Elbow hemiarthroplasty for the management of distal humeral fractures: current technique, indications and results

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Abstract

There has been a growing recent interest in the use of elbow hemiarthroplasty for the treatment of distal humeral trauma in select patients. However, the current available evidence regarding outcome after elbow hemiarthroplasty is limited to case series and biomechanical data. Consequently, the procedure remains unfamiliar to many surgeons. The aim of the present review is to outline the evidence regarding elbow hemiarthroplasty and to use this, along with the author's experience, to better describe the indications, surgical technique and outcomes after this procedure.

Keywords

arthroplasty, distal humerus, elbow, fracture, hemiarthroplasty, trauma

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Introduction

Complex distal humeral fractures pose a surgical challenge, especially in older patients with severe articular comminution. Appropriate treatment is individualized and based on patient, fracture and surgeon factors. The elbow's propensity for stiffness means that early range of motion is desirable, whatever the chosen treatment. Non-operative treatment can result in painful non-union and should be reserved for undisplaced stable fractures, noncompliant patients or those with low functional demand and/or significant medical comorbidities.^{1–3}

Modern techniques allow stable fixation to be achieved in very complex fractures; however, there remains a subset of fractures that are difficult to reconstruct as a result of poor bone quality and articular comminution.^{4,5}

In this scenario, total elbow arthroplasty (TEA) offers superior functional outcome, albeit with introduction of a new spectrum of complications; namely, aseptic loosening, polyethylene wear, osteolysis and peri-prosthetic fracture.^{6–8}

Consequently, there has been interest in elbow hemiarthroplasty (EHA) as an alternative that may provide the advantages of an arthroplasty without the complications related to the linked articulation and ulnar component of

a TEA. Conversely, hemiarthroplasty may be associated with wear of the native ulna and radial head or lead to instability because of its unlinked nature.

The aims of the present review are to summarize and appraise the current and historic studies on elbow hemiarthroplasty, and to provide recommendations based on the available literature and the authors' clinical experience regarding patient selection, outcome and surgical technique of elbow hemiarthroplasty.

Historical perspective

Mellen and Phalen⁹ first described four cases of EHA in 1947 using a non-anatomic acrylic implant that was used for salvage of high-energy injuries during the Second World War, whereas Venable¹⁰ and

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MacAusland¹¹ were the first to report the use of EHA for acute fractures in the 1950s.

These early implants were made from a variety of materials including nylon,¹⁰ acrylic,⁹ vitallium,^{11–13} titanium and stainless steel.¹⁴ Most were anatomic in design, created by plaster cast moulds of cadaveric humeri^{12,13} or from excision of the fractured fragments in a staged procedure.¹¹ Implant fixation was a problem before the advent of orthopaedic cement, and hence most stemmed implants were fixed using transfixing screws through the stems,^{11–13} although Street and Stevens¹⁴ published the largest series at the time using a resurfacing, stemless prosthesis.

These early studies reported better results when the indication was acute fracture rather than when surgery was for salvage treatment of failed open reduction internal fixation (ORIF), non-union or malunion.^{11,14}

The longest follow-up of an EHA to date has been by Shifrin et al.¹³ who published the 21-year follow-up of a 19-year-old man treated with EHA for post-traumatic pain and disability. They reported full unrestricted pain free function, although radiographs demonstrated evidence of asymptomatic ulnohumeral joint space narrowing. Table 1 outlines the published data on historical series of EHA.

In the 1970s, EHA became less common as a result of the advent and popularity of linked TEA and the advances in internal fixation developed by the Arbeitsgemeinschaft für Osteosynthesefragen (AO) group.

Table 2 illustrates the chronologic development of EHA up to the current fourth generation of implant. The evidence discussed in the remainder of this article will focus on the more recent data derived from third and fourth generation implants (Table 3).

‘Modern’ implants used for EHA

Three implants have contemporary published outcome data about their use as an EHA. These are the Kudo (Biomet Ltd, Bridgend, UK), the Sorbie-Questor (Wright Medical Technology, Arlington, TNUSA) and the Latitude (Tornier, Montbonnot-Saint-Martin, France).

EHA has been used in the UK, Europe, Australasia and the USA; however, in the USA, these implants do not currently have Food and Drug Administration approval, and therefore have been used off label.

The Kudo is a non-anatomic prosthesis with an excellent long-term track record as an unlinked TEA.^{15,16} The humeral component has been used as an EHA in one report.¹⁷

The Sorbie-Questor is a three part unlinked TEA, which has an anatomic, stemmed humeral component that has been used as an EHA, but is no longer

Table 1. Published series of elbow hemiarthroplasty using historical implants.

Author	Patients	Mean follow-up (months)	Mean age (years)	Indication for surgery	Prosthesis	Functional scores	Complications and re-operations
MacAusland 1954 ¹¹	4	22	37.8	Fracture = 1 Non-union/malunion = 2	Custom	Not performed	Prosthetic stem fracture = 1
Venable 1952 ¹⁰	1	15	Not stated	Fracture = 1	Custom	Not performed	None
Shifrin 1990 ¹³	1	240	19	Non-union	Custom	Not performed	None
Barr and Eaton 1965 ¹²	1	48	28	Non-union	Custom	Not performed	Progressive loosening
Street and Stevens 1974 ¹⁴	5	43	52.4	Non-union/malunion = 4 Fracture = 1	Custom	Not performed	Radial nerve palsy = 1 Ulnar nerve palsy = 1 Heterotopic ossification = 1 Capsular release = 1 Deep infection = 1 Resection arthroplasty = 1
Mellen and Phalen 1947 ⁹	4	11	22.5	Non-union/malunion = 4	Custom	Not performed	Radial nerve palsy = 1 Unstable sensation = 1

Table 2. Chronologic evolution of elbow hemiarthroplasty.

First generation 1947–1955	Second generation 1950–1980	Third generation Kudo	Fourth generation Sorbie-Questor Latitude

<ul style="list-style-type: none"> • Non-anatomic • Synthetic materials (Acrylic, Nylon) 	<ul style="list-style-type: none"> • Anatomic • Stemmed • Vitallium • Screw fixation/press fit 	<ul style="list-style-type: none"> • Proven record as TEA • Non-anatomic • Cement fixation 	<ul style="list-style-type: none"> • Anatomic • Specifically designed for use as DHH

DHH, distal humeral hemiarthroplasty; TEA, total elbow arthroplasty.

Table 3. Published series of elbow hemiarthroplasty using contemporary implants.

Author	Patients	Mean follow-up (months)	Mean age (years)	Indication for surgery	Prosthesis	Mean functional scores	Complications and re-operations
Homan et al. ²¹	7 (7 presented in full)	36	64	Fracture = 5 Failed ORIF = 2	Latitude	MEPS = 75 qDASH = 33 ASES = 61	Metalwork removal = 3, Peri-prosthetic fracture = 1, Ulnar nerve irritation requiring subsequent surgery = 1
Adolfsson and Nestorson ¹⁷	8	54	79	Fracture = 9, Failed ORIF = 1	Kudo	MEPS = 90.6	Peri-prosthetic fracture n = 1
Smith and Hughes ¹⁸	26 (17 presented in full)	80	63	Fracture = 21 Failed ORIF = 5	Sorbie-Questor = 12 Latitude = 14	MEPS = 90.4 qDASH = 19	Metalwork removal = 10, Ulnar nerve irritation requiring subsequent surgery = 4, Revision to TEA = 4, Infection/wound related = 2, Peri-prosthetic fracture = 1, Contracture release = 1
Argintar et al. ²⁰	10	12	72	Fracture = 9 Non-union = 1	Latitude	MEPS = 77.2 qDASH = 35.1	Ulnar nerve irritation = 1, Peri-prosthetic fracture = 1, Metalwork removal = 1
Burkhardt et al. ²²	10	12.1	75	Fracture = 8 Failed ORIF = 2	Latitude	MEPS = 91.3 qDASH = 11.5	Ulnar nerve irritation = 1, Infection = 1, HO = 2
Phadnis et al. ²³	18	35	79	Fracture = 18	Latitude	MEPS = 89.5 qDASH = 11.2 OES = 43.7	Ulnar nerve irritation = 1
Nestorson et al. ²⁴	42	34	72	Fracture = 42	Latitude	MEPS = 90 DASH = 20	Aseptic loosening (revised to TEA) = 1 Lateral collateral reconstruction for PLRI = 1 Ulnar nerve irritation = 3 Superficial infection = 1 Heterotopic ossification = 19 Radio-ulnar synostosis = 1 Removal of HO = 4

ASES, American Shoulder and Elbow Score; fx, fracture; HO, heterotopic ossification; MEPS, Mayo Elbow Performance Score; OES, Oxford Elbow Score; ORIF, open reduction internal fixation; PLRI, Posterolateral Rotatory Instability; qDASH, Quick Disabilities of Arm, Shoulder and Hand; TEA, total elbow arthroplasty.

available. Smith and Hughes¹⁸ performed 14 cases using the Sorbie-Questor, although later cases in their series were performed using the Latitude system.

When using the Kudo or Sorbie, supplemental hardware is required to stabilize the condyles to the implant to achieve joint stability. If instability is encountered after EHA with either device, the humeral stem must be removed to implant a linked prosthesis because both the Kudo and Sorbie were only available as an unlinked TEA.

The Latitude is a three-part linked or unlinked TEA with an anatomic, stemmed humeral component and an anterior flange. The humeral component is designed for use as an EHA and comprises three modular parts: the stem, an anatomic spool and a cannulated pin, which is used to attach the spool to the stem. The cannulation allows suture fixation of the collateral ligaments and condyles through the implant to provide joint stability. This negates the need for supplementary hardware in most cases. Should the need for revision to TEA arise, the EHA can be converted to an unlinked or linked TEA without extraction of the humeral component.

Current published data indicates that the Kudo has been used for EHA in eight cases, the Sorbie-Questor in 12 cases and the latitude in 101 cases. The relative merits of each implant are summarized in Table 4. Our experience of EHA has been predominantly with the Latitude implant.

Indications

EHA has been reported for the treatment of acute fractures;^{17–24} for the salvage of sequelae related to non-operative management or failed internal fixation^{17,18,20–22} and, in one series, for the management of rheumatoid arthritis.²⁵

Acute trauma

The primary indication for EHA is an acute, intra-articular distal humeral fracture in an active older patient, where sufficiently stable internal fixation is unlikely to be achieved. Low trans-condylar and coronal shear fractures in these patients are also relative indications for EHA. In younger patients, every attempt should be made to perform internal fixation. In older, low demand patients, non-operative treatment may be appropriate.

Sub-acute traumatic pathology

EHA appears to be an attractive option for treatment of failed internal fixation and for non-union or malunion of a non-operatively treated distal humeral

fracture. However, all reports concerning EHA being performed for these indications describe inferior motion, functional scores and an increased complication rate compared to when EHA was performed for acute trauma.^{10,17,18,21,22} This is likely a result of pre-existing joint contracture, poor quality collateral ligaments and compromised ulnar and radial head articular surfaces.

Based on the current evidence, we feel that EHA should be used with caution for salvage of failed internal fixation, although it is noteworthy that the complication rate, functional scores and survivorship of TEA when performed for failed ORIF are also inferior compared to acute trauma.²⁶

Contraindications

Contaminated open fractures or chronic infection are absolute contraindications to EHA. Relative contraindications include younger patients where fixation is preferred and older patients with very low functional demand or co-morbidities that make surgery unsafe.

Fractures involving both the distal humerus and olecranon or radial head are also relative contraindications. Fixation of the radial head or olecranon with EHA is possible, and has been described for the olecranon in two patients;²⁴ however, the risk is that the damaged articular surfaces may accelerate chondral wear. In addition, failure to anatomically reconstruct the radial head may contribute to instability if an EHA is performed because of the unlinked nature of the articulation.

Pre-existing arthritis is also a relative contraindication to EHA because of the risk of pain caused by accelerated chondral wear and the difficulty in ensuring joint stability as a result of a loss of normal bony architecture and attenuation of the collateral ligaments, particularly in inflammatory arthritis. Nevertheless, Swobodo and Scott²⁵ did report successful EHA in seven cases performed for rheumatoid arthritis, all in patients < 50 years of age. All patients had excellent pain relief, although only two regained a functional arc of motion >100°. Nestorson et al.²⁴ reported on one case in their series with pre-existing osteoarthritis. This patient achieved a flexion arc of 85° and had inferior Disabilities of Arm, Shoulder and Hand (DASH) and Mayo Elbow Performance Score (MEPS) scores compared to most of their cohort.

Surgical technique

The fundamental steps required to achieve a successful EHA are:

1. Adequate pre-operative planning

Table 4. Modern implants with published results for elbow hemiarthroplasty.

Implant	Advantages	Disadvantages
Kudo	Proven track record as TEA	Non-anatomic Not modular No anterior flange Not convertible to linked TEA
Sorbie-Questor	Anatomic Preserves more metaphyseal bone – allows easier supplementary plate fixation	No anterior flange Not convertible to linked TEA Limited modularity No longer available
Latitude	Anatomic design Anterior flange Highly modular Convertible to linked or unlinked TEA Allows fixation of condyles and collateral ligaments to the implant	Takes up more metaphysal bone

TEA, total elbow arthroplasty.

2. Choosing the optimal surgical approach
3. Safe management of the ulnar nerve
4. Ensuring joint stability
5. Allowing early range of motion

Pre-operative planning

Where possible, the decision to perform EHA should be made pre-operatively with the aid of multiplanar computed tomography (CT) imaging. This avoids

embarking on internal fixation and then converting intra-operatively to an arthroplasty, which results in a longer operating time and raises the risk of infection. The surgical exposure should be tailored to a specific procedure. For example, if the surgeon feels that a TEA may be required, an olecranon osteotomy should not be performed because this could jeopardize the stability of the ulnar component. If there is doubt regarding the reconstructibility of the fracture, it is reasonable to initially expose the fracture using a triceps on approach, at which point an intra-operative decision can be made to proceed to fixation and osteotomy or arthroplasty without violating the olecranon.

We recommend that EHA should be performed using an implant that allows intra-operative conversion to a linked TEA, in case intra-operative instability is encountered. If there are large condylar fractures that extend into the humeral columns, peri-articular plates should be available, although these are rarely required.^{23,24}

Surgical approach

The selected approach should allow sufficient access for articular fragment resection, condyle/collateral ligament repair and humeral instrumentation. There should also be sufficient exposure of the radial head and ulna to allow accurate sizing of the articular components.

A commonly described approach for EHA is via an olecranon osteotomy (39 patients),^{17,18,20,21} which

affords good visualization of the distal humeral articular surface,²⁷ but requires fixation with further hardware. Of the 39 reported cases of olecranon osteotomy for EHA, 13 patients (33%) required further surgery for problems related to the olecranon osteotomy (12 metalwork removal, one ORIF of extended olecranon fracture). In addition, given that ulna wear is a concern after EHA, we feel that violating the olecranon with an osteotomy may exacerbate this problem. Finally, if there is instability on trialling the EHA, then conversion to TEA may be compromised by the osteotomy.

The most commonly described approach in the literature has been the triceps split by Adolfsson's group in Scandinavia;^{17,24} however, their approach differs from the traditional triceps split by not fully reflecting the medial half of the triceps from the olecranon.

Other reported approaches are the Bryan-Morrey triceps reflecting approach in 10 patients²² and a medial condyle osteotomy in one patient.¹⁸

Twenty-two reported cases used a 'triceps on' approach.^{18,21,23} This approach has been described in detail previously.^{23,28} We favour this approach because it facilitates early-unrestricted range of motion and negates the issues of subcutaneous hardware and triceps failure (Figure 1).

As part of the surgical approach, the ulnar nerve is identified, mobilized and protected but is not routinely transposed, unless it lies in a hostile bed, is unstable or

Figure 1. Triceps on surgical approach. The surgical approach has been completed, the articular fragments resected and the distal humerus prepared. A trial implant has been placed. The triceps remains attached to the olecranon and the triceps fascia has been split in continuity with the anconeus fascia on the lateral aspect of the olecranon. To gain access, the distal humerus has been subluxated laterally. Note the trochlea spool is overlying the radial head.

is under excessive tension. Our experience has been that transposition is not usually required and, when performed routinely, does not necessarily reduce the risk of postoperative neuropraxia.

Ensuring joint stability

This is an absolute pre-requisite of an EHA and is achieved by repair of the condyles/collateral ligaments, restoration of the flexion–extension axis and correct implant rotation.

Restoration of flexion–extension axis and correct implant rotation

Stability throughout the full range of motion after EHA is dependent on placing the implant such that it replicates the native flexion–extension axis of the elbow and allows restoration of the collateral ligaments to their isometric points.²⁹

The flexion–extension axis is influenced by implant height, alignment and rotation.

Correct humeral height is judged in two ways: first, by referencing against the patient's native olecranon fossa, the proximal part of which is usually recognizable even in multi-fragmentary fractures, and, second, by aligning the collateral ligament's (attached to the humeral epicondyles) to the implant's epicondylar axis during trialling. Rotation of the implant is assessed by referencing against the flat posterior cortex of the humerus, proximal to the olecranon fossa. The implant should be internally rotated (mean 14°), and not parallel to the posterior humeral cortex line, to most accurately restore the flexion–extension axis.³⁰

Correct sizing of the articular surface is achieved by trialling the articular spools against the native radial head and ulna during motion, where they should remain congruent throughout the full arc. If the native spool lies between two sizes, the surgeon should select the larger size to decrease the risk of point loading on the native ulna and radial head.³¹

Condyle/collateral ligament repair

The key component of ensuring stability after EHA is to restore the collateral ligaments to the flexion–extension axis of the implant. In a fracture, the ligaments usually remain attached to the fractured condyles.

Preservation and repair of the condyles provides mechanical support to the distal aspect of the implant and permits bony union to the humeral shaft, although it is important to understand that repair of the collateral ligaments is the most important factor for joint

stability. Bony reconstruction should be considered a positive by-product of ligament repair.

Condyle/collateral ligament repair has been performed using sutures alone or with supplementary metalwork such as K-wires; screws or plates. Smith and Hughes¹⁸ performed supplementary stabilization of 17 condyles and 17 epicondyles in their series when using the Sorbie-Questor prosthesis. Adolfsson and Nestorson¹⁷ also frequently used plates in their series of eight Kudo hemiarthroplasties. Those who report use of the Latitude, in contrast, favour suture fixation through the implant with use of supplementary plating or wires only when the condyle fracture extends into the adjacent humeral column proximal to the olecranon fossa.^{20–24}

The suture repair technique has been described in detail previously (Figure 2).²³ It involves whip stitching both collateral ligaments with a non-absorbable suture, passing these sutures through the cannulated axis pin of the implant and through the opposite collateral ligament. Hence the sutures in the lateral collateral are tied over the medial collateral ligament and vice versa. Supplementary cerclage and tension band sutures can be added but are not routinely necessary. A technical pearl is to tie the medial collateral ligament sutures (on the lateral aspect of the joint) first. If the lateral collateral sutures are tied, there is a risk the tension created can cause the implant to 'jump' medially because the prosthetic lateral trochlea ridge is shallower than the medial ridge.

Only two studies have reported the results of condyle union to the humeral shaft.^{23,24} Phadnis et al.²³ reported a condyle union rate of 94% (15/16 patients) when using sutures only. Similarly, Nestorson et al.²⁴ had a union rate of 95% (37/39 patients) when using either suture only, or sutures with cerclage wires or K-wires. In both studies, the condyles, which had not united, did not displace away from the implant indicating that the sutures were likely to be intact.

Postoperative protocol

An advantage of arthroplasty for fracture is that the patient can reliably commence full early range of motion if the soft tissues permit. A triceps on approach facilitates this. We do not provide prescriptive restrictions on weight lifting or activity as some surgeons do following TEA. Our experience has been that patients do not adhere to such instructions. We do, however, recommend that patients limit heavy or repetitive activities to minimize the joint reaction force, particularly for the first 6 weeks when the condyles and collateral ligaments are healing.

Figure 2. Reconstruction of fractured condyles. (a) Drill holes made in medial and lateral condylar fragments. (b, c) 2-0 Fibre wire passed through cannulation in spool and pre-made drill holes, then whip-stitched into collateral ligaments. (d) Condyles reduced to implant and humeral columns and tied firmly to each other through the cannulated spool. (e, f) Condyles further secured with tension band sutures via drill holes and cerclage sutures to the implant.

Outcome data

The mean follow-up of the 121 reported cases was 37.5 months (range 6 months to 127 years). The mean age of the patients was 72.6 years (range 29 years to 92 years).

Functional outcome scores

All studies report using the MEPS, whereas some also used the Quick Disabilities of Arm, Shoulder and Hand (qDASH) score,^{18,20–24} American Shoulder and Elbow Score^{18,21} and Oxford Elbow Score.²³

The mean reported MEPS was 87.6 (SD 14.5) (107 patients). According to the MEPS, the outcome was classified as excellent in 65 patients (61%), good in 27 (25%), fair in nine (8%) and poor in six (6%). The characteristics of the 15 patients with fair or poor MEPS are shown in Table 5. Patients who had an olecranon osteotomy had significantly lower MEPS than patients with all other approaches (mean: 75.1, SD: 14.8 versus mean: 90.7, SD: 9.5) ($p \leq 0.001$, independent Student's *t*-test). There was a nonsignificant trend that younger patients also had a lower MEPS score.

Most studies report using the DASH or quick DASH score to assess their patient measured functional outcomes.^{18,20–24} The mean quick DASH score (94 patients) was 18.3 (SD 21.2). Overall, there was good

correlation between the MEPS and DASH scores (Pearson's correlation co-efficient 0.77, $p \leq 0.01$).

These functional results are comparable to the good results reported for TEA performed for fracture.^{6,7,26,32,33}

Range of motion

All studies reported the postoperative range of motion (ROM). The mean flexion arc and pronosupination arcs achieved were 108° (SD 19.6°) and 176° (SD 15.3°), respectively (excludes one patient with a radio-ulnar synostosis from an associated forearm fracture). This range of motion is similar to following TEA³³ or ORIF.^{34–36} The difficulty in restoring pre-operative motion emphasizes that any intervention should permit early range of motion. TEA and EHA have an advantage over ORIF in this respect.

Radiographic outcomes

Loosening

A theoretical benefit of EHA is that there should be less torque on the implant–cement and cement–bone interface than a linked device. There is also no potential for polyethylene-induced osteolysis.

Table 5. Characteristics of patients in the published literature with poor or fair Mayo Elbow Performance Scores following elbow hemiarthroplasty (60% of these patients had an olecranon osteotomy performed as part of the surgical approach).

Patient	Age	Approach	Complications/re-operations	Ulnar wear
1	33	Olecranon osteotomy	None	Present
2	29	Olecranon osteotomy	Ulnar nerve neuropraxia	Present
3	81	Olecranon osteotomy	None	Not mentioned
4	79	Bryan and Morrey	None	Present
5	80	Olecranon osteotomy	None	Not mentioned
6	74	Olecranon osteotomy	None	Not mentioned
7	59	Olecranon osteotomy	Metalwork removal	Present
8	62	Olecranon osteotomy	Metalwork removal	Not present
9	76	Olecranon osteotomy	None	Present
10	69	Olecranon osteotomy	None	Not mentioned
11	75	Triceps split	None	Present
12	80	Triceps split	None	Not mentioned
13	60	Triceps split	None	Not present
14	66	Triceps split	Radio-ulnar synostosis	Not present
15	58	Triceps split	None	Not present

The presence of radiolucent lines around the humeral stem have been reported in 11 of the 94 patients who had radiographic assessment for aseptic loosening.^{18,20,21,23,24} Nestorson et al.²⁴ noted lucencies within three zones in the same patient and, although Phadnis et al.²³ noted 13 nonprogressive radiolucent lines in 11 patients, 12/13 of these lines were seen in the area between the reconstructed condyle and implant (zone 1) where bony union or cement is not expected.

Revision to TEA for aseptic loosening has only been reported in three cases, two by Smith and Hughes¹⁸ and one by Nestorson et al.²⁴

In comparison, the incidence of symptomatic aseptic loosening after TEA is up to 15% with the incidence of radiolucent lines much higher, although it is noteworthy that some of these studies have longer follow-up.^{33,37} Aseptic loosening also affects the ulnar stem to a greater degree, which is likely related to the inferior fixation achieved in the ulna.^{32,37,38}

Olecranon and radial head wear

A concern with any hemiarthroplasty is wear of the native joint it articulates with. There is a disparity in

the modulus of elasticity and surface roughness between articular cartilage and a metallic prosthesis.³⁹ This, combined with altered loading, means cartilage wear does occur with time even in anatomic implants.^{40,41}

The question is how quickly this wear occurs, and whether cartilage wear manifests as pain that is unacceptable to the patient.

The studies reporting wear after EHA found evidence of ulna and radial head wear in 40/98 (41%) and 11/98 (11%) patients, respectively.^{17,18,21–24} Smith and Hughes¹⁸ observed that ulna wear was progressive with time. On pooling of the data, it was evident that there was a trend for patients with ulna wear to have a lower mean MEPS than those without ulna wear, although the mean MEPS in this group was still high (mean: 86.8, SD 17.5 versus mean: 95.7, SD 5.0) ($p = 0.06$).

Problems with assessing wear

A major issue with assessment of wear is that current methods based on plain X-rays are unreliable because neither the anterior–posterior (AP) or lateral

radiographs can be properly standardized in terms of rotation, forearm position and elbow extension.^{18,23} For example, on the AP view, the degree of wear is likely to be overestimated because patients cannot usually extend the elbow fully after surgery. Hohman et al.²¹ proposed a CT-based technique that quantified ulna wear as a percentage of the opposite elbow. Although promising, only four of their patients consented to having a repeat CT scan, highlighting the issues of additional radiation dosage and cost with this modality.

Complications and re-operations

Of the 121 reported cases, there were 22 (18%) surgical complications, 34 (28%) re-operations and three deaths from unrelated causes. The complications and re-operations are summarized in Tables 6 and 7.

Five cases have been revised to TEA.¹⁸ Three patients had a Sorbie-Questor¹⁸ and one patient had a Latitude EHA.²⁴ Three patients had revision for primary aseptic loosening at 18 months, 22 months and 66 months postoperatively. The first was treated with EHA for salvage of a failed ORIF, the second for acute fracture and the third for salvage of failed non-operative treatment where non-union and avascular necrosis of the lateral condyle had occurred. The other two patients underwent revision at 140 months and 54 months postoperatively for non-union and progressive loosening caused by peri-prosthetic fracture after a fall in a previously asymptomatic well-fixed implant.¹⁸ In addition to these published cases, we have revised a Latitude EHA to a TEA, for severe ulnar wear in a young man treated with EHA for salvage of failed fixation after a gunshot to the elbow.⁴² Although there has not been a published case of

dislocation after EHA, we are aware of an unpublished case revised to TEA for instability in a patient with juvenile rheumatoid arthritis, treated with EHA for salvage of failed ORIF. Nestorson et al.²⁴ also performed a lateral collateral ligament reconstruction in one patient for posterolateral rotatory instability without complete dislocation.

These experiences further emphasize that the results of EHA are better for acute fracture than salvage surgery and achieving stability is of prime importance.

The most common reason for re-operation was removal of symptomatic metalwork in 14 patients. Twelve of 14 (86%) of these were for metalwork used to fix an olecranon osteotomy. In addition, one reported peri-prosthetic fracture was an intra-operative extension from an olecranon osteotomy, which required repeat fixation.

The complication rate of EHA outlined in this review is comparable to internal fixation or TEA,^{8,33,37,43} although the follow-up data after EHA are not yet as long as after TEA. Of interest, the complication profile after EHA is different from TEA. With EHA, there is no polyethylene wear, peri-prosthetic fracture or loosening around the ulnar component or un-coupling of the linkage. Table 8 shows the complication profile of TEA and ORIF in elderly patients treated for acute fractures.

Table 6. Complications in the published literature following elbow hemiarthroplasty.

Cause	Number of clinical complications
Ulnar nerve irritation	11
Peri-prosthetic fracture	5
Infection/wound breakdown	2
Primary aseptic loosening	3
Posterolateral rotatory instability	1
Total	22
Percentage of all cases	22/121 (18%)

Table 7. Re-operations in the published literature following elbow hemiarthroplasty.

Indication	Patients
Metalwork removal	14
Ulnar nerve surgery	6
Revision to TEA	5
Infection	2
ORIF fracture	1
Contracture release	1
Excision of heterotopic bone	4
Lateral collateral ligament reconstruction	1
Total	34
Percentage of all cases	34/121 (28%)

Note that 41% of re-operations were for removal of metalwork, of which 12/14 (86%) were after fixation of an olecranon osteotomy. ORIF, open reduction and internal fixation; TEA, total elbow arthroplasty.

Table 8. Complication profile of TEA for trauma and ORIF.

	Patients	Mean follow-up	Number of complications	% Patients with a complication	% Patients with a reoperation	Other
ORIF						
McKee 2009 ⁶	15	24	21	53%	27%	1 revision to TEA
Athwal 2009 ³⁵	37	27	24	53%	32%	
Frankle 2003 ⁷	12	57	4	33%	33%	3 revision to TEA
TEA						
McKee 2009 ⁶	25	24	18	40%	12%	1 revision
Kamineni 2004 ³³	49	84	20	29%	20%	5 revisions
Frankle 2003 ⁷	12	45	5	42%	25%	1 uncoupling

ORIF, open reduction and internal fixation; TEA, total elbow arthroplasty.

Recommendations

1. On the basis of this literature review, as well as our own experience with EHA, we recommend that EHA be considered as an alternative form of arthroplasty in active, elderly patients with an acute distal humeral fracture.
2. We would temper but not exclude the use of EHA for post-traumatic salvage and in younger patients because of the inferior functional results, higher complication rate and propensity for ulnar wear with time.
3. If EHA is performed, we recommend against an olecranon osteotomy given the higher re-operation rate, violation of the articular surface and inferior functional outcome.
4. Paramount importance should be given to achieving stability through fixation of the collateral ligaments and condyles, and an implant that is convertible to a linked TEA is recommended.
5. Future research may focus on developing better methods of quantifying ulna wear, aiming to further the understanding of elbow kinematics after EHA and to explore the role of more 'cartilage friendly' bearing materials.

Declaration of Conflicting Interests

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