Radial Head Arthroplasty

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KEYWORDS

• Radial head • Fracture • Arthroplasty

Radial head fractures are relatively common and found in approximately 20% of all elbow trauma.[1] Radial head arthroplasty is indicated in the treatment of radial head or neck fractures when comminution precludes stable internal fixation of an unstable forearm or elbow. Radial head resection is another treatment option for comminuted radial head fractures; however, it may be associated with delayed complications, including pain, instability, proximal radial translation, ulnohumeral osteoarthrosis, decreased strength, and cubitus valgus.[1–3] In comminuted fractures, radial head resection should be avoided in the presence of lateral ulnar collateral complex injury and possible interosseous membrane injury. In such situations, radial head arthroplasty is a reliable alternative to restore radiocapitellar contact, which functions as an important stabilizer of the elbow and forearm articulations.[4] Several different arthroplasty options exist, including metal unipolar and bipolar radial head implants. This article reviews the literature related to the indications, advantages, disadvantages, techniques, and outcomes of various arthroplasty options.

ANATOMY

The articular surfaces of the radiocapitellar joint are congruent and contribute osseous stability to the elbow. The radial head is an important primary stabilizer to longitudinal stress and a secondary stabilizer against valgus stress to the elbow. The concave surface of the radial head articulates with the hemispheric-shaped capitellum and the radial head rim articulates with the lesser sigmoid notch. Articular cartilage covers the concave surface as well as an arc of approximately 280° of the rim.[5] The radial head is not perfectly circular and is variably offset from the axis of the neck, which has important implications in radial head reconstruction. The primary stabilizer to varus stress consists of the lateral collateral ligament complex (LCL). The LCL complex consists of four components: radial collateral ligament, the lateral ulnar collateral ligament, the annular ligament, and the accessory collateral ligament. The lateral ulnar collateral ligament is one of the primary elbow constraints because it provides varus and posterolateral stability by its insertion distal to the posterior attachment of the annular ligament on the crista supinatoris.[6]

INDICATIONS

The indications for use of a metallic radial head prosthesis include an acute comminuted fracture in which satisfactory reduction and stable fixation cannot be obtained. Radial head replacement may also be considered in patients with complex elbow injuries that involve greater than 30% of the articular rim of the radial head, which cannot be reconstructed.[7] Data by Ring and colleagues[4] suggest that open reduction and internal fixation are best reserved for minimally comminuted fractures with 3 or fewer articular fragments. Patients who present in a delayed manner with persistent pain and instability from radial head primary resections, malunions, or posttraumatic arthritis or after complex elbow fracture-dislocations involving the radial head are also candidates for radial head arthroplasty.

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Active infection is a contraindication to radial head arthroplasty.[7] Radial head arthroplasty may also be contraindicated in patients with advanced radiocapitellar arthrosis where the capitellum is destroyed or devoid of any articular cartilage.

AVAILABLE IMPLANTS

Several current implant options are available. Major differences between current implants include unipolar versus bipolar heads, cemented versus cementless stems, and monoblock versus modular designs (**Table 1**).

The Ascension Modular Radial Head (Ascension Orthopedics, Austin, TX, USA) is a unipolar head (**Fig. 1**). The radial head resection guide has two different levels depending on the amount of radial neck involved in the fracture. The implant can be assembled in situ by placing the head on the morse taper of the stem and using an offset head impactor. Multiple head/stem sizes and configurations accommodate a broad range of patient anatomy. These include 3 diameters of long and standard length heads combined with 3 different stem diameters and a long stem that mimics the proximal radial bow (**Fig. 2**). Ascension is also developing a pyrolytic carbon implant (**Fig. 3**).

The CRF II by Tornier (Saint-Ismier Cedex, France) developed by Judet and colleagues,[8] was the first radial head bipolar prosthesis. It is available in 2 head and 3 stem diameters (**Fig. 4**). The cemented stem has a 15° proximal angle and the bipolar articulation of polyethylene on cobalt chrome allows for a range of motion of 35° between the head and stem. This motion is thought to provide full radial head articulation on the capitellum throughout elbow range of motion. The set also includes a radial resection template for a precise cut.

The Evolve Modular Radial Head (Wright Medical Technology, Arlington, TN, USA) is another modular implant that allows for in situ assembly (**Fig. 5**). The system has a radial neck planer that slips over the trial stem to create a smooth contact surface on the radial neck, perpendicular to the longitudinal axis of the radial neck. An in situ assembly tool with a long lever arm is used to ensure a 2000-N assembly load is applied to secure the head on the morse tapered neck.[9]

The Katalyst by KMI (Carlsbad, CA, USA) is also a bipolar radial head system. Three radial head diameters are available and the radial head height is adjustable through a telescoping neck by increments of 2 mm to 10 mm (**Figs. 6** and **7**). The neck length is secured with screws. Two options are available for stem diameter. The bipolar articulation consists of a cobalt chrome ball and an ultra–high molecular weight polyethylene socket. The articulation allows for 15° of motion between the neck and head. The modular design is suggested to allow implant insertion without disruption of the lateral ligament complex.

The Solar Radial Head Implant System (Stryker, Mahwah, NJ, USA) (**Fig. 8**) is a monoblock cobalt chrome implant that is available in 5 sizes with heads available in 2 diameters. This implant is available only for cement fixation.

The Swanson Titanium Radial Head implant (Wright Medical, Arlington, TX, USA) (**Fig. 9**) features a titanium implant with nitrogen ion implantation for increased surface hardness. It has a short, wider stem to allow easier placement. Permanent fixation in the intramedullary canal is not required. The implant is available in 5 different sizes.

The ExploR® Modular Radial Head by Biomet (Warsaw, IN, USA) (**Fig. 10**) is a modular head and stem that does not require assembly before implantation, allowing for in situ replacement. Three head diameters, each with 5 different lengths (15 head options), and 5 different stem options provide for optimal patient sizing with more than 75 different combinations. There is a bond-coated stem that theoretically allows for enhanced fixation.

The rHead radial implant system by Small Bone Innovations (SBI, Morrisville, PA, USA) (**Fig. 11**) offers a modular unipolar implant with 3 different heights and diameters. There is also an extended collar to be used with distally migrated fractures of the proximal radius. The system includes a radial head resection guide that is used to cut the proximal radius at 3 different heights corresponding to the 3 different thicknesses of radial head implant available. After broaching, the stem is inserted in an arc-like fashion, facilitated by the curve of the stem that corresponds to the 15° lateral angle created by the native radial head and shaft. The head is then inserted onto the neck taper.

TECHNIQUE

The radial head may be approached through a lateral or posterior approach. Often when concomitant fractures about the elbow are present and require fixation, an extensile posterior approach is preferred. A curvilinear incision is made between the lateral condylar ridge and the midaxial line of the radial neck. Dissection through the Kocher interval between the anconeus and extensor carpi ulnaris or the Kaplan interval between the extensor carpi radialis longus and extensor digitorum communis or splitting the extensor digitorum communis, as described by

Table 1
Radial head implants

rHead (Small Bone Innovations)	Liverpool Radial Head Replacement (Biomet Merck)	Ascension (Ascension Orthopedics)	CRF II (Tornier)	Katalyst (KMI, Carlsbad, CA, USA)	Swanson Titanium Radial Head (Wright Medical Technology)	Evolve (Wright Medical Technology)
• Unipolar/ bipolar option 20° arc • Modular • 3 Head heights • 3 Head diameters • 8 Stem sizes • Porous coated stem • In situ assembly	• Unipolar • Monoblock • 15 Implant sizes • Porous coated stem	• Unipolar • Modular • 2 Head heights • 3 Head diameters • 4 Stem sizes • In situ assembly	• Bipolar—arc 35° • Modular • 4 Head diameters • 5 Stem diameters • 2 Stem lengths	• Bipolar—arc 15° • Modular • 2-mm Spacers to adjust head height up to 10 mm in situ • 3 Diameters • 2 Stem sizes	• Unipolar • Monoblock • 5 Implant sizes	• Unipolar • Modular • 15 Head sizes • 10 Stem sizes • In situ assembly

Fig. 1. The Ascension Modular Radial Head (Ascension Orthopedics, Austin, TX, USA).

Fig. 3. The Ascension Modular Radial Head, pyrolytic carbon (Ascension Orthopedics, Austin, TX, USA).

Hotchkiss, may be performed.[10] Care should be taken to protect the LCL complex posteriorly when using the Kocher approach as well as protecting the posterior interosseous nerve when using the Kaplan approach.[11] All the ligamentous origin may be taken down anterior to a line bisecting the articular surface of the capitellum from a lateral vantage point.[10] A cadaver study of radial head plating by Tornetta and colleagues[12] reported that in only 1 (2%) of 50 arms did the posterior interosseous nerve lie directly on the radius. The average distance from the radial head to the origin of the posterior interosseous nerve was 1.2 $\pm$ 1.9 mm, with the takeoff being proximal to the radial head in 31 cases. The muscular branch to the extensor carpi radialis longus was located 7.1 $\pm$ 1.8 mm from the radial head.[12] Inspection of the LCL complex should be performed. The elbow capsule and annular ligament should be incised in line with the posterior margin of the extensor carpi ulanris. The capsule can also be incised in a ligamentous-sparing Z capsulotomy, as described by Bain.[7] The capsule is elevated off the anterior distal humerus and more of the radiocapitellar joint may be exposed by elevating the origin of the brachioradialis. At all times, every effort is made to keep the forearm pronated and vigorous traction on the anterior soft tissues is avoided so as to reduce the possibility of any iatrogenic injury to the posterior interosseous nerve. Retraction is best done with sutures placed in the anterior capsule. Exposure provided by retractors, such as the Hohmann retractor placed anteriorly around the radial head or neck, is excellent; however, the authors recommend against their use to prevent any form of traction on the posterior interosseous nerve. Should the radial head need to be delivered into the wound for enhanced exposure, placing a small Hohmann

Fig. 2. The Ascension Modular Radial Head (Ascension Orthopedics, Austin, TX, USA).

Fig. 4. The CRF II by Tornier (Saint-Ismier Cedex, France).

Fig. 5. The Evolve Modular Radial Head (Wright Medical Technology, Arlington, TN, USA).

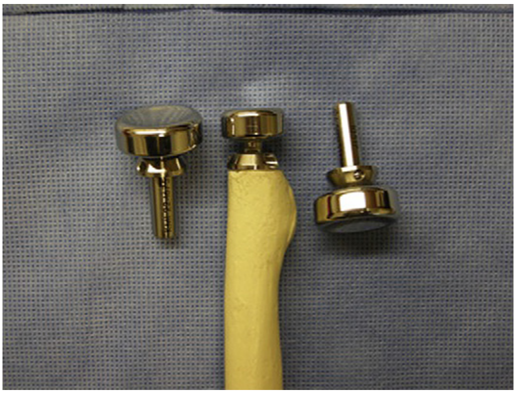

Fig. 7. The Katalyst by KMI (Carlsbad, CA, USA).

retractor gently on the dorsal surface of the head is helpful in elevating the radial head into the wound.[10]

Once the radial head is exposed, the degree of comminution is assessed and a decision made whether or not to attempt fixation or replacement. Although current implants and techniques for internal fixation of small articular fractures have made it possible to repair most fractures of the radial head, data by Ring and colleagues[4] suggest that open reduction and internal fixation are best reserved for minimally comminuted fractures with 3 or fewer articular fragments. Goals of implant placement are to replicate the native radial head anatomy as closely as possible with special attention paid to radial head size and height.[13] Multiple biomechanical studies have demonstrated the importance of accurate radial head sizing.[14–16] The fractured head should be reassembled as close to anatomically as possible, and an appropriate head size is selected. Care should be taken to avoid overstuffing the radiocapitellar joint because it has been associated with radiocapitellar wear and erosion.[16] The longitudinal height of the prosthetic head is selected based on the height of the radial head fragments with use of a trial prosthesis for comparison. If comminution of the radial head prohibits accurate measurement of length, the lateral edge of the coronoid process at the proximal portion of the lesser sigmoid notch may be used as a landmark. Doornberg and colleagues[17] demonstrated in CT scans of 17 elbows that the native radial head lies an average of 0.9 mm distal to the proximal margin of the sigmoid notch. In general, it is preferable for the diameter and the thickness of the prosthesis to be slightly undersized.[18] A prosthesis with a diameter that is too large points load on the margins of the sigmoid notch, whereas a prosthesis that is too small points load on the sigmoid notch.[19] A radial head with an incorrect diameter also has a cam effect, which produces abnormal loading on the capitellum. Insertion of a radial head that is too short contributes to radiocapitellar instability.[19]

A neck planer may be used to create a smooth contact with the radial head implant. The radial neck is then reamed to remove cancellous bone and reaming is complete when cortical bone is reached. In most contemporary radial head replacement systems, a stem size that is one

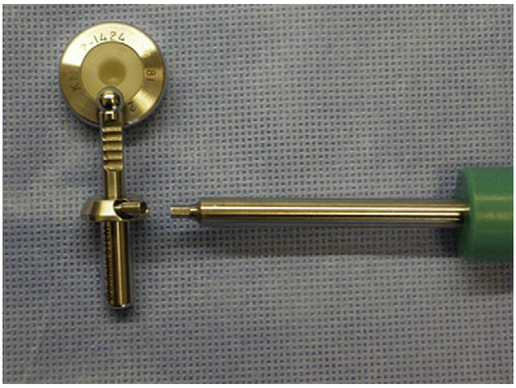

Fig. 6. The Katalyst by KMI (Carlsbad, CA, USA).

Fig. 8. The Solar Radial Head Implant System (Stryker, Mahwah, NJ, USA).

Fig. 9. The Swanson Titanium Radial Head implant. (*Courtesy of* Wright Medical Technology, Arlington, Texas; with permission.)

size smaller than the final reamer is selected. The fit between the stem and radial neck is loose in most implants to allow the annular ligament to guide radiocapitellar articular contact rather than the fixed stem. A loose fitting stem compensates for the shortcomings of a well-fixed stem attempting to restore the variable radial head anatomy with an elliptical head and an offset neck. Inserting the stem may be difficult if the LCL is intact. An effective way to facilitate prosthesis insertion is to place a retractor under the radial neck and lever the proximal part of the radius anteriorly and laterally away from the capitellum.[18]

Once the radial head implant is placed, elbow range of motion and stability are tested. Formal assessment of elbow stability as described by Bain includes stress testing with the elbow in 30° flexion and the forearm pronated.[7] In this position, narrowing of the radiocapitellar joint by 2 mm with valgus stress testing is indicative of loss of integrity of the anterior band of the ulnar collateral ligament. Transosseus sutures should be used for stabilization of the LCL with the elbow in 30° flexion and the forearm in full pronation.[19] Beingessner and colleagues[20] reported in a biomechanical study that varus-valgus laxity was corrected after radial head arthroplasty and LUCL repair but not after radial head arthroplasty without ligament repair. They noted only a small amount of instability in elbows with disrupted medial collateral ligaments after radial head replacement, which they attributed to compensatory stabilization from the biceps and brachialis.

POSTOPERATIVE REHABILITATION

Postoperatively, early range of motion is important to ensure a successful outcome. Patients begin formal rehabilitative therapy for active and active assisted range of motion within the first week after surgery. Stability of the surgical wound must be confirmed before instituting rehabilitation. Splinting between rehabilitation exercises is based on the particular elbow injury encountered and, in most circumstances, is discontinued within the first 2 to 3 weeks after surgery. Strengthening is initiated 6 weeks after surgery.

OUTCOMES

Unipolar Implants

Most contemporary radial head implants are made of cobalt-chromium or titanium. Silicone implants used in the past have been found to provide inadequate stability and in most circumstances tend to break down over time causing synovitis and its sequelae.[21,22] Metallic implants have been shown to reproduce the loads across the elbow more closely than silicone implants.[19] Pyrolytic carbon is now being considered as an implant material in radial head implants. Theoretic advantages include an elastic modulus close to cortical bone, favorable wear characteristics,[23] and less wear damage to cartilage in canines.[24]

The stems of unipolar implants are loose fitting or fixed stems. Fixed stems require a close approximation to native anatomy to achieve joint

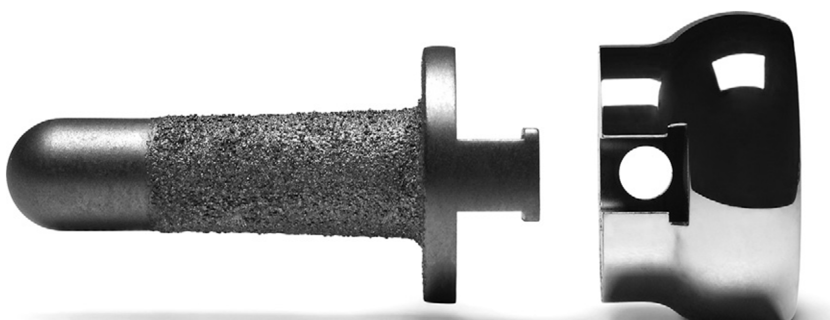

Fig. 10. The ExploR® Modular Radial Head by Biomet. (*Courtesy of* Biomet Orthopedics, Warsaw, IN; with permission.)

Fig. 11. The rHead by Small Bone Innovations. (*Courtesy of* SBI, Morrisville, Pennsylvania; with permission.)

congruity. It is believed that smooth stems allow the radial head implant to settle in an anatomic position during range of motion and act as a spacer arthroplasty.

Grewal and colleagues[25] reported 12 excellent, 4 good, 6 fair, and 2 poor results in 26 patients with Mason type III fractures at an average of 25 months after fracture. Harrington and colleagues[26] reported 12 excellent, 4 good, 2 fair, and 2 poor results an average of 12 years after surgery in 14 Mason type IV (comminuted fracture dislocations), 3 Monteggia fracture dislocations, 2 medial ligament tears associated with radial head fractures, and 1 Mason type II radial neck and coronoid fracture. Eighty percent of the patients had good to excellent overall modified Mayo Clinic functional rating index system scores.[27] All had radiologic lucency around the stem. Eleven patients showed no evidence of degenerative joint disease. After an average of 58 months, mild changes were observed in 6 patients, moderate changes in 2, and severe changes in only 1 patient with a combined radial head fracture and medial ligament tear.[26]

The majority of patients with loose fitting stems have radiographic lucency around the stem at follow-up as reported by Doornberg and colleagues.[28] They followed 27 patients, 11 with Mason type II and 16 with Mason type III fractures, for an average of 40 months and reported average range of motion of -20° extension, 131° flexion, 73° pronation, and 57° supination. Ten radial head fractures were associated with a posterior fracture-dislocation of the olecranon and a coronoid fracture; 16 were associated with a complete posterior dislocation of the elbow, and 1 was associated with an MCL rupture and subluxation. Twenty of 27 patients had excellent results on Mayo Elbow Performance Index.[27] Seven patients had subsequent operations to treat residual instability, heterotopic ossification, elbow contracture, ulnar neuropathy, or a misplaced screw. The implants were intentionally inserted loosely to accommodate for the inevitable differences between the implant and native radial head.[28] In a study of 25 patients, 10 with Mason type III and 15 with Mason type IV injuries, with an average of 39 months' follow-up, Moro and colleagues[29] reported lucency around the stem without subsidence as being the norm.

Knight and colleagues[30] reported a reliable restoration of stability and prevention of proximal radial head migration after unipolar metal prosthesis in 31 patients at an average of 4.5 years' follow-up; 68% of the radial head fractures were associated with elbow dislocations. They noted a low complication rate and only 2 implants were removed for aseptic loosening.

Bipolar Implants

Judet and colleagues[8] reported results of a floating prosthesis in 12 patients at an average of 2 years' follow-up. Of 5 patients treated acutely, 3 had excellent results and 2 were classified as having a good result. Seven patients were treated with radial head arthroplasty after failed open reduction internal fixation. There were 1 excellent, 4 good, and 3 fair results. Holmenschlager and colleagues[27,31] reported on 16 bipolar prostheses with a 19-month follow-up. There were 2 excellent, 12 good, 1 fair, and 1 poor result using the evaluation system of Morrey.[27] Complications included 1 transient radial nerve palsy, 1 reflex sympathetic dystrophy, and 1 asymptomatic loosening.[31] Pomianowski and colleagues[14] performed a cadaver study that showed that a bipolar radial head prosthesis can be as effective as a solid monoblock prosthesis in restoring valgus stability in a medial collateral ligament–deficient elbow.

SUMMARY

Reported clinical outcomes of metallic radial head arthroplasty indicate that radial head arthroplasty is a reasonable treatment option to offer patients with comminuted radial head fractures in which stable internal fixation is not possible in an unstable forearm or elbow. Careful attention to surgical anatomy and technique is crucial to ensuring a good outcome. Several implant options and techniques of implantation are available to orthopedic surgeons to help optimize patient outcome.

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