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MINI-SYMPOSIUM: THE ELBOW

(ii) Radial head replacement

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Summary Radial head replacement is controversial as radial head excision is usually effective for isolated comminuted fractures and arthritis. The main role is to aid stability in acute fracture-dislocations and permit early mobilization when the radial head, a secondary stabilizer, cannot be rigidly fixed. Metal radial head replacements are superior to silicone prostheses as they do not deform under load, break or induce inflammatory reactions. There is however little evidence to support the use of a prosthesis for an acute radial head fracture when the medial collateral ligament of the elbow, the primary stabilizer, is intact. There are few successful reports of its use for chronic valgus instability, neglected posterior elbow subluxation and proximal radial migration.

INTRODUCTION

Radial head replacement is controversial, as simple excision provides an effective solution for the majority of clinical problems at the radio-capitellar and superior radio-ulnar joints. Resection is usually performed acutely for comminuted fractures to prevent stiffness due to impingement caused by displaced fragments. It is also carried out to abolish the pain, crepitus and restricted movement caused by a deformed or subluxed radial head due to previous trauma, rheumatoid or occasionally degenerative arthritis.

A number of studies have demonstrated good long-term results after radial head excision for fractures.[1–3] However, valgus elbow instability, restriction of elbow movement and forearm rotation, proximal radial migration and degenerative changes in the elbow and wrist may occur giving rise to chronic pain and loss of strength and function. Radial head replacement has therefore been used to try to prevent and treat these complications.

Radial head excision and synovectomy often relieves pain in the rheumatoid elbow, at least in the short term, with the majority of operations carried out in significantly eroded joints. Poor clinical results may be due to recurrence of synovitis and further erosion, but increased stress applied to the medial soft tissues due to valgus instability may be a significant contributing factor. In theory, radial head replacement could address this mechanical problem. However, erosion of the capitellar articular surface, as well as the humero-ulnar joint resulting in malalignment of the radius on the capitellum, makes radial head replacement in rheumatoid arthritis impractical.

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ANATOMY

The radial head consists of a concave articular dish with a radius of curvature greater than that of the capitellum to allow congruent tracking and normal translation during elbow and forearm motion. The radial head is slightly oval rather than round but does not have a consistently elliptical shape. The head and neck are offset to a variable degree, with a neck-shaft angle of approximately 15°.[4] These features make it unlikely that an exact replica of the anatomical structure and precise positioning can be achieved by a prosthesis, accurately reproducing normal load transmission.

The strongest part of the medial collateral ligament is the easily identified anterior band, which is the primary constraint of the elbow joint to valgus stress. It inserts at the base of coronoid process and a displaced fracture at this site will defunction the ligament.

BIOMECHANICS

Elbow

On gripping an object with the hand, the forearm muscles, which cross the elbow joint, contract to stabilize the wrist and apply a posteriorly directed force on the elbow. Compressive forces are then transmitted roughly equally to the trochlea and capitellum of the humerus via the coronoid process and radial head, respectively. These forces are magnified up to three times body-weight due to the lever arm of the forearm. In this situation, relatively little force is exerted on the medial ligament (Fig. 1A).

However, on lifting an object between both hands, contraction of pectoralis major internally rotates the humerus exerting force through the palms and fingers. The resulting external rotation force on the forearm produces compression at the radio-capitellar joint and tension in the medial ligament (Fig. 2).

Laboratory experiments on cadavers have demonstrated that the anterior band of the medial collateral ligament is the primary stabilizer of the humeroulnar joint in resisting valgus stress. Radial head excision has little effect on the valgus stability of the elbow if the medial ligament is intact (Fig. 1B). If only the ligament is divided valgus laxity occurs and the radial head then provides significant resistance to valgus displacement throughout the arc of motion — i.e. *the radial head is a secondary stabilizer.* Rupture of the ligament and loss of stability of the radial head produces gross valgus instability (Fig. 3), and subluxation/dislocation if sufficient force is applied.[5] In clinical practice, it is essential to recognize the potential pitfalls when managing this combination of injuries (Figs. 4–9).

Forearm

Cadaveric experiments have shown that the central band of the interosseous membrane is important in preventing proximal migration of the radius after radial head excision.[6]

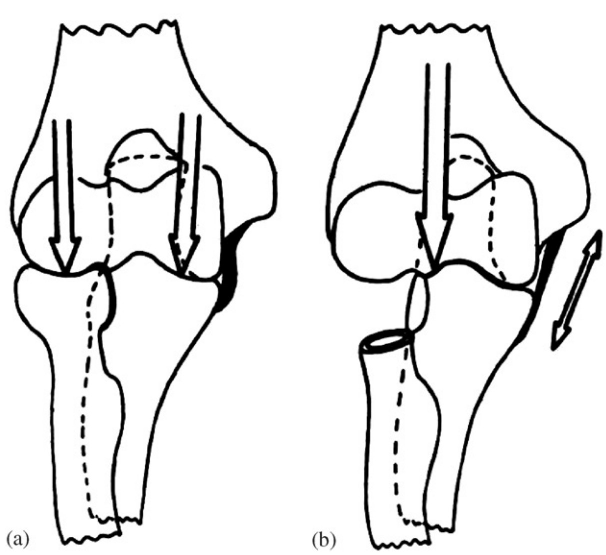


Figure 1 (A) Compression forces transmitted equally to distal humerus on grasping an object due to contraction of the forearm muscles. (B) The tendency of the forearm to go into valgus after radial head excision is prevented by an intact medial collateral ligament with compression at the lateral lip of the trochlea.

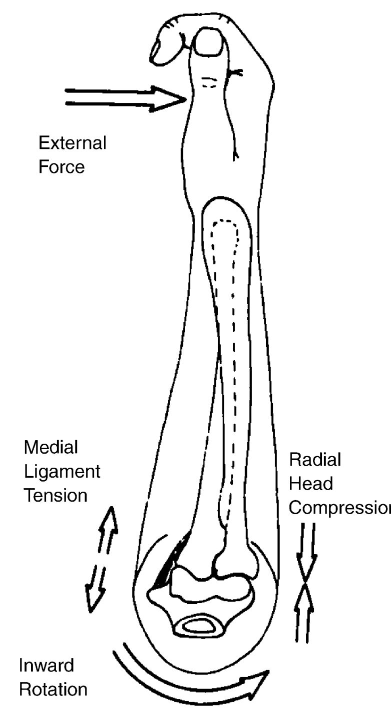


Figure 2 When an object is lifted between both hands, internal rotation of the humerus due to pectoralis major results in tension in the medial collateral ligament and compression of the radio-capitellar joint.

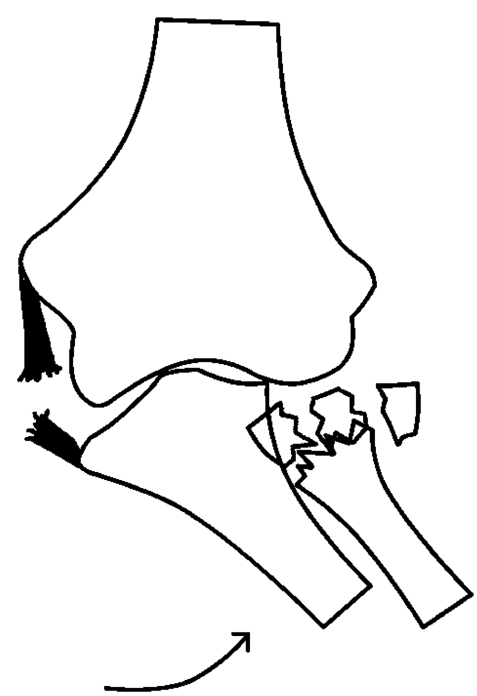


Figure 3 A fracture of the radial head associated with a medial ligament tear results in major valgus instability.

It is likely that a spectrum of injury exists from an isolated radial head fracture with an intact interosseous membrane to an 'Essex-Lopresti' injury, with distal

Figure 4 A fracture of the medial column of the distal humerus with gross displacement of the trochlear fragment, and the radial neck with displacement of the radial head and of the tip of the coronoid process.

Figure 5 Same as Fig. 4.

radio-ulnar joint and central band disruption. In the majority of patients the extent of proximal migration after radial head excision is only a few millimeters (Fig. 10) with satisfactory long-term clinical results, although strength may be decreased. Occasionally, however, radial head excision can produce very significant proximal translation resulting in pain and stiffness due to ulno-carpal impingement.

PATTERNS OF INJURY

Mason classified fractures of the radial head into three types (Fig. 11).

Type 1: Fissure or marginal fractures without displacement.
Type 2: Marginal sector fractures with displacement.
Type 3: Comminuted fractures involving the whole head of radius.

A displaced fracture of more than a third of the radial head circumference results in loss of 'capture' of the capi-

Figure 6 Post-operative radiographs after open reduction and internal fixation of the distal humerus through an olecranon osteotomy.

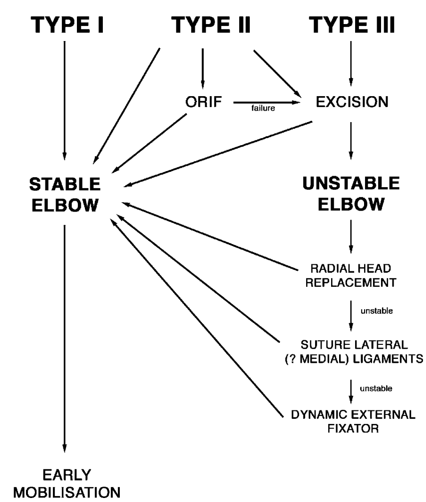
Figure 7 Same as Fig. 6.

Figure 8 Posterior dislocation 1 month post-operatively as the medial collateral ligament, the primary stabilizer, had ruptured and the radial head, the secondary stabilizer, had not been fixed or replaced.

tellum by the dish of the radial head and therefore stability is decreased. Elbow dislocation associated with a radial head or neck fracture (Fig. 12) is often referred to as Mason Type 4, and the results reported as a separate group. However, the severity of the radial head fractures associated with instability ranges from Mason Type I to 3 and therefore the management and prognosis will vary significantly.

Management of radial head fractures

Hotchkiss modified Mason's classification system for fractures of the radial head to reflect the options available for treatment (see algorithm).



Algorithm: Management of radial head fractures using Mason's classification. Coronoid/proximal ulnar fractures should be rigidly fixed if possible. The elbow is considered to be unstable if it subluxes at $>40^\circ$ of extension under anaesthetic.

Figure 9 Same as Fig. 8.

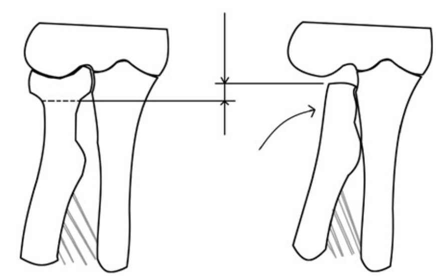


Figure 10 Proximal migration of a few millimetres and ulnar deviation following radial head excision associated with an intact interosseous membrane.

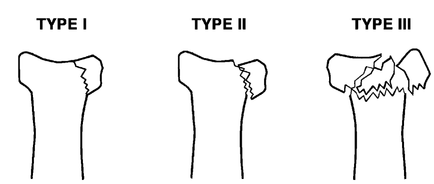


Figure 11 Mason's classification for radial head fractures.

Type I includes undisplaced or minimally displaced (less than 2 mm) marginal lip fractures with no mechanical block to motion. These are treated with early movement.

Type 2 includes larger displaced fractures with or without a mechanical block, which are amenable to rigid internal fixation.

Type 3 are displaced, comminuted radial head or neck fractures which cannot be reconstructed and are therefore excised and replaced if the elbow is unstable.

Simple elbow dislocations

The elbow joint is one of the most stable in the body. A number of studies demonstrated that complete rupture of the medial and lateral collateral ligaments was present in nearly every simple dislocation that had been explored.[7] Despite this, early active mobilization after closed reduction gives optimal results and redislocation and instability are uncommon. The elbow is initially held in a reduced position by biceps, brachialis and triceps exerting proximally directed forces, and the coronoid process and radial head then act together to resist posterior subluxation.

Elbow fracture dislocations

An elbow dislocation associated with a fracture of the radial head will tend to be less stable after reduction than a simple dislocation. Prolonged immobilization tends to produce poorer results and redislocation may still occur in plaster if the soft-tissue injury has been severe.[8,9] Open reduction and rigid fixation of a displaced radial head fracture should improve stability and allow

Figure 12 Fracture of radial neck/displaced radial head associated with a posterior elbow dislocation (Mason Type 4).

Figure 13 Fracture of coronoid process and radial head associated with a posterior dislocation—the 'terrible triad' of Hotchkiss.

early active movement. In practice, this can be difficult or impossible to achieve, with comminution and osteoporotic bone contributing to failure of fixation. The skill and experience of the surgeon is likely to be a significant factor affecting the outcome.

Partial excision of displaced, unfixable fragments of the radial head can be carried out with the remaining intact part retained for stability. However, the elbow will still tend to be unstable and a raw cancellous surface will remain with the probable formation of dense adhesions leading to restriction of forearm rotation. Excision of the intact part of the head will only worsen the instability, but radial head replacement in this situation often restores stability and allows early active motion. Scar tissue cannot adhere to the smooth surface of the radial head implant and restrict movement.

Combined radial head and coronoid fractures

The elbow will be grossly unstable and sublux posteriorly if major fractures of the coronoid and radial head are present — Hotchkiss has named this combination the 'terrible triad' (Fig. 13). Ring et al.[10] recently reported on 11 patients with this pattern of injury, all of whom had Type 2 Regan–Morrey coronoid fractures (Fig. 14). Seven elbows redislocated in a splint after manipulative reduction. Five, including all four treated with resection of the radial head, redislocated after operative treatment. Fractures of the radial head and coronoid process may be associated with fractures of the olecranon/proximal ulna (Figs 15 and 16) and are especially prone to subluxation, instability and post-traumatic arthritis.

The coronoid process fracture should be rigidly fixed if possible to restore stability and prevent posterior subluxation. If the coronoid fracture is large, i.e. Regan and Morrey Type 3 (Figs 15 and 16), the function of the anterior band of the medial ligament will also be restored with fixation as it inserts near the base of the coronoid process. However, fixation of this fragment with one or

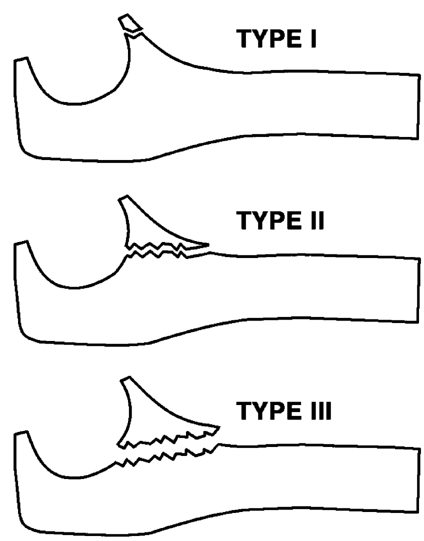


Figure 14 Regan–Morrey classification of fractures of coronoid process.

two lag screws is often sub-optimal due to its size, comminution and bone quality. If the radial head has been excised the large forces exerted on the coronoid process may lead to loosening of the screws and recurrence of the posterior subluxation until the radial neck impinges on the capitellum. A radial head replacement should protect the often tenuous fixation of the coronoid and avoid this situation (Figs 17 and 18) which, especially in a younger patient, is very difficult to salvage.

However, the elbow may still be unstable despite coronoid/proximal ulnar fixation, radial head reconstruction or replacement and suture of the lateral soft tissues. Medial ligament repair may then be considered but can be technically difficult and the repair weak. Application of a dynamic external fixator will then provide stability and allow active movement as the bony and soft tissue injuries heal.

Figure 15 Grossly unstable elbow due to fracture of radial head and proximal ulna with a large coronoid fragment.

Figure 16 Same as Fig. 15.

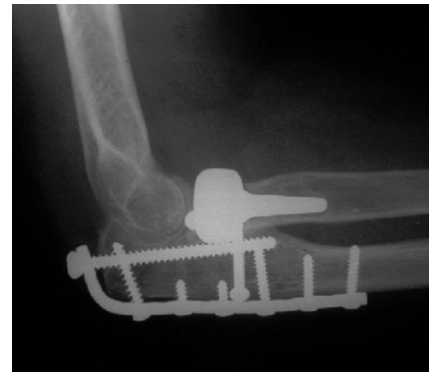


Figure 17 Radiographs at 1 year after radial head replacement and internal fixation of the coronoid process and proximal ulna with a very satisfactory clinical result.

Figure 18 Same as Fig. 17.

CLINICAL RESULTS

Acute unreconstructable radial head fractures associated with elbow instability

Evidence for currently available metal radial head replacements is shown in Table 1.

Judet et al. (1996) inserted a bipolar design (Fig. 21) in five patients with Mason 3 fractures shortly after the injury '*in most there was symptomatic or clinical evidence of medial ligament injury*'.

No cases of instability, valgus deformity or prosthetic failure were identified in any of the above series.

Acute isolated radial head fractures—Mason Type 3

Although two studies[12,15] have reported satisfactory outcomes with a metal replacement, similar results have been obtained with radial head excision in stable joints.[1–3]

Acute Essex–Lopresti injuries

Moro *et al*.[15] reported on three such injuries with one good, one fair and one poor result. The severity of the radio-ulnar dissociation was not mentioned.

CHRONIC POST-TRAUMATIC PROBLEMS

Judet et al.[16] reported on seven patients in whom a bipolar prosthesis had been inserted between 2 and 156

Figure 19 Leeds–Glasgow vitallium radial head prosthesis.

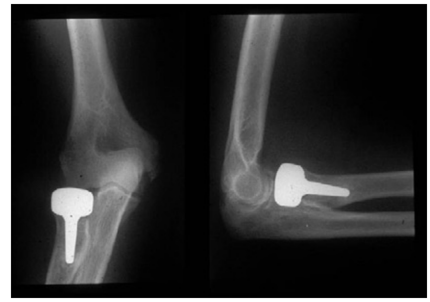


Figure 20 Radiographs of Leeds–Glasgow prosthesis.

Table 1

	Mason Type 4 i.e. associated elbow dislocation	Olecranon/proximal ulna/significant coronoid #	Medial collateral ligament tear	Prosthesis
Harrington and Tountas[11]	4	8	5	Titanium (+ 2 silastic)
Knight et al.[12]	13	8	0	Vitallium (Figs. 19 and 20)
Popovic et al.[13]	8	3	0	Bipolar–judet Co–Cr stem and cap over HDP head
Harrington et al.[14]	14	4	2	Titanium
Moro et al.[15]	15	1	1	Titanium

months after injury. Two had distal radio-ulnar problems with proximal radial migration, one of whom also had elbow instability—both had good results. Another with elbow instability had an excellent result. The extent of the instability and correction in the cases was not described.

The primary complaint in four was reduced flexion/extension and four had loss of pronation/supination. Although the results were reported as good to fair, clearly the improved range of movement was directly due to the soft-tissue release that had been performed. The question remains as to whether insertion of a radial head replacement improved the result of the arthrolyses.

WHICH RADIAL HEAD REPLACEMENT?

Silicone rubber vs metal

Although silicone replacements were the most popular radial head prostheses, and are still being inserted, there is considerable evidence that they are an inferior material compared to metal.[17] Cadaveric studies have consistently demonstrated that silicone deforms easily under load and transfers minimal load to the capitellum. It therefore functions poorly as a spacer with no improvement in valgus or axial stability after radial head excision and medial ligament transection. In contrast, a replacement made of metal maintains the space providing valgus and axial stability approaching that of an intact radial head.[12,18] A silicone rubber prosthesis may also fracture (Fig. 22) or cause a particulate synovitis, whereas metal replacements are biologically inert and do not break.

INSERTION OF THE RADIAL HEAD PROSTHESIS

Acute unstable elbow injuries

The Kocher approach through the anconeus and extensor carpi ulnaris interval is usually used with division of the annular ligament. Insertion of the prosthesis is usually straightforward in acute, unstable elbow injuries as the elbow joint can be easily subluxed, and the lateral collateral ligament complex/common extensor muscles are often disrupted. The radial neck can be manipulated into the wound allowing preparation of the canal for insertion of a prosthesis with a straight, rigid stem. However, the margin for error to fill

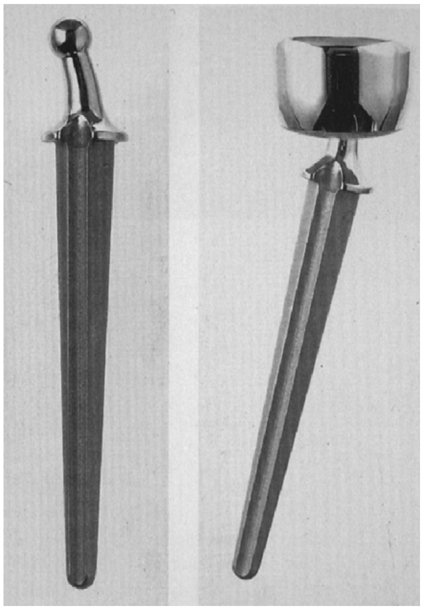


Figure 21 Judet bipolar radial head prosthesis.

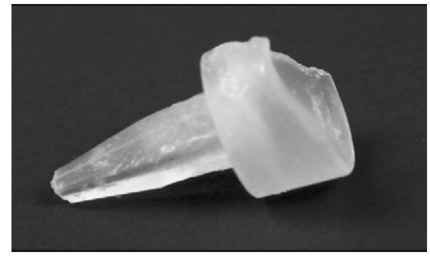


Figure 22 Broken silicone radial head prosthesis.

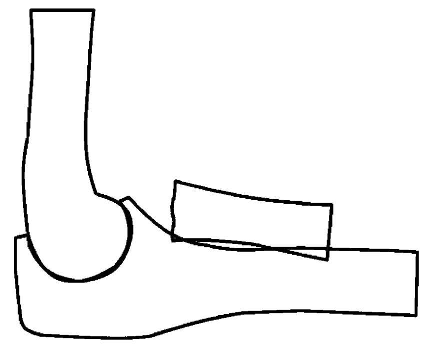


Figure 23 Anterior subluxation of the radial neck following radial head excision due to the pull of the biceps.

the void created by radial head excision is narrow. If the prosthesis fails to restore radial head length by more than 3 mm, it is unlikely to significantly aid stability.

In contrast, if the prosthesis is left proud of the coronoid articular surface it will 'overstuff' the lateral aspect of the elbow joint and is likely to cause instability or restrict movement.

Provided that the elbow was normal preoperatively, or a fractured proximal ulna has been anatomically reconstructed, the radial head should articulate satisfactorily with the capitellum and lesser sigmoid notch before the soft tissues are approximated. Fluroscopy should be used to ensure that a stable and congrous joint has been achieved.

Most of the evidence of benefit of a radial head replacement is as a spacer to aid stability in acute injuries and allow early active movement while soft tissue and bony healing occurs. However, osteoporosis of the capitellum is often seen in successful results indicating that compressive forces are mostly transmitted through the humero-ulnar rather than radio-capitellar joint. There have been no reports of elbow subluxation, recurrent dislocation or subsequent development of valgus angulation after removal of a metal implant. The evidence therefore suggests that radial head replacements are only of temporary value, but as they are usually well tolerated few need to be removed.

There is little evidence that the prostheses function as true replacements transmitting physiological loads in the long term.

RADIAL HEAD REPLACEMENT—HEAD AND STEM DESIGN

Temporary spacer in unstable injuries

The fundamental design characteristics of a temporary spacer are that it should be easy to insert and, if necessary, removed once soft-tissue and bony healing has occurred. Studies have shown that there is little correlation between the native radial head diameter and size of the medullary canal of the radial neck, i.e. a large head may have a narrow intramedullary canal and vice versa.[4] Long or bulky stems may be difficult or even impossible to implant in a narrow canal. Even if the stem of the smallest size of an implant fits the canal it may fail to fill the space left by the radial head resection.

The 'Leeds–Glasgow' and Smith and Nephew Richards cementless prostheses have short, slim, smooth radial stems irrespective of head size (Figs 19 and 20). Both replacements have been shown to be effective in clinical practice.[12,15] The 'Evolve' modular radial head implant allows the surgeon to choose the most appropriate head and uncemented stem size separately, which are then assembled via a Morse-taper connection. There are 15 head and five stem sizes giving a choice of 75 combinations. The proximal radius may rotate around the stem with such designs, but this is thought by some to be a desirable feature, as it may reduce stress and therefore wear of the capitellar cartilage. Removal of any implant requires considerable soft-tissue release to allow dislocation of the radial head.

'True' replacement for chronic problems

Ideally, a prosthesis would exactly replicate the native head which has an oval shape with a variably offset head and neck, but if these features were incorporated in the design very precise positioning and fixation would be required. Replacements therefore usually have round heads with straight stems. The Judet and 'Evolve' prostheses allow separate insertion of the stem into the radius followed by coupling with the radial head. The radial head is therefore easier to replace in a stable elbow than with a standard prosthesis.

The radius is usually malaligned medially and anteriorly on the capitellum following radial head excision due to the forces exerted principally by the supinator and biceps (Figs 10 and 23). A metal monoblock prosthesis inserted in a chronic case is unlikely to rotate about the correct axis and maltracking will tend to occur producing subluxation and impingement.

A 'floating' prosthesis (bipolar) may accommodate a degree of radial malalignment, maintaining full contact at the radio-capitellar and superior radio-ulnar joints during movement of the elbow and forearm. In theory, this feature should help in chronic problems after radial head resection: for example, proximal radial migration, medial ligament instability or a posterior subluxation after failure of fixation of the coronoid. However, there have been few reports of successful outcomes in such cases.

The design characteristics of a 'true' replacement, i.e. to transmit physiological forces permanently, include optimal fixation of the intramedullary stem. Several designs have long or bulky stems but these may be difficult to insert due to the 15° neck-shaft angulation of the radius. The radial neck has to be resected to accommodate the bipolar mechanism of the Judet replacement, whose cemented stems are 5.5 and 6 cm long. Removal of long stems, especially if beaded surfaces have been used, can be very difficult with risks of damage to the posterior interosseous nerve and painful instability of the radial stump with forearm rotation.

CONCLUSIONS

- Elbow valgus stability is primarily provided by an intact medial collateral ligament—the radial head is a secondary stabilizer.
- There is little evidence to support the use of a radial head prosthesis when the medial collateral ligament is intact. Results are usually good in the long-term after radial head excision for an isolated fracture.
- There is evidence for metal replacement if a radial head fracture cannot be rigidly fixed acutely in an unstable elbow, due to soft-tissue injury/coronoid fracture
  (*The prosthesis aids stability to allow early active motion*.
- Silicone rubber is a poor material for a spacer—it deforms easily under load and may break or cause soft-tissue inflammatory reactions.
- Replacement in chronic problems may fail due to impingement/subluxation caused by malalignment of the radius on the capitellum. Bipolar replacements may be the solution but there is little evidence as yet.
- In theory, metal radial head replacement could be effective in preventing/treating proximal radial migration, although there are few detailed reports.

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