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Is an extension of the safe zone possible without jeopardizing the proximal radioulnar joint when performing a radial head plate osteosynthesis?

Christian Ries, MD[a,d,*], Marcel Müller[a], Kilian Wegmann, MD[a,d], Doreen B. Pfau, DMD[b], Lars P. Müller, PhD[a,d], Klaus J. Burkhart, PhD[c]

[a]*Department of Trauma and Orthopaedic Surgery, University of Cologne, Cologne, Germany*
[b]*Department of Neurophysiology, Center of Biomedicine and Medical Technology Mannheim, Ruprecht-Karls-University Heidelberg, Mannheim, Germany*
[c]*Department for Shoulder Surgery, Rhön-Klinikum, Bad Neustadt, Germany*
[d]*Cologne Center for Musculoskeletal Biomechanics, Medical Faculty, University of Cologne, Cologne, Germany*

Background: Proximal radial fractures are common elbow injuries. Because of the fracture pattern, stability criteria, or plate configuration, a plate position outside the "safe zone" (SZ) may be required in some cases when performing a radial head plate osteosynthesis. We examined the gross anatomy of the radial head and analyzed different so-called low-profile and precontoured radial head and neck plates with respect to the SZ.
Materials and methods: Macroscopic measurements of the radial head and neck of 22 formalin-fixed human cadaveric upper extremities were obtained. The SZ was determined by maximum forearm rotation. If the edge of a plate could be extended beyond the respective SZ boundary without jeopardizing the proximal radioulnar joint (PRUJ) in maximum forearm rotation, a new plate-specific SZ boundary was set.
Results: The mean SZ was 133° (SD, 14°). Among the 5 plates studied, only the 2 radial neck designs allowed the anterior edge of the plate to partially pass the lesser sigmoid notch of the ulna and consequently afforded a significant extension of the SZ in maximum pronation. All 3 radial head designs had to remain within the SZ to avoid interference with the PRUJ. A safe plate position depends on individual plate dimensions, particularly the proximal plate width, and the diameter of the radial head. The smaller the head diameter, the more accurately a plate must be placed within the SZ.
Conclusions: If an extension of the SZ in radial head plate osteosynthesis is not essential, we recommend respecting the SZ to minimize the possibility of interference with the PRUJ.
Level of evidence: Anatomy Study, Cadaveric Dissection.

Keywords: Radial head; fracture; plate osteosynthesis; safe zone

The study was approved by the university's ethics committee and conformed with the Declaration of Helsinki.

*Reprint requests: Christian Ries, MD, Department of Trauma and Orthopaedic Surgery, University Hospital Cologne, Kerpener Strasse 62, D-50924 Köln, Germany.

E-mail address: christian.ries@uk-koeln.de (C. Ries).

Fractures of the proximal radius account for approximately one-third of all elbow injuries.[12] In the intact elbow joint, the radial head plays an important role as a secondary stabilizer of the elbow joint: The radial head and the medial collateral ligament stabilize the joint against valgus stress,[14] whereas the

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radial head and the coronoid process contribute to resistance against posterolateral rotatory loads.[17] Furthermore, up to 60% of an axial load applied to the hand is transferred through the radial column in an intact elbow.[13] Resection of a fractured radial head would therefore potentially result in valgus instability and would increase the load transfer through the ulnar column, which in turn may result in early osteoarthritis. Satisfactory functional results at long-term follow-up, despite degenerative changes detected in most of the cases, have been shown for early resection arthroplasty in radial head fractures.[7] However, radial head fractures—especially displaced fractures—are accompanied by ligamentous injuries in up to 87.5% of cases.[10] Ikeda et al[8] reported that patients in whom the comminuted radial head fracture was treated with open reduction–internal fixation had satisfactory joint motion with greater strength and better function than patients who had undergone radial head resection. Concomitant ligamentous injuries are not accommodated adequately by radial head resection alone. Therefore, restoration of the radial column is recommended for acute radial head fractures. Because the long-term outcome of radial head arthroplasty is not known, every effort should be made to preserve the radial head and neck—particularly in young and active patients.[6,15] In 2002, Ring et al[16] recommended open reduction–internal fixation only for minimally comminuted fractures with 3 or fewer articular fragments. They noted an increased risk of compromised long-term results of radial head repair—especially regarding restoration of forearm rotation—due to associated fracture-dislocation of the elbow or forearm. Nevertheless, over the past decade, new techniques that include specific angular locking and precontoured radial head and neck plates have been developed that potentially offer superior primary stability for radial head repair.[1,2] Fortunately, even for comminuted radial head fractures, good results have been reported with plate osteosynthesis.[8,9,21]

Plate osteosynthesis should be performed within the ‘‘safe zone’’ (SZ), that is, the part of the radial head that does not articulate with the proximal radioulnar joint (PRUJ). If the SZ is not adequately respected, soft tissue irritations or interference with the PRUJ can ensue. However, placement of internal fixation within the SZ does not necessarily guarantee optimal stability,[4] and both the fracture pattern and the configuration of a plate may require placement that crosses a SZ boundary. Thus, the aim of this cadaveric study was to (1) analyze different so-called low-profile and precontoured radial head and neck plates regarding the SZ, (2) examine when the SZ can be extended without interfering with the PRUJ, and (3) offer recommendations for plate positioning.

Materials and methods

Specimens

A total of 22 formalin-fixed human cadaveric upper extremities (11 pairs), disarticulated at the glenohumeral joint (8 male and 3 female cadavers; mean age at death, 75.9 years [range, 44-100 years]), were available from the university’s department of anatomy. All specimens were screened for pre-existing pathologies involving a deformity or subluxation of the radial head. No elbow had undergone a previous operation.

Preparation and macroscopic measurements

All upper extremities were carefully disarticulated at the elbow joint. The PRUJ and the first third of the forearm were completely dissected of all soft tissue. The interosseous membrane was preserved.

Macroscopic measurements were performed independently by the first and second authors (C.R. and M.M.) using a digital caliper (Meister Tools, Wuppertal, Germany) and a conventional measuring tape. The following parameters were measured in all specimens (Fig. 1): (1) circumference of the radial head, (2) maximum and minimum diameter of the radial head, (3) maximum size of the cartilage layer at the side of the radial head, (4) length of the radial head (ie, the distance between the radial lip and the neck-head border), and (5) maximum and minimum diameter of the radial neck.

Plates

On the basis of the study of Burkhart et al,[3] we examined the following 5 plates (Fig. 2): (1) Aptus 2.0 radial head rim plate (MRP) (Medartis, Basel, Switzerland); (2) Aptus 2.0 radial head buttress plate (MBP) (Medartis); (3) 2.4-mm limited-contact plate (LCP) radial head rim plate (SHP) (Synthes Inc., West Chester, PA, USA); (4) 2.4-mm LCP radial head-neck plate (SNP) (Synthes); and (5) proximal radial head plate (WHP) (Evolve; Wright Medical Technology, Arlington, TN, USA).

Both the MRP and MBP are available in a single size. The plates are made of grade IV titanium, are 1.3 mm thick, and have 2.0-mm screw options (multidirectional locking and nonlocking). According to the manufacturer’s instructions, the MRP (Fig. 2, *A*) should be positioned at the level of the articular cartilage of the radial head under the annular ligament. In contrast, the MBP (Fig. 2, *B*) should be placed distal to the articular surface of the radial head to avoid interfering with the PRUJ during forearm rotation. The MBP allows for the maintenance of the annular ligament.

Both the SHP and SNP are available in titanium and stainless steel with either a long shaft (4 shaft holes) or a short shaft (2 shaft holes), and they are 1.8 mm thick. We used only the titanium short design of each. The plates can be fixed with 2.4-mm unidirectional locking screws or 2.4- and 2.7-mm nonlocking screws. The SHP (Fig. 2, *C*) is distinguished by left- and right-hand versions that are positioned at the level of the articular cartilage of the left radial head and right radial head, respectively, under the annular ligament. The SNP (Fig. 2, *D*) should be placed distal to the articular surface of the radial head to avoid interfering with the PRUJ during forearm rotation. The SNP allows for the maintenance of the annular ligament.

The WHP (Fig. 2, *E*) is made of stainless steel, is available in 4 sizes, and has a thickness of 1.0 to 2.5 mm. The choice of size depends on the diameter of the radial head (20, 22, 24, and 26 mm). The shaft is available in a long version (3 shaft holes) and a short version (2 shaft holes). We only used the short version of each size. The WHP should be placed at the circumference of the