(ii) Total elbow arthroplasty

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Summary
Elbow arthroplasty has an important role in the treatment of many conditions affecting the elbow, including inflammatory arthritis, osteoarthritis, fracture and instability. The types of implant differ in the degree of constraint they provide. Some are linked and highly constrained implants, whereas others have a "sloppy hinge" which allows some varus/valgus play. Yet others are completely unlinked and provide the least constraint, relying on ligament and muscle balance for stability. A variety of implants have achieved good results in terms of pain relief and range of movement, which usually leads to significant functional benefit to the patient. However, this surgery is not without risk and the main complications include loosening, infection, instability, dislocation and nerve dysfunction. As with other forms of arthroplasty, but particularly the elbow, it is important to scrutinise the indication for surgery when considering the results of elbow arthroplasty; the majority of procedures are performed for inflammatory arthritis. The precise difference in outcome between unlinked, linked and sloppy articulations appears to be small and the exact role for each implant type is yet to be precisely defined.

Indications for elbow arthroplasty
Elbow arthroplasty is performed with the intention of providing pain relief, improving range of movement or treating painful instability. These symptoms are most commonly due to inflammatory arthritis of the elbow, but other indications include osteoarthritis, post-traumatic arthritis and distal humeral fractures (Table 1). The only absolute contraindication is active sepsis, either local to the joint or distal to it. There are several situations in which particular consideration must be exercised prior to performing elbow arthroplasty (Table 2).

Elbow biomechanics
The elbow is a complex synovial joint consisting of three points of articulation, which include (1) the humero-ulnar joint — involving the olecranon and the trochlea,
approximately 5 degrees.
by approximately 25 degrees and internally rotated by ap-
that the humeral articular surface is anteriorly angulated
approximately 6 degrees of varus in full flexion and (2) the fact

The normal range of motion is 0–145 degrees of flexion, 75
degrees of pronation and 85 degrees of supination. Hyper-
extension is common, although greater than 10 degrees is
usually regarded as abnormal and may be associated with
hyperlaxity. The elbow is clearly not a simple hinge joint
and besides rotation of the radial head on the capitellum
it also allows more subtle movements, which are not obvi-
ous to the naked eye. During both flexion/extension and
during rotation, valgus/varus movement will occur through
an arc of approximately 9 degrees. In addition, internal ro-
tation of the humero-ulnar joint has been identified during
flexion/extension. Other idiosyncrasies include (1) the car-
ying angle, which results from a 6 degree valgus inclination
of the humeral articular surface and creates approximately
10–14 degrees of valgus in full extension and approxi-
ately 6 degrees of varus in full flexion and (2) the fact
that the humeral articular surface is anteriorly angulated
by approximately 25 degrees and internally rotated by ap-
proximately 5 degrees.

**Types of elbow arthroplasty**

The first arthroplasty was performed in 1927 by Robineau
and consisted of a distal humeral hemiarthroplasty. Prior to
this, excisional arthroplasty was performed. The early total
elbow replacements were single axis hinges. Today elbow
replacements are predominantly of three designs; (1) linked protheses, (2) unlinked, and (3) those which can be
converted from unlinked to linked. The radial head is
usually excised and most implants do not replace it.

A trade off exists between stability of the elbow and
loosening of the humeral components. This occurs due to
force transmission from the joint to the cement mantle. A
recognised mechanism of failure is for the distal part of
the humeral component to gradually tilt posteriorly, causing
the superior tip of the prosthesis to migrate anteriorly and
sometimes penetrate the anterior humeral cortex.

Unlinked replacements involve resurfacing of the ulna
and the distal humerus. There are stems on the components
to reduce the risk of loosening. Stability is largely provided
by the soft tissues, although the congruency of the compo-
nents can provide some intrinsic stability. Examples of
this type of replacement are the Kudo, iBP and Souter-
Strathclyde arthroplasties. The theoretical benefit of the
unlinked prosthesis is that by allowing more movement
between the implant surfaces the stresses on the cement
mantle will be reduced. The disadvantages are the higher
risk of instability and the patient must have intact ligaments
around the elbow to provide stability. There is also the risk
of point loading occurring, leading to premature wear.

Linked implants often involve a sloppy hinge, which
allows some play in a varus-valgus direction in addition to
flexion and extension. The theoretical advantage lies in the
increased stability. This reduces the risk of dislocation and
allows compensation for deficient stabilising structures in
the native elbow. However, there may be more stress transfered from the joint to the cement mantle, which
may then encourage loosening. Examples of this type of
arthroplasty are the Coonrad-Morrey (Zimmer), GSBII
(Zimmer) and the Discovery (Biomet).

Convertible implants are a recent introduction to the
market. They can be used as unlinked or linked protheses
and examples include the Latitude (Tornier) and Acclaim
(DePuy) arthroplasties (Figs. 1–3).

**Surgical technique**

The majority of elbow arthroplasties are performed through
a posterior approach, with either a triceps-sparing or a tri-
ceps-splitting approach to the humerus. In a triceps sparing
approach the triceps is elevated off the humerus, which
reduces post-operative extension weakness, but may com-
promise visualization at the time of surgery. A triceps splitting
approach provides good visualization, but the triceps apo-
neurosis is divided distally and then elevated proximally to
the humeral epicondyles, which may lead to extension
weakness. The other area of disagreement between surgeons
is in the need to perform ulnar nerve transposition.

The senior author’s preferred technique is described
here — this was originally described by Mr Joe Pooley, who
has recently published an article containing a description of
his technique.¹

The patient is positioned in a lateral position with the
upper arm supported in a small gutter e.g. Carter Brain,
with the elbow flexed and the arm hanging free.

A midline incision is performed over the distal 10 cm of
the humerus which is then curved to the radial side of the
olecranon and then carried on down the proximal ulna.
Full thickness fascio-cutaneous flaps are raised medially
and laterally. The ulnar nerve should be regularly palpated
to confirm its position and when visualised, identified with
rubber loops passed around it. The triangle of anconeus is
defined laterally.

A transverse incision is made in the triceps aponeurosis,
approximately 10 cm from the olecranon and continued to
the raphe medially. The incision is then continued distally

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**Table 1**

<table>
<thead>
<tr>
<th>Indications for total elbow replacement</th>
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</thead>
<tbody>
<tr>
<td>Inflammatory arthritis</td>
</tr>
<tr>
<td>Post-traumatic osteoarthritis</td>
</tr>
<tr>
<td>Primary osteoarthritis</td>
</tr>
<tr>
<td>Distal humeral fractures — acute and non-union</td>
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<tr>
<td>Chronic elbow instability</td>
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<tr>
<td>Musculoskeletal tumours — primary or metastasis</td>
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**Table 2**

<table>
<thead>
<tr>
<th>Contraindications to total elbow replacement</th>
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</thead>
<tbody>
<tr>
<td>Absolute</td>
</tr>
<tr>
<td>Sepsis — locally or distally</td>
</tr>
<tr>
<td>Relative</td>
</tr>
<tr>
<td>Arthrodesis</td>
</tr>
<tr>
<td>Neuropathic joint</td>
</tr>
<tr>
<td>Paralysis of biceps/triceps</td>
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<tr>
<td>Osteoarthritis in young heavy manual workers</td>
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</table>

splitting the raphe to the olecranon and on to the radial neck at the ECU/anconeus border. An incision is then made in the lateral aspect of the triceps fascia and continued distally to the olecranon. The Triceps is then raised off the bone working distally. The ulnar nerve is elevated with its bed and the blood supply therefore maintained. The residual flap of triceps aponeurosis is then carefully secured to the olecranon.

The radial head is generally excised, protecting the radial nerve in the process. The humeral component is then sized and the humeral cuts performed which will vary depending upon the implant. Some humeral shaping is inevitably performed, freehand with high speed burrs. Appropriate ulnar preparation is then performed. Once satisfactory trial reduction has been performed the definitive implants are seated.

A careful, well tensioned and secure repair of triceps is essential, as ineffectual repair will impact on function and may lead to dislocation. The rest of the repair should be meticulous to reduce the risk of haematoma or wound problems — clearly important in a subcutaneous joint. The arm is rested in a plaster of Paris backslab post-operatively to allow wound healing, then rehabilitation is commenced (Figs. 4–6).

Outcome assessment

When reviewing the literature the endpoints used differ between studies, as do the definitions of complications e.g.

**Figure 1** A Coonrad Morrey prosthesis, on the right is the ulna component next to it the larger humeral component. The bushings are inserted when the elbow is in its reduced position making this a linked prosthesis.

**Figures 2 and 3** Anteroposterior and lateral radiographs of an iBP total elbow arthroplasty. The humeral and ulnar components are not linked with a bushing which allows for greater freedom between the two components.
the assessment of loosening. Radiological loosening is more common than gross clinical loosening requiring revision and studies vary in which they use as the endpoint. Trail et al have devised a system for describing the areas of loosening around a total elbow prosthesis. Further confusion relates to the fact that there is no single outcome score or outcome measure used in the literature. Many papers use scoring systems devised by the authors themselves. One of the most commonly used scoring systems is the Mayo elbow performance score (Table 3).

Results

A systematic review of the literature regarding total elbow arthroplasty demonstrated the problems associated with this area of research. Most of the published work consists of case series and the publishing group have often been involved in the development of the prosthesis. Furthermore outcome is often assessed using different endpoints (Figs. 7–10).

Pain relief is obtained in the vast majority of patients and persists long term. There has been one paper which suggested that the incidence of pain at rest may increase with time but this did not reach statistical significance. The range of movement improves after arthroplasty. Little, Graham and Carr found that patients treated for post-traumatic arthritis appear to obtain a greater range of movement than those treated for rheumatoid arthritis (median improvement 49 degrees compared to 28 degrees). The same study found that linked prosthesis (fixed hinge and sloppy hinge) obtained a better range of movement than unlinked prostheses (medians-fixed 33 degrees, sloppy 34 degrees and unlinked 23 degrees).

Most of the literature examines the outcome in patients suffering from rheumatoid arthritis in whom ulnar loosening can be a problem. The rate of ulnar loosening appears to be higher with uncemented components compared to cemented components. It has been suggested that linked components should be used in rheumatoid arthritis due to the associated bone loss and ligament laxity. Good results however have been obtained with the Kudo prosthesis (unlinked) even in the presence of gross deformity. The Souter-Strathclyde, Kudo and Coonrad-Morrey implants have been compared in patients suffering rheumatoid arthritis. There were better results with the Coonrad Morrey prosthesis in terms of survival (90%) and radiographic signs of loosening at 5 years (86%) There was, however, a significant rate of focal osteolysis of the ulnar component with this implant, the long term effect of which is uncertain. The age at the time of surgery (42 years vs 64 years) appears to have no influence on outcome when arthroplasty is performed for inflammatory polyarthritis.

There are fewer studies of elbow arthroplasty in the treatment of osteoarthritis compared to the treatment of...
rheumatoid arthritis. Some of the studies contain patients suffering from post-traumatic osteoarthritis, whereas others concern patients being treated for primary osteoarthritis of the elbow.

The largest study of the outcome of elbow arthroplasty for post-traumatic osteoarthritis was published by Schneeberger et al.11 Forty one patients were reviewed at an

Table 3  
Mayo elbow performance score (max 100 points)3

<table>
<thead>
<tr>
<th>Category</th>
<th>Max Points</th>
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<tbody>
<tr>
<td>Pain (max., 45 points)</td>
<td></td>
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<tr>
<td>None (45 points)</td>
<td></td>
</tr>
<tr>
<td>Mild (30 points)</td>
<td></td>
</tr>
<tr>
<td>Moderate (15 points)</td>
<td></td>
</tr>
<tr>
<td>Severe (0 points)</td>
<td></td>
</tr>
<tr>
<td>Range of motion (max., 20 points)</td>
<td></td>
</tr>
<tr>
<td>Arc &gt; 100 degrees (20 points)</td>
<td></td>
</tr>
<tr>
<td>Arc 50 to 100 degrees (15 points)</td>
<td></td>
</tr>
<tr>
<td>Arc &lt; 50 degrees (5 points)</td>
<td></td>
</tr>
<tr>
<td>Stability (max., 10 points)</td>
<td></td>
</tr>
<tr>
<td>Stable (10 points)</td>
<td></td>
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<tr>
<td>Moderately unstable (5 points)</td>
<td></td>
</tr>
<tr>
<td>Grossly unstable (0 points)</td>
<td></td>
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<tr>
<td>Function (max., 25 points)</td>
<td></td>
</tr>
<tr>
<td>Able to comb hair (5 points)</td>
<td></td>
</tr>
<tr>
<td>Able to feed oneself (5 points)</td>
<td></td>
</tr>
<tr>
<td>Able to perform personal hygiene tasks (5 points)</td>
<td></td>
</tr>
<tr>
<td>Able to on shirt (5 points)</td>
<td></td>
</tr>
<tr>
<td>Able to put on shoes (5 points)</td>
<td></td>
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</tbody>
</table>

Figures 7 and 8  Pre-operative radiographs of a patient who suffers from rheumatoid arthritis. There is marked loss of joint space and there is osteopenia secondary to steroid treatment.
average of 5 years. Satisfactory outcomes were obtained but there was a major complication in 27% (11/41) of patients and 22% (9/41) had to undergo further surgery. Six patients had to have further surgery due to mechanical failure of the prosthesis, this involved fracture of the ulnar component in 4 patients. The 5 year follow up data are satisfactory but, given the higher demand placed upon the prosthesis by this patient group, long term follow up data are required.

The largest study concerning the treatment of primary osteoarthritis involved 11 elbow arthroplasties in 10 patients examined at a mean of 68 months after surgery. All patients were pain free at rest but 3 had activity related pain. The mean flexion/extension arc improved from 69 to 107 degrees. Only 1 patient required revision for loosening but 5 components were radiologically loose, although these were clinically asymptomatic. The meta-analysis by Carr identified 120 patients in all articles where the indication for surgery was osteoarthritis. The median revision rate was 13% (higher than 10% in rheumatoid arthritis) with lower loosening rates but higher radiological lucency rates compared to inflammatory arthritis. Excellent improvements in range of movement can be obtained in the context of osteoarthritis. The outcomes for elbow arthroplasty performed for osteoarthritis can be acceptable but the complication rate is higher than when it is performed for inflammatory arthritis.

There appears to be little difference between linked and unlinked implants. There is very little literature available on the newer convertible implants. One series of 36 patients reviewed at a mean of 36 months post surgery demonstrated acceptable results. However there had been 11 cases of intra-operative distal humeral fracture and the cutting jigs have since been altered to reduce this. Longer term results are awaited (Figs. 11–15).

Complications

Loosening

The definition of loosening varies in the literature which affects the interpretation of results. Little et al. defined loosening as component migration, radiolucency of 2 mm or any radiolucency with symptoms of loosening. The overall loosening rate was 9% at approximately 5 years. They found linked implants to have a lower rate (5%) compared to unlinked sloppy-hinge implants (10%) and fixed hinge implants (11%). Patients treated for rheumatoid arthritis had higher rates of loosening than other indications. When loosening is defined as any radiolucency greater than 1 mm the results are different. The overall loosening rate is the 14%; 15% for linked sloppy hinge implants, 10% for unlinked implants and 23% for fixed hinges. The rate of loosening is then found to be higher in patients treated for post-traumatic arthritis than other causes.

Infection

The deep infection rate in total elbow arthroplasty has been shown to be approximately 5% although in more recent studies there is a trend towards a rate of 4%. Post-operative
Total elbow arthroplasty may be a treatment for distal humeral fractures or in this case failed fracture fixation. The CT scan reveals a comminuted distal humeral fracture. Fixation was undertaken which failed and the fracture went on to non-union. A total elbow arthroplasty was performed as a salvage procedure with good results.
wound problems are seen in 7–9% of patients. The risk of wound problems is greater if the arm is not immobilised post-operatively. The use of immobilisation for greater than nine days is associated with a wound problem rate of 6% compared to 9.8% with only 2 days immobilisation.

**Instability**

Instability includes gross dislocation of the implants or radiographic signs of subluxation or disassembly/breakage of a component. The rate is higher in unlinked prostheses (6%) compared to linked implants (1%).

**Ulnar nerve problems**

Permanent sensory or motor lesions of the ulnar nerve were found in 120/2416 patients (5%). Transient ulnar nerve lesions are not recorded in many series. In the papers which have commented on transient ulnar nerve dysfunction it has occurred with a median incidence of 2% (0–27%). These cases have not always been confirmed by nerve conduction studies. Only 15% of papers document the pre-operative state of the ulnar nerve. Many of the patients involved suffer from RA and therefore are at a higher risk of ulnar nerve dysfunction e.g. mononeuritis multiplex. There is insufficient evidence to support routine transposition of the ulnar nerve- but it is a valuable decision should revision surgery be required!

**Triceps insufficiency**

Triceps complications are not mentioned in many papers. A large single series had a re-operation rate for triceps insufficiency of 2%. Little found a rate of 3% in their meta-analysis. The rate of triceps insufficiency appears to relate to the approach used. The rate is lowest when a triceps turndown is used and may be up to 11% when the triceps is completely removed from the ulna.

**Other**

Pulmonary embolism is extremely uncommon after total elbow arthroplasty with a reported incidence of clinical pulmonary embolism of 3 in 1076 (0.0028%) primary and revision elbow arthroplasties. Ninety day mortality was 0.62% in a series of 1441 patients who had undergone primary or revision elbow arthroplasty.

**Revision elbow arthroplasty**

Revision elbow arthroplasty is most commonly performed for periprosthetic infection or aseptic loosening and although there is little published literature on revision elbow arthroplasty the Mayo clinic has published their own experience in which they used several different prostheses. Humeral loosening was the most common indication for surgery, and occasionally ulnar loosening, which was either in isolation or in conjunction with humeral loosening. The most common operative complication was breech of the bone cortex during cement removal, which occurred in 8/33 (24%) of patients. The incidence was almost equal in the humerus and the ulna. At a minimum of 3 years following revision 18/33 (55%) of patients were regarded as having a good result and 15/33 (45%) a poor result. Poor results were due to further loosening, pain, poor range of movement and infection (3 cases, all resulted in resection arthroplasty). More than 1 revision procedure was performed on 15 of the 33 patients. Only 13 (40%) of patients had no complications related to their revision procedure.

Later King et al published further results of revision surgery from the Mayo clinic using the Coonrad Morrey prosthesis. Forty one patients were reviewed at an average of 6 years and aseptic loosening was by far the most common indication for revision. There were no cases of periprosthetic infection in this series. Fourteen patients sustained a cortical perforation or fracture at the time of revision and 3 of these caused injury to the radial nerve. There were no cases of post operative infection. Twenty two patients had complete relief of pain and 16 had mild discomfort. The Mayo elbow performance score had improved following revision.

Good results in revision surgery have also been achieved using the Souter Strathclyde prosthesis but with a high complication rate. Fifty patients were reviewed at a mean of 53 months after revision. The majority of revisions were for aseptic loosening, with only 2 cases of periprosthetic infection in this series. Pain relief and an acceptable range of movement were obtained but 30% of patients had some form of complication and 8 required further major surgical intervention. Infection recurred in 2 cases and there were 2 new cases of periprosthetic infection.

Few publications address the topic of revision arthroplasty for infection. In a series of 305 primary arthroplasties from a single centre, 6 (1.9%) had to have revision surgery...
The senior author's preferred management of infected prostheses is a two stage revision. Figures 16 and 17 show antibiotic loaded cement spacers in situ to elute antibiotics and hold the soft tissues to length whilst the infection is bought under control. Figures 18 and 19 are the post-operative radiographs following the second stage of the revision procedure.
due to periprosthetic infection. Each of these had rheumatoid arthritis and the infecting organism was staphylococcus aureus. Single stage revision was performed in each case. The sepsis was controlled in five patients but recurred in one leading to resection arthroplasty (Figs. 16–19).

Severe bone loss can be a problem in revision surgery and a series of 21 patients with massive proximal ulnar bone loss were treated with an allograft strut and a Coonrad-Morrey prosthesis. Improvements were noted in both pain and function at a mean of 4 years and most of the cases had good levels of graft incorporation. Impaction bone grafting with or without the addition of strut allograft augmentation has also been used to restore bone stock during revision surgery complicated by massive bone loss.

At an average follow up of 5 years, of 12 elbows treated with impaction bone grafting and revision arthroplasty 8 were still functioning satisfactorily. However 6 patients had required further surgery.

In summary, revision elbow arthroplasty can yield acceptable results, but there is a high complication rate even when these procedures are performed in tertiary referral centres.

Conclusion

Total elbow arthroplasty can provide good levels of pain relief, an acceptable range of movement and a stable elbow. Component loosening is the most common cause of failure and in this scenario there is no clear evidence to favour either linked or unlinked implants as the definition of loosening seems to vary amongst series.

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References