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Current concepts in elbow arthroplasty

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- Distal humeral replacement and the total elbow are two commonly-used arthroplasties
- Each prosthesis has evolving indications and surgical techniques
- Recent changes in device design and implantation methods are due to biomechanical and clinical outcome-based research
- New prostheses and methods provide: better elbow kinematics, more durable bearings and longer-lasting joint replacement potential

Keywords: elbow arthroplasty; unicompartmental, distal humerus hemi-arthroplasty; total elbow arthroplasty

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Introduction

In 2017 there are two most commonly-used elbow arthroplasties: distal humeral replacement or hemi-arthroplasty and total elbow arthroplasty (TEA). Each type of prosthesis has ever-evolving indications and surgical techniques. The many changes in recent years are due to ongoing biomechanical as well as clinical outcome-based research. These studies are driving the overall use of these devices and implantation methods towards those that are able to better reproduce elbow kinematics, thus becoming more durable, and long-lasting joint replacement procedures.

Radial head replacement and unicompartmental arthroplasty

Arthroplasty

Replacing the radial head is a hemi-arthroplasty of the radio-capitellar and proximal radio-ulnar joints. This procedure is indicated in the acute traumatic setting where the radial head is fractured beyond repair. These are Mason Type III or IV radial head fractures with greater than three pieces of comminuted bone and are associated with less than ideal results if treated with open reduction and internal fixation (ORIF).[1] Many implants are on the market with varying design features. When choosing a device to replace the radial head, consideration should be given to restoration of the radial length without over- or under-stuffing,[2] restoring the contact mechanics of the native radius and its articulation,[3,4] and using a system that can restore stability to an elbow that has concomitant ligamentous injuries.[5]

Unicompartmental arthroplasty is the replacement of the radiocapitellar joint with a metallic capitellum and mating radial head covered with a polyethylene cap. This novel procedure is used in patients with isolated lateral elbow compartment primary and post-traumatic osteoarthritis.[6] Although little has been reported on this type of arthroplasty, one multicentre case-series has shown good short-term results.[7]

Elbow hemi-arthroplasty

Elbow hemi-arthroplasty (HA) is the replacement of the distal humerus with a prosthesis designed to re-create the articulation with the proximal ulna and radial head. There were several historical devices used for this purpose although only one is currently available, the Latitude EV manufactured by Wright Medical Technology (Arlington, TN, USA), and formerly by Tornier (St Ismier, France). The general design concept is a modular spool and stem combination to re-create the articular surface and mechanical support of the distal humerus. The polished cobalt-chrome metal spool is shaped to mimic the native capitellum and trochlea. The stem has medial and lateral fins as well as an anterior flange to provide additional rotational stability. Reconstruction or repair of the medial and lateral ligamentous complexes together with reconstruction of medial and lateral bony columns is necessary to restore varus and valgus stability. A cannulated screw locks the humeral stem to the spool and allows for the use of non-absorbable suture through the spool to secure the epicondyles and collateral ligaments if they are fractured or torn.

Indications

Currently elbow HA is used in the setting of the unfixable distal humerus fracture in the physiologically active patient. Additional indications include distal humeral nonunion after a failed attempted ORIF. Relatively preserved cartilage on the radial head and proximal ulna is a prerequisite for the use of elbow HA. Surgeons should be aware that elbow HA for any indication is an off-label use of this device by some regulatory offices including the FDA of the United States.

Techniques

The surgical technique for implementation of elbow HA is similar to that of TEA in that proper distal humerus exposure is required regardless of the device system being used. One major difference between these two procedures is that extensive proximal ulna visualisation needed for TEA is not required with elbow HA, making triceps-on approaches more attractive if the distal humerus fracture allows. These approaches have produced excellent early-term range of motion and patient-reported outcome data[8] without reported extensor mechanism complications as described previously with triceps-off approaches.[9-11] Olecranon osteotomy can be used if the epicondyles are intact; which allows for great exposure, but also comes with major drawbacks including potential for posterior ulnohumeral joint malalignment, more complicated further revision of elbow HA to TEA, prominent ORIF hardware requiring revision, as well as a small risk of nonunion.

In the setting of the distal humeral fracture, there are some unique steps in the implantation of the Latitude arthroplasty. First, capitellum and trochlear fragments must be carefully excised. During a triceps-on exposure, choosing the side from which to work is dependent on assessment of whether medial or lateral collateral ligaments are preserved, maintaining the intact side when possible. Next, the medial and/or lateral epicondyles are reconstructed with native bone fragments cut to align with the device spool. They are then secured to the implant with a non-resorbable suture that passes through the cannulated screw that locks the spool onto the stem. Depending on fracture type and surgeon preference; either K-wires, plates, lag screws, or figure-of-eight sutures are placed on or through the fractured epicondyles and secured to the humerus proximal to the fracture to restore axial stability. As with TEA, an anterior flange is present in the hemi-arthroplasty to secure the device against posteriorly directed forces applied by biceps, brachialis and triceps, and to provide rotational stability of the component. This requires bone graft that can be obtained from the fracture fragments.

Future aspects

Ideally prospective research studies would be performed in the setting of distal humeral fracture for patients undergoing elbow HA, with ORIF or TEA used as a control group. Sub-group analysis of studies like these evaluating age and pre-operative functional status would be necessary to appropriately stratify patients to treatment modalities.

Mid-term data of outcomes for prolonged articulation of the proximal ulnar cartilage against a metallic elbow HA has been shown to be associated with ulnar wear, however no change in functional outcomes have been correlated to these findings.[8-11] Although the Latitude EV is convertable to TEA with only ulnar component revision, there are no reports of patients undergoing this conversion to date. Evaluation in the long-term of this prosthesis system will necessary to determine the efficacy and appropriate use criteria for this device as a hemi-arthroplasty potentially in younger, more active patients.

Total elbow arthroplasty

TEA is the replacement of the ulno-humeral articulation with or without the replacement of the radio-capitellar and radio-ulnar joints. Currently manufactured total elbows have some conceptual similarities and other differentiating factors. All of the humeral and ulnar stems are cemented. The bearing surfaces include varying designs consisting of wheel and spool portions of polished metal articulation with ultra-high molecular weight polyethylene. Humeral and ulnar component linkage and the inherent amount of constraint that the prosthesis provides is of particular interest. A list of currently manufactured total elbow prostheses are listed in Table 1.

Total elbow prostheses can be grouped according to their basic design characteristics including constraint, linkability, and presence of a radio-capitellar articulation.

All manufactured implants have some amount of inherent constraint due to the intentional mated interaction between the ulnar and humeral components. As opposed to an older generation of simple hinge designs where this interaction was fixed, none of the currently marked implants are completely constrained. With high levels of constraint there was a high prevalence of aseptic loosening due to increased forces transmitted to the prosthesis-cement interface. Current designs are described as a semi-constrained “sloppy” hinge, allowing for five or more degrees of varus and valgus angulation. The amount of constraint is dependent on many design properties of the implant.[12]

Implants can be unlinked, linked or linkable. The native ulnohumeral articulation is an unlinked system, however replacing it with an unlinked prosthesis proved to have

Table 1. Currently marketed total elbow prosthesis and their distinguishing characteristics

Prosthesis	Manufacturer	Constraint	Linkage	Radio-capitellar Option
Coonrad-Morrey	ZimmerBiomet	Semi-constrained (Varying amounts)	Linked	No
Discovery	DJO			
Nexel	ZimmerBiomet			
Solar	Stryker			
Latitude	Wright-Tornier		Linkable	Yes

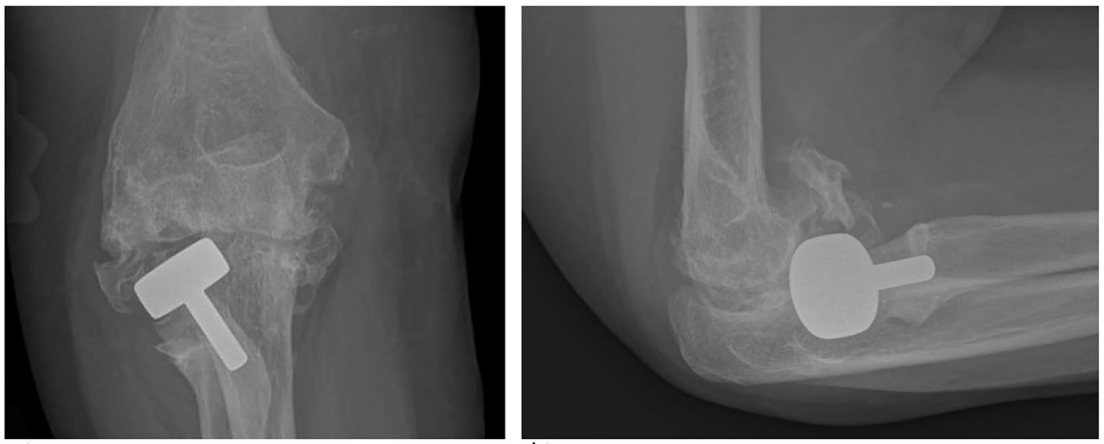

Fig. 1 a,b) Pre-operative anteroposterior and lateral radiographs of a patient with severe post-traumatic arthritis in which a total elbow arthroplasty was performed. Resection of a chronically malaligned radial head, in this case a prior arthroplasty, is preferred by the senior author over replacement.

challenges including precise placement of both components and reliance on soft tissue stabilisers to maintain the proper tracking. Of note, many formerly marketed unlinked implants are no longer sold. By contrast, linked implants replace the elbow with a humeral spool and mating wheel or toroid ulnar component. The main advantage of linked implants is the inherent stability provided in the absence of intact or reconstructable collateral ligaments. Lastly, one design of a total elbow prosthesis, the Latitude, features an additional component that can be used at the time of primary implantation or revision to convert an unlinked implant into a linked one and thus is a linkable type. This implant allows for the theoretical restoration of the anatomical unlinked kinematics of the native elbow in situations where placement of the components along the mechanical axes is confirmed and the ligaments are intact or have been restored with repair or reconstruction. This prosthesis is convertible and able to be used in linked-mode when the prior two conditions cannot be met. This decision to implant a linked or unlinked prosthesis can be determined at the time of the surgery.

Of note there is an association between linkage and constraint, however these two properties are not interchangeable. Although linked prostheses do provide constraint to component dislocation, there should be caution when equating these two features, as some unlinked designs allow for more overall constraint than linked designs.[12]

Most TEAs do not include the radio-capitellar articulation. Some historical designs as well as the Latitude provide the option to reconstruct this portion of the elbow joint mechanics. It is known that > 50% of the axial load of the native forearm is transmitted from the strut-acting radius through the capitellum in certain positions.[13] There is thus a theoretical advantage to having a radio-capitellar portion to an arthroplasty for load sharing, however, alignment of the components is often challenging, especially in the setting of post-traumatic arthritis where the radial head and neck was previously resected or deformed (Fig. 1).

TEA is indicted in older patients with low functional demands that are unable to perform activities of daily living due to pain and stiffness at the elbow. The first total elbow procedures reported were performed in rheumatoid patients.[14] However, the indications have been expanded over the years. A recent report of a United States national database inquiry between 2005 and 2012, showed elbow arthroplasty is most frequently used in Medicare patients with fractures of the distal humerus (AO Type C2-3) that are acutely irreparable (32%), primary osteoarthritis (21%), end-stage rheumatoid arthritis (Mayo III-V) that was either not responsive to disease-modifying anti-rheumatic treatment or undertreated (21%), distal

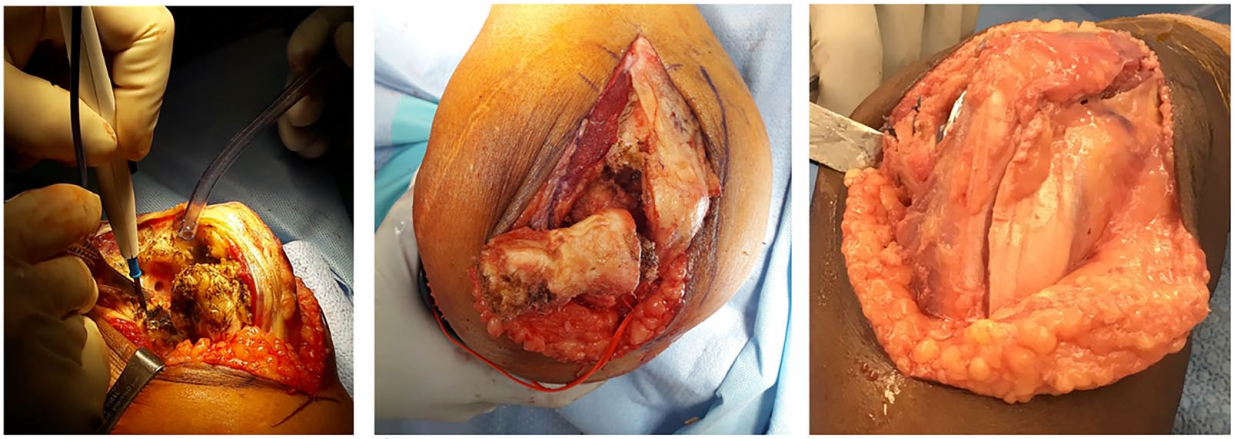

Fig. 2 Intra-operative clinical photographs showing a) medial and b) lateral views of the para-tricipital approach. c) The implants are placed and elbow is re-located following arthroplasty with the extensor mechanism preserved.

humeral nonunion (19%), and post-traumatic osteoarthritis (7%).[15] Other less frequent indications are reconstruction following primary or metastatic bone tumour resection[16] and ankylosis.[17]

TEA procedures that are performed for inflammatory arthritis have more satisfactory outcomes than those performed in the setting of trauma or post-traumatic arthritis. These results can be attributed to the lower demands of the lifestyle of the rheumatoid patient. Recommendations have been made to limit the use of TEA for acute fractures to patients > 65 years of age, and for those likely to be compliant with post-operative restrictions in an effort to improve the outcomes of this cohort. Lovy et al recently reported a multivariate analysis of risk factors for complications following TEAs using a national database.[18] Their study showed significantly lower risk of infection for the non-smoking patient as well as those undergoing shorter operation time.[18] Patients should counselled on smoking cessation prior to performing elective TEA. Although operation time is confounded by many variables including case difficulty, those surgeons performing relatively few (< 5 annually) TEAs have been reported to have worse outcomes, and all surgeons are encouraged to review techniques and instrumentation prior to performing the operation.

It should be noted that TEA is not the initial treatment indicated for primary osteoarthritis of the elbow. In many cases failed conservative management strategies can be successfully followed with arthroscopic elbow debridement procedures if the pain secondary to arthritis is the end-range impingement kind of pain.

Techniques

There are five different types of approaches used during TEA, each comes with its own unique advantages and disadvantages. All start with a single posterior skin incision. Most surgeons subcutaneously transpose the ulnar nerve as part of the procedure, although some do limited releases and restore the protected nerve to its native position. One or both sides of the collateral ligaments are taken down and dependent on the prosthesis may be repaired back. The main distinction is the handling of the extensor mechanism. In accessing the ulnohumeral joint the triceps must be either worked around, or released.

The para-tricipital, or Alonzo-Llames approach is the work around the triceps approach with medial and lateral windows for visualisation (Fig. 2). This approach is commonly associated with adequate distal humeral exposure, but with less proximal ulnar visualisation. The advantage to triceps-on techniques are lower risk of triceps rupture, or decreased post-operative extension strength of the elbow as a post-operative complication.[19] The trade-off has been less-than-ideal surgical exposure, the requirement to take larger portions of humeral bone to obtain implantation of the stem or significant devascularisation by reflecting soft-tissue attachments on either humeral or ulnar side to facilitate implantation. In the setting of acute fracture or nonunion when large portions of fracture fragments of the distal humerus are present, easier access may be obtained using a triceps-sparing approach through excision or mobilisation of the fragments around the intact collateral ligament.

In the lateral para-olecranon approach, the triceps tendon is incised down to the anconeus interval then split equally for proximal exposure. This is a hybrid of the previous and following approaches, allowing for increased visualisation due to more complete mobilisation while preserving the majority of the tendon insertion onto the olecranon.

Triceps-splitting is a trans-muscular approach that requires the surgeon to separate the medial and lateral

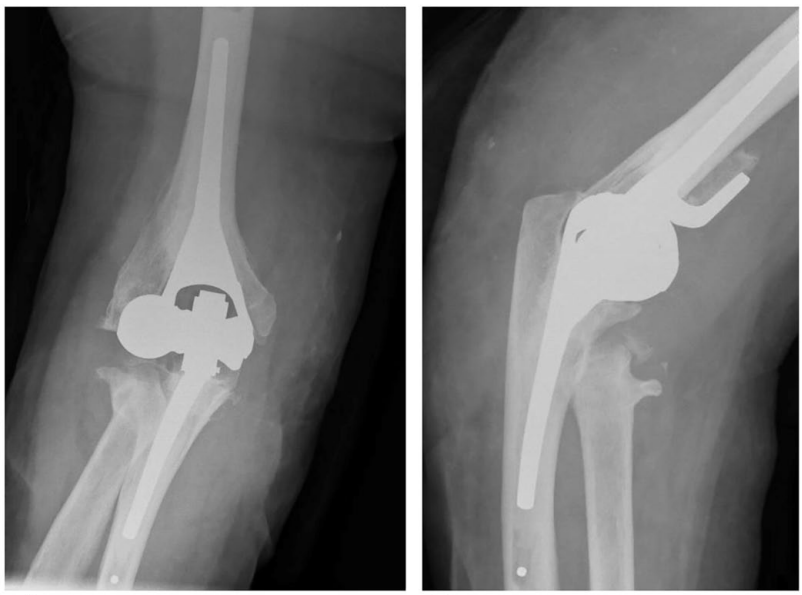

Fig. 3 a,b) Post-operative anteroposterior and lateral radiographs demonstrating a linkable prosthesis used in linked mode. In this particular patient, extensive scar tissue, and inability to reconstruct the radial head led to the senior author's decision to link the device.

halves of the tendon insertion onto the olecranon. The disadvantages related to this approach are those inherent to a trans-muscular approach with associated difficulty to balance the triceps repair, with a tendency for lateral subluxation. This approach was also found to have 24% decreased strength of the elbow replaced when compared with the contralateral in the same patient. This weakness was not observed in the lateral para-olecranon or triceps-on approaches.[20]

Very commonly used approaches to the elbow are the triceps-reflecting or triceps-tongue approaches. No difference in triceps tendon complication rate has been shown with these two approaches.[21]

The triceps-reflecting approach, as described by Bryan and Morrey,[22] provides exposure through the medial to lateral reflection of the triceps off the olecranon at its insertion. The triceps tendon is subsequently repaired with a figure-of-eight suture through a bone tunnel on the olecranon.

Alternatively, the triceps-tongue approach leaves the insertion of the triceps tendon intact and an incision is made through the tendon proximal to its insertion. Following implantation, the tendon is repaired.

Component implantation

Implantation of the components is device specific, but generally requires rasping or reaming the humeral and ulnar canals, device-specific cutting guides for distal humeral and proximal ulnar preparation, bone autografts or allografts used to augment the anterior humeral cortex-to-device flange interface, and cementing the components into the canal with the use of cement restrictors (Fig. 3).

Future aspects

Throughout the course of arthroplasty, better bearing surfaces have been developed. For the TEA, recent changes have been made in late generation devices to incorporate larger wheel and spool interfaces. In theory, the newer designs, will permit less polyethylene wear and osteolysis, and will allow for fewer restrictions on the patient. Long-term outcomes of these newer, larger bearing surface elbow arthroplasty devices are yet to be reported. It is possible that the data collected on this new generation of TEA implants will provide justification for use with more active patients.

Aseptic loosening is of continued concern in TEA, especially in the younger, more active patient. Other arthroplasties that started as primarily cemented have progressed towards press-fitted components to attempt to avoid this complication. It is conceivable that TEA will have a non-cemented option in the future.

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