arthroplasty, knowledge gained from the failures of early hemiarthroplasty designs, and access to commercially available implants have led to renewed interest in distal humeral hemiarthroplasty. As the linkage mechanism and ulnar component are thought to be the primary contributors to mechanical failure, distal humeral hemiarthroplasty obviates the need for the same stringent activity restrictions. Moreover, leaving the ulna intact preserves bone stock for later conversion to total elbow arthroplasty, reduces morbidity, and may result in relatively shorter operative times and a decreased risk of infection. Furthermore, in the scenario that a fracture is only deemed unreconstructable intraoperatively after an olecranon osteotomy has already been performed, distal humeral hemiarthroplasty may be a better or at least a less technically difficult salvage method than total elbow arthroplasty.

This article reviews and compares the use of distal humeral hemiarthroplasty and linked, semiconstrained total elbow arthroplasty for acute intra-articular distal humeral fractures. The authors discuss indications and contraindications, implant considerations, surgical techniques, complications, and outcome data from recent studies. Detailed discussions of unlinked total elbow arthroplasty or the use of distal humeral hemiarthroplasty and total elbow arthroplasty for indications other than acute trauma are beyond the scope of this review.

**INDICATIONS AND CONTRAINDICATIONS**

Total elbow arthroplasty is indicated for acute intra-articular distal humeral fractures in physiologically elderly patients with low physical demands and in those with fractures deemed unreconstructable due to fracture pattern (ie, extensive articular comminution, significant loss of cartilage or subchondral support for cartilage, or multifragmentary patterns not amenable to fixation) or poor bone quality (eg, severe osteoporosis, inflammatory elbow disease, pathological bone). Other indications to consider include articular fractures in older patients with preexisting symptomatic osteoarthritis/inflammatory arthritis and fractures in patients of any age with a limited life expectancy. Total elbow arthroplasty is contraindicated for patients who are unable or unwilling to comply with postoperative activity restrictions. As a general rule, prosthetic replacement of any joint should be avoided in younger patients.

In 2 recent series, total elbow arthroplasty was performed in patients 40 years or younger for nonfracture indications, and both reported a 22% revision rate with average follow-up of 7.6 years and 10.8 years, respectively. With more than 1 in 5 patients requiring revision by the tenth anniversary of their replacement, the authors recommend against the use of total elbow arthroplasty in younger patients. At the same time, a strict age cutoff should be avoided, and the decision should be individualized based on patient activity level, functional status, hand dominance, and medical comorbidities.

Indications for distal humeral hemiarthroplasty are not as well defined, although it should at least be considered for patients with unreconstructable acute distal humeral fractures who are not good candidates for total elbow arthroplasty. From that point, the contraindications of distal humeral hemiarthroplasty, or lack thereof, can be used to determine if a patient is eligible.

Importantly, without a linked articulation, joint stability after distal humeral hemiarthroplasty is conferred by the same constraints as the native elbow: the ulnohumeral and radiocapitellar articulations, and the collateral ligaments. Consequently, contraindications for distal humeral hemiarthroplasty include insufficient or unreconstructable medial and lateral humeral bone columns, insufficient or irreparable medial and lateral collateral ligaments, irreparable coronoid fracture, radial head resection, irreparable extensor mechanism, and developmental or otherwise preexisting deformities of the distal humerus, proximal ulna, or proximal radius resulting in nonanatomic bony architecture. Significant chondral loss from the greater sigmoid notch or the radial head from concomitant fractures or preexisting arthritis is a relative contraindication to distal humeral hemiarthroplasty.
plasty because this may lead to chronic pain or premature wear of the implant.47 Rheumatoid arthritis and other inflammatory arthropathies are contraindications due to concern for attenuated collateral ligaments and progressive degeneration of the proximal radius and ulna potentially resulting in chronic instability, premature wear, or painful motion.49

Distal humeral hemiarthroplasty has also been suggested for elderly patients with low transcondylar or coronal shear fractures because the columns and collateral ligaments are spared.37,50 Achieving stable anatomic reduction to allow early motion can be difficult because of the small size of the fragments, and in these cases, distal humeral hemiarthroplasty should be considered.50,51

Absolute contraindications common to both total elbow arthroplasty and distal humeral hemiarthroplasty include active infection, grossly contaminated open fractures, inadequate bone stock to support implants, poor soft tissue coverage, neuropathic arthropathy, or neurologic compromise of the affected limb.14,35-37,41,46,47

**Implant Considerations**

Total elbow arthroplasty prostheses are categorized as linked or unlinked based on the presence or absence of a mechanical linkage between the humeral and ulnar components. The first linked prostheses were fully constrained, simple hinges that created excessive shear stresses at the bone–cement interfaces, leading to component loosening and failure.9,52 Modern linked prostheses are semiconstrained, “sloppy hinge” designs with polyethylene bushings that better mimic normal elbow kinematics by allowing more physiologic varus–valgus motion and axial rotation.30 They rely on a balanced, surrounding soft tissue envelope to limit excessive motion and prevent transfer of stresses to the bone–cement interface.9,53,54 Another feature of modern implants worth noting is the extracortical anterior flange, which is thought to improve posterior and rotary stability and reduce humeral component loosening by improving load transfer.54,55 The 2 currently available linked, semiconstrained prostheses with published literature of their use in the treatment of acute distal humeral fractures are the Coonrad/Morrey Total Elbow (Zimmer, Warsaw, Indiana) and the Discovery Elbow System (Biomet, Warsaw, Indiana). Although there are no published studies, the Latitude EV Total Elbow Prosthesis (Tornier, Edina, Minnesota) has been used for this purpose as well.

Various unlinked total elbow arthroplasty implants were initially developed as a product of high failure rates with early linked prostheses. These rely on the collateral ligaments and surrounding soft tissues as well as congruence of the implant surfaces for stability, similar to distal humeral hemiarthroplasty. The Kudo (Biomet) prosthesis is one example consisting of a cemented ulnar component and an uncemented humeral component with a nonanatomic “saddle” type articulation that requires excision of the radial head for implantation. Although outcomes as a total elbow arthroplasty were good, including long-term survival, instability was a common complication.56 The humeral component was used as a distal humeral hemiarthroplasty prosthesis in one small series with reasonable mid-term results; however, radiographic signs of attrition of the coronoid process were noted in 3 of the 8 patients, likely secondary to the incongruent articulation.57 Although this did not appear to affect clinical outcomes,57 the authors still recommend against the use of nonanatomic or un cemented distal humeral hemiarthroplasty prostheses. The Kudo is no longer commercially available.

The Sorbie Questor Total Elbow System (Wright Medical Technologies, Arlington, Tennessee) is another unlinked model that includes cemented, stemmed humeral and ulnar components as well as a stemmed radial head component. The cobalt chrome humeral component is a monobloc construct designed to replicate the normal articular surface geometry of the distal humerus, making it a popular prosthesis for distal humeral hemiarthroplasty.58 Although not modular, the 3 available sizes allow an accurate fit in 95% of patients.47,58 Without an anterior flange or attachment sites for ligament or condylar reconstruction, supplementary fixation is mandatory.58 With adequate fixation, conversion to unlinked total elbow arthroplasty is possible without removing the implant. The Sorbie Questor humeral component was the authors’ preferred distal humeral hemiarthroplasty prosthesis, but it is no longer commercially available. The Video shows a distal humeral hemiarthroplasty using this implant.

The Latitude is a modular system that can be converted between linked and unlinked configurations, with an optional bipolar radial head component for increased stability and load dispersion.59 The cobalt chrome humeral component is the most commonly used prosthesis for distal humeral hemiarthroplasty in the published literature. It is modular itself, composed of a stem with an anterior flange, an anatomic articulating spool, and a camu lated bolt to connect them.57 The central hole in the bolt allows for suture fixation of the condyles to the implant, limiting the need for supplemental hardware, or if the condyles cannot be adequately reconstructed, the collateral ligaments by themselves can be fixed in a similar manner.46,47 Like the Sorbie Questor, this prosthesis allows for conversion to an unlinked total elbow arthroplasty but with the added option of a linked configuration if the surgeon is concerned about instability. Unfortunately, the anatomic spool is no longer available in the United States for use as part of a hemiarthroplasty prosthesis.

**Preoperative Considerations**

Meticulous preoperative planning is paramount to achieve a successful outcome. This includes a thorough history detailing recent or active infections, pre-
diffuse osteopenia is present, and comminution of the distal humerus is noted posteriorly and medially (AO/OTA type 13-C). The medial epicondyle fragment is completely displaced. The olecranon, coronoid, and radial head appear intact.

Preoperative templating is recommended, and radiographs of the contralateral elbow may be used if necessary. The humeral bow and medullary canal size as well as the shape and size of the proximal ulna should be assessed. For total elbow arthroplasty, the medullary canal of the ulna should be measured on both anteroposterior and lateral views. For distal humeral hemiarthroplasty, if there is concern about cartilage loss at the radial head or greater sigmoid notch, preoperative magnetic resonance imaging should be considered.

The approach must be intimately familiar with manufacturer-recommended techniques and instrumentation, as these can vary significantly between implants. Moreover, hemiarthroplasty is not a Food and Drug Administration–approved procedure and implants are used off label, so step-by-step instructions will not be available. For example, the technique manual accompanying the Sorbie Questor does not describe hemiarthroplasty via any approach, but it is critical that the surgeon know its instrumentation is not designed for use with an olecranon osteotomy, a commonly used approach for distal humeral hemiarthroplasty. The authors therefore recommend that less-experienced surgeons practice these procedures on cadavers to learn potential limitations of the instrumentation and to troubleshoot issues that could create an unnecessarily challenging operation.

**Surgical Pearls**

**Total Elbow Arthroplasty**

The authors’ preferred technique begins with a posterior incision centered slightly medial to the tip of the olecranon followed by careful elevation of full-thickness fasciocutaneous flaps. The ulnar nerve is identified proximally, released until its first motor branch, and mobilized with a wide pen rose drain, without the use of a clamp to minimize the risk of traction injury. An anterior subcutaneous transposition is performed prior to wound closure.

A triceps-on approach, preserving the triceps insertion, is used, although it should be emphasized that there is a steep learning curve for these approaches. Humeral exposure and preparation may be straightforward, but obtaining an adequate ulnar exposure can be difficult, particularly for inexperienced surgeons.

The approach begins medially, sharply releasing all soft tissue attachments from the medial epicondylar fragments. Accessible fracture fragments are excised, and the same procedure is repeated laterally after release of soft tissue attachments from the lateral epicondylar fragments. Excision of fracture fragments is important to improve ulnar visualization and minimize potential pain or healing issues. If fractured, entire condyles may be resected without a significant effect on functional outcome.

The humerus is then delivered to the medial or lateral aspect of the triceps for canal preparation—lateral is preferred to avoid injury to the ulnar nerve. If necessary, a trial implant is placed, and additional bony cuts can be made. The canal is opened at the apex of the olecranon fossa, and serial rasping is performed.

Accurate component sizing and positioning provides the best chance for the prosthesis to mimic the elbow’s normal kinematics, thereby reducing mechanical complications and prolonging implant survival. Proper depth of the humeral component is achieved when the flange rests on the roof of the coronoid fossa; however, with significant bone loss, depth can be determined by referencing the proximal olecranon fossa after placing the trial component, flexing the elbow to 90° and applying an axial load.

An often-referenced cadaveric study by Schuind et al evaluated joint kinematics using malpositioned total elbow arthroplasty components. They found that if the humeral component is internally or externally malrotated more than 10°, the...
valgus or varus limit, respectively, of the sloppy hinge would be reached, negating the function of the design. A recent study using 50 cadaveric elbows discovered that the posterior humeral cortex just proximal to the olecranon fossa can be used as a reproducible landmark. The humeral component should be internally rotated relative to this point by a mean of approximately 14°. Notably, a statistically significant difference in the position of this landmark was found between sexes, with women requiring more internal rotation than men on average (16.4° and 12.6°, respectively; \( P=.0024 \)). The study authors therefore concluded this to be a reliable landmark; however, due to the normal variation, a computed tomography scan of the contralateral elbow could be useful to determine the correct rotation.

The other potential reference for appropriate rotational alignment is the anatomic flexion–extension axis. However, with excision of the condyles, accurate determination of this axis is not possible. As such, the current authors prefer to use the posterior humeral cortex as described.

Although not required for stability with linked total elbow arthroplasty designs, the radial head is preserved as a potential source of proximal bone stock. Resection or debridement is only performed for proximal radial ulnar joint arthrosis, significant articular cartilage loss, fracture, or radial head deformity interfering with motion.

The ulna is then exposed medial to the triceps, releasing up to one-quarter of the medial triceps insertion if necessary for adequate visualization. The tip of the olecranon is removed to access the medullary canal and to prevent impingement in extension. A burr is used to open the canal at the base of the coronoid process, and careful rasping is performed using posterior pressure to stay in the canal.

The ulnar component should be placed at a depth midway between the olecranon and coronoid process. If it is placed too deep, anterior impingement between the anterior flange and the cement mantle of the ulna or the coronoid process will occur. The coronoid process can be resected down to the level of the brachialis insertion if necessary or as a prophylactic measure, as this may also improve overall flexion. Anterior capsulectomy can also be performed if extension is significantly limited.

Once implant sizes and positions are determined, intramedullary cement restrictors are placed, and antibiotic-laden cement with colored dye is prepared. Proper cementation technique is critical, especially if the condyles have been resected. A pressurized cement gun is used, injecting both the humeral and ulnar canals. The ulnar component is placed first. Fluoroscopy can be used to ensure appropriate placement and minimize risk of fracture. The humeral component is then inserted with a wedge of bone placed between the flange and anterior humeral cortex, and the joint is reduced. After anterior subcutaneous transposition of the ulnar nerve, the flexor–pronator and extensor–supinator origins are repaired to the medial and lateral sides of the triceps, respectively. A drain is placed, the subcutaneous layer is loosely approximated, and the skin is closed with nylon in an interrupted, vertical mattress fashion.

**Distal Humeral Hemiarthroplasty**

The authors’ technique begins in the same manner as a total elbow arthroplasty. However, after the ulnar nerve is decompressed and mobilized, either a transverse or shallow chevron osteotomy of the olecranon is performed. When using the Sorbie Questor humeral component, a cut extending proximal to the bare area of the olecranon may impede the cutting block. Ensuring the osteotomy is made at the bare area will also minimize the risk of articular cartilage damage. The olecranon and triceps are reflected posteriorly, and the anterior capsule is released off the distal humerus as necessary to achieve full extension.

Component size is estimated at this point by comparing trials with the remaining native trochlea and capitellum and assessing the articulations of the trials with the greater sigmoid notch and radial head to ensure congruency. When using a Latitude prosthesis, if between sizes, the larger spool has been shown to have better joint congruency than an undersized component in biomechanical studies.

Access to the intramedullary canal is necessary for the cutting jig systems, and if intact bone is blocking the canal, freehand cuts are made to resect the trochlea to the proximal aspect of the olecranon fossa. If fracture fragments are blocking the canal, the minimum necessary to gain access is removed. At the same time, if too much cortical bone is left anteriorly or posteriorly, the intramedullary guide rod may be inserted in an extended or flexed position, respectively.

Condylar reconstruction, if required, is performed prior to the distal humeral cuts as the insertions of the medial and lateral collateral ligaments on their respective epicondyles are referenced for correct rotational alignment. The authors have had success using K-wire fixation for this, as it is both forgiving and cost-effective, but periarticular plates can be used as well. Proper depth is achieved with the same methods as described for total elbow arthroplasty. Fluoroscopy is used during trialing to ensure appropriate position and tracking of the prosthesis and anatomic reconstruction of the condyles.

After size and position are determined, the implant is cemented as described for total elbow arthroplasty. The olecranon osteotomy is repaired with a plate or tension band construct (Figure 2). Range of motion and stability are again assessed under fluoroscopy. The ulnar nerve is then evaluated through the full range of motion, and an anterior subcutaneous transposition is performed if concern exists regarding tension or impingement and in patients with preexisting ulnar nerve dysfunction.
that adequate pain relief and restoration of functional status was achieved by the majority of the patients. Furthermore, without the need for prolonged postoperative immobilization, patients are able to return to activities of daily living soon after surgery, although with required activity restrictions. These results support the continued use of total elbow arthroplasty for the primary treatment of acute distal humeral fractures, but importantly, the patients included in these studies were all older than 65 years.

In their systematic review, Voloshin et al reported a 21.5±9.2% overall complication rate with total elbow arthroplasty for acute distal humeral fractures, consistent with findings of the studies the current authors reviewed.\textsuperscript{19,21,42,60,67-76} Common complications include ulnar nerve dysfunction, triceps weakness or rupture, wound issues, infection, and aseptic loosening or mechanical complications.

In the studies listed in Table 1, the rates of reoperation for ulnar neuropathy ranged from 0% to 13%, and no reoperations were required in the studies in which only decompression without transposition was performed.\textsuperscript{42,60,71} Routine anterior transposition of the ulnar nerve may increase the risk of reoperation for postoperative ulnar nerve dysfunction, although this is debatable with the available literature.

One study with a total of 7 patients reported 1 (14%) patient with persistent triceps weakness, and this study used a triceps-reflecting approach.\textsuperscript{72} No triceps ruptures were reported, and no additional surgery was performed for triceps-related complications. These findings likely relate to the increased use of triceps-on or triceps-sparing approaches.

Reoperation rates for deep or superficial surgical site infections ranged from 0% to 18.8%. Rates of additional surgery for wound issues such as skin flap necrosis or hematomas ranged from 0% to 11.5%.

Bushing wear and aseptic loosening have been the primary modes of late failure of linked total elbow arthroplasty implants. The rates of reoperation for these causes in the studies the authors reviewed ranged from 0% to 25%, with higher rates seen in studies with longer follow-up periods. Many studies reported high rates of radiographic or asymptomatic loosening, but longer follow-up is needed to determine the clinical significance of these findings.

Distal Humeral Hemiarthroplasty

Recent studies of distal humeral hemiarthroplasty for acute distal humeral fractures with a mean follow-up of at least 2 years are summarized in Table 2.\textsuperscript{30,55,77,79-81}

All studies reported average flexion-extension arcs of 100° or greater (range, 100°–116°), and this improved motion with distal humeral hemiarthroplasty relative to total elbow arthroplasty is expected without an ulnar component or linked articulation. Average MEPS values ranged from 79.4 to 90.4, with 4 studies reporting good outcomes and 2 reporting excellent outcomes. These results are similar to those of total elbow arthroplasty and imply adequate pain relief and restoration of functional status after distal humeral hemiarthroplasty. Importantly, the average ages of the patients in these studies ranged from 44 to 78.7 years, with 2 studies reporting average ages younger than 60 years.

Reoperation rates after distal humeral hemiarthroplasty ranged from 0% to nearly 100% in these studies. Rates of ulnar nerve dysfunction requiring additional surgery ranged from 0% to 15.4%. In contrast to total elbow arthroplasty, the majority of reoperations were in cases where the nerve was initially decompressed but not transposed. This lends support to routine anterior transposition of the ulnar nerve when performing distal humeral hemiarthroplasty for fractures, but again, these findings are debatable with the available literature.

Triceps weakness was not reported in any studies. However, the rates of
Table 1

Results of Recent Studies Using Total Elbow Arthroplasty for Acute Distal Humeral Fractures With Average Follow-up ≥ 2 Years

<table>
<thead>
<tr>
<th>Study</th>
<th>No. of Procedures</th>
<th>Average Age, y (Range)</th>
<th>Average Follow-up, y (Range)</th>
<th>Implants</th>
<th>Average F-E Arc</th>
<th>Average MEPS</th>
<th>Average Operative Complications</th>
<th>Average Nonoperative Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gallucci et al</td>
<td>73</td>
<td>76.4 (43-87)</td>
<td>3.3 (1.1-8.0)</td>
<td>C/M</td>
<td>106°</td>
<td>83.5 (30-100)</td>
<td>Bushing wear (2), implant assembly error (1), ulnar neuropathy (3), skin necrosis (1), nonunion (1)</td>
<td>Symptomatic aseptic humeral component loosening (2)</td>
</tr>
<tr>
<td>Prasad et al</td>
<td>71</td>
<td>66.5 (40-81)</td>
<td>13.5 (8.7-17.5)</td>
<td>C/M</td>
<td>85°</td>
<td>85 (50-95)</td>
<td>Bushing wear (1), aseptic humeral component loosening (2)</td>
<td>Symptomatic HO (2), radial nerve neuropraxia (1)</td>
</tr>
<tr>
<td>Giannicola et al</td>
<td>67</td>
<td>78 (66-89)</td>
<td>2.8 (2.4-3.6)</td>
<td>Discovery b</td>
<td>122.5°</td>
<td>99.5 (95-100)</td>
<td>None clearly reported</td>
<td>HO (2), lateral epicondyle fracture (1), progressive aseptic humeral component loosening (1)</td>
</tr>
<tr>
<td>Ducrot et al</td>
<td>75</td>
<td>80 (65-93)</td>
<td>3.6 (1.7-5.4)</td>
<td>C/M</td>
<td>97°</td>
<td>83 (60-100)</td>
<td>Ulnar neuropathy (1)</td>
<td>Ulnar neuropathy (1), HO (6)</td>
</tr>
<tr>
<td>Mansat et al</td>
<td>76</td>
<td>79 (65-93)</td>
<td>3.1 (0.5-8.8)</td>
<td>C/M (85), Discovery (1), Latitude c (1)</td>
<td>97°</td>
<td>86 (45-100)</td>
<td>Skin necrosis (1), ulnar neuropathy (1), deep SSI (1), periprosthetic fracture (2), aseptic loosening (1), contracture or HO (2)</td>
<td>Hematoma (5), CRPS (2), ulnar neuropathy (5), radial neuropathy (1), median neuropathy (1), aseptic loosening (1)</td>
</tr>
<tr>
<td>Streubel et al</td>
<td>25</td>
<td>67 (NR)</td>
<td>9.7 (5.0-15.0)</td>
<td>C/M (NR)</td>
<td>NR</td>
<td>79.3 (35-100)</td>
<td>Deep SSI (4), aseptic loosening or periprosthetic fracture (7)</td>
<td>Aseptic loosening or periprosthetic fracture (3)</td>
</tr>
<tr>
<td>Antuña et al</td>
<td>68</td>
<td>76 (57-89)</td>
<td>4.8 (2.0-7.6)</td>
<td>C/M</td>
<td>90°</td>
<td>73 (30-100)</td>
<td>Superficial SSI (2), deep SSI/septic loosening (1)</td>
<td>Ulnar neuropathy (8), symptomatic aseptic loosening (2)</td>
</tr>
<tr>
<td>Ali et al</td>
<td>42</td>
<td>72 (62-92)</td>
<td>5.3 (3.0-9.0)</td>
<td>C/M</td>
<td>98°</td>
<td>92 (75-100)</td>
<td>None</td>
<td>Superficial SSI (1), radial nerve neuropraxia (1), HO (2)</td>
</tr>
<tr>
<td>Chalidis et al</td>
<td>74</td>
<td>80 (75-85)</td>
<td>2.8 (1.0-5.0)</td>
<td>Discovery</td>
<td>107°</td>
<td>90 (80-95)</td>
<td>Aseptic loosening/periprosthetic fracture (1)</td>
<td>Ulnar neuropathy (1)</td>
</tr>
<tr>
<td>McKee et al</td>
<td>19</td>
<td>78 (NR)</td>
<td>2.0 (2.0-2.0)</td>
<td>C/M</td>
<td>NR</td>
<td>86 (82-89)</td>
<td>Contracture (1), ulnar neuropathy/HO (1), deep SSI (1)</td>
<td>Ulnar neuropathy (1), wound issues/hematoma (4), contracture (1)</td>
</tr>
<tr>
<td>Prasad and Dent</td>
<td>69</td>
<td>75 (61-89)</td>
<td>4.6 (2.3-7.3)</td>
<td>C/M</td>
<td>93°</td>
<td>83.1 (60-100)</td>
<td>Aseptic loosening (1)</td>
<td>CRPS (1)</td>
</tr>
<tr>
<td>Kamineni and Morrey</td>
<td>60</td>
<td>69 (34-92)</td>
<td>7.0 (2.0-15.0)</td>
<td>C/M</td>
<td>NR</td>
<td>93 (75-100)</td>
<td>Hematoma (3), prominent implants (1), wound dehiscence (2), deep SSI/septic loosening (1), component fracture (2)</td>
<td>Periprosthetic fracture (1), ulnar neuropathy (2), CRPS (1), stroke (1), myocardial infarction (1), bushing wear (4), HO (7)</td>
</tr>
<tr>
<td>Frankle et al</td>
<td>21</td>
<td>72 (65-88)</td>
<td>3.8 (2.0-6.0)</td>
<td>C/M</td>
<td>113°</td>
<td>95 (85-100)</td>
<td>Uncoupled prosthesis (1), hematoma (1), superficial SSI (1)</td>
<td>Contracture (1), ulnar neuropathy (2), symptomatic ulnar loosening (1)</td>
</tr>
<tr>
<td>Ray et al</td>
<td>72</td>
<td>82 (74-88)</td>
<td>2.6 (2.0-4.0)</td>
<td>C/M</td>
<td>NR</td>
<td>79 (85-100)</td>
<td>None</td>
<td>Superficial SSI (1), triceps weakness (1)</td>
</tr>
</tbody>
</table>

Abbreviations: CRPS, complex regional pain syndrome; F-E, flexion-extension; HO, heterotopic ossification; MEPS, Mayo Elbow Performance Score; NR, not reported; SSI, surgical site infection.

- **a** Coonrad/Morrey Total Elbow (Zimmer, Warsaw, Indiana).
- **b** Discovery Elbow System (Biomet, Warsaw, Indiana).
- **c** Latitude EV Total Elbow Prosthesis (Tornier, Edina, Minnesota).
- **d** Unpublished data described by DeSimone and Sanchez-Sotelo.
prominent subcutaneous implants requiring removal ranged from 0% to 38.4%. Two studies that did not require reoperation for this indication used either a triceps-splitting or a triceps-on approach. However, in the study using a triceps-splitting approach, nearly 50% of the patients were found to have heterotopic ossification, and 10% required surgical excision. In the study using a triceps-on approach, one-third of the patients developed heterotopic ossification but none required surgery. These 2 studies reported average follow-up periods of 2-3 years. Longer follow-up is needed to determine whether more patients become symptomatic.

Instability is a concern with distal humeral hemiarthroplasty, but only 1 case was reported in all studies. A triceps-splitting approach was used, and the patient developed posterolateral rotatory instability requiring lateral reconstruction. Notably, no instability was reported with the use of triceps-on approaches.

A concern with any hemiarthroplasty is wear of the native cartilage articulating with the implant. For distal humeral hemiarthroplasty, this correlates to the development of ulnar wear and subsequent osteoarthritis that could promote subcutaneous osteoarthrits that could

<table>
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<tr>
<th>Study</th>
<th>No. of Procedures</th>
<th>Average Age, y</th>
<th>Average Follow-up, y</th>
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<th>Primary Approach</th>
<th>Ulnar Nerve Transposed at Index Procedure</th>
<th>Average F-E Arc</th>
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<th>MEPS</th>
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<tr>
<td>Schultzel et al</td>
<td>7</td>
<td>71.9 (56-81)</td>
<td>6.1 (3.0-8.0)</td>
<td>Latitude&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Olecranon osteotomy</td>
<td>7</td>
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<td>89.23 (75-100)</td>
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<td>Prominent implants (1), intraoperative olecranon fracture (1)</td>
</tr>
<tr>
<td>Smith et al</td>
<td>6&lt;sup&gt;e&lt;/sup&gt;</td>
<td>44 (29-52)</td>
<td>6.8 (2.0-11.1)</td>
<td>Latitude (3), SQ&lt;sup&gt;d&lt;/sup&gt; (3)</td>
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<td>Prominent implants (4), ulnar neuropathy (1), contracture (1)</td>
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<tr>
<td>Phadnis et al</td>
<td>16&lt;sup&gt;e&lt;/sup&gt;</td>
<td>78.7 (60-90)</td>
<td>2.9 (2.0-6.6)</td>
<td>Latitude</td>
<td>Triceps-on</td>
<td>0</td>
<td>116&lt;sup)c&lt;/sup&gt;</td>
<td>89.6 (65-100)</td>
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<td>Ulnar wear (10), radial wear (3), asymptomatic HO (6), ulnar nerve neuropraxia (1)</td>
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<td>Hohman et al</td>
<td>5&lt;sup&gt;f&lt;/sup&gt;</td>
<td>68.4 (59-75)</td>
<td>3.0 (2.2-5.0)</td>
<td>Latitude</td>
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<td>101&lt;sup&gt;e&lt;/sup&gt;</td>
<td>79.4 (67-95)</td>
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<td>Prominent implants (3), ulnar neuropathy (1)</td>
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<tr>
<td>Smith and Hughes</td>
<td>14&lt;sup&gt;e&lt;/sup&gt;</td>
<td>59 (29-81)</td>
<td>6.5 (2.1-11.1)</td>
<td>Latitude (10), SQ (4)</td>
<td>Olecranon osteotomy</td>
<td>5</td>
<td>115.9&lt;sup&gt;c&lt;/sup&gt;</td>
<td>90.4 (55-100)</td>
<td></td>
<td>Ulnar wear (11), HO (1)</td>
</tr>
</tbody>
</table>

Abbreviations: F-E, flexion-extension; HO, heterotopic ossification; MEPS, Mayo Elbow Performance Score; PLRI, posterolateral rotatory instability; SSI, surgical site infection.

<sup>a</sup>Deceased, 2; lost to follow-up, 1.
<sup>b</sup>Latitude EV Total Elbow Prosthesis (Tornier, Edina, Minnesota).
<sup>c</sup>Revised to total elbow arthroplasty and excluded, 2.
<sup>d</sup>Sorbie Questor Total Elbow System (Wright Medical Technologies, Arlington, Tennessee).
<sup>e</sup>Lost to follow-up, 1; distal humeral hemiarthroplasty performed >3 months after failed open reduction and internal fixation, 2.
<sup>f</sup>Deceased, 4; declined participation, 1; only partially reviewed, 3; revised to total elbow arthroplasty and excluded, 4.
lead to chronic pain. The rates of ulnar wear reported in these studies ranged from 0% to 83.3%. Interestingly, none of these patients with radiographic ulnar wear were symptomatic. Longer follow-up will be important to determine if these findings become clinically significant.

**Conclusion**

The impetus for distal humeral hemiarthroplasty as a primary treatment for acute distal humeral fractures has been concern over early or late mechanical failure of total elbow arthroplasty from noncompliance with activity restrictions. On the other hand, distal humeral hemiarthroplasty may result in early ulnar wear and hence painful motion. The available literature shows equivalent outcomes for distal humeral hemiarthroplasty and total elbow arthroplasty at short- and mid-term follow-up, but distal humeral hemiarthroplasty carries a higher overall reoperation rate. This is primarily due to prominent implants after olecranon osteotomy fixation. Although more technically challenging, increased use of triceps-sparing approaches over the olecranon osteotomy may lower the risk of additional surgery. Longer follow-up and prospective, randomized studies are needed, but the authors believe that with careful patient selection, use of modern, anatomic implants, and continued optimization of surgical techniques, distal humeral hemiarthroplasty will become not only an alternative treatment to consider for acute distal humeral fractures but one that is preferred in select patient populations.

**References**


