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Research Article

Relationship between the tilt angle of bipolar radial head prostheses and radiological radiocapitellar instability

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ABSTRACT

Objective: This study aimed to radiologically assess the relationship between the tilt angle of the bipolar radial head prostheses and radiocapitellar instability.

Methods: In this radiological study, 28 consecutive patients (13 females and 15 males: mean age=47 years and age range=23-77 years) who underwent cemented bipolar radial head arthroplasty (Judet CRF II) because of comminuted radial head fracture with elbow instability were retrospectively reviewed.

Results: There was excellent intra- and interobserver reliability for the measurements of the tilt angle and the radiocapitellar distance. ICC for interobserver reliability of the tilt angle was 0.93, and ICC for intraobserver reliability for the 2 observers was 0.96 and 0.97, respectively. ICC for interobserver reliability of the radiocapitellar distance was 0.87, and ICC for intraobserver reliability for the 2 observers was 0.91 and 0.93, respectively. The mean tilt angle was 17.6° (range=1°-35°), and the mean radiocapitellar distance was 8 mm (range=1–17 mm). Pearson's correlation revealed a strong significant positive correlation between the tilt angle and the radiocapitellar distance ($r=0.77$ and $p<0.001$).

Conclusion: Evidence from this study has demonstrated a strong positive correlation between the tilt angle of bipolar radial head prostheses and radiocapitellar instability. The tilt angle can be used as an indicator of radiocapitellar joint instability following bipolar radial head prostheses.

Level of Evidence: Level IV, Diagnostic study

Radial head arthroplasty is an accepted treatment modality for unreconstructable radial head fractures with elbow instability (1-3). Various types of metallic radial head prostheses have been developed, and clinical results for these implants have generally been satisfactory (4, 5). Currently, the available types include press-fit monopolar implant, loose-fit monopolar implant, and cemented or noncemented bipolar implant.

The bipolar radial head prosthesis has a mobile head that articulates with the intramedullary stem. The concept of the design is that the increased freedom of motion allows more congruent articulation of the radial head component to the capitellum (6). Short- to mid-term clinical outcomes using the bipolar implant revealed satisfactory results (6-8). Recently, the complications associated with the bipolar prosthesis, including loosening, polyethylene wear, and dissociation of the prosthesis, have been reported (8, 9). In particular, subluxation or disassembly of the radial head is a serious complication leading to revision surgery (10, 11).

Tilting of the bipolar head on radiographs is a common observation that represents an attempt by the prosthesis to align itself to the subluxating radiocapitellar joint. This tilting property was believed to restore the elbow stability when proper alignment is difficult to attain. However, biomechanical studies demonstrated that the bipolar design had lesser capacity than unipolar implant to resist radiocapitellar subluxation, and tilting of the bipolar head had an adverse effect on the stability of the radiocapitellar joint (12, 13). Clinically, the correlation between tilting of the bipolar prosthesis and radiocapitellar

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subluxation has not been reported previously. The purpose of this study was to assess the relationship between the tilt angle of the bipolar radial head and radiocapitellar instability in patients with bipolar radial head prostheses.

Materials and Methods

We retrospectively reviewed 31 consecutive patients who underwent Judet's bipolar radial head arthroplasty (CRF II bipolar implant, Tornier SA, Saint-Ismier, France) between April 2007 and July 2016 in our hospitals. In addition, 2 patients were lost to follow-up, and 1 patient was excluded because of early failure by technical error; 28 patients who had been followed for more than 12 months were included in this study.

The indications for radial head arthroplasty were an acute, comminuted, and unreconstructable radial head fracture combined with elbow instability (27 patients) and nonunion of the radial neck with valgus instability (1 patient). The associated elbow injuries in the acute cases included coronoid fracture, olecranon fracture, and collateral ligament rupture (lateral and/or medial). Mean duration of the follow-up was 16.7 months (range, 12-96 months). We examined the patients clinically and radiographically at regular intervals after surgery.

The mean age of the patients at the time of radial head replacement was 47 years (range, 23-77 years). Preoperative radiographs and computed tomography evaluations performed routinely for all patients were used to identify the radial head fracture pattern, other osseous injuries, and the status of the elbow joint. Of the 28 patients in the study, 11 had terrible triad injuries (radial head fracture, coronoid tip fracture, and elbow dislocation), 8 had a radial head fracture with an olecranon fracture and dislocation, and 5 had a radial head fracture with elbow dislocation. One patient had a radial head fracture with medial collateral ligament rupture, and 1 had chronic valgus instability caused by previous radial neck nonunion. One patient had a radial head fracture and a triceps avulsion injury with medial collateral ligament rupture. One patient had Essex-Lopresti injury (Table 1). The surgical technique for radial head arthroplasty was based on the protocol established by the prosthetic manufacturer, and the associated injuries of the coronoid, olecranon, and lateral and/or medial collateral ligaments were managed, as necessary, to enable fracture union and ensure a stable elbow joint.

The cemented bipolar prosthesis (Judet CRF II) was implanted in this study. This implant has a modular head made of cobalt chrome and a cemented long stem. The collared stem has an offset of 15°. The bipolar design allows a 35° arc of uniplanar movement in any direction with free rotation. The radial head component is available in 2 sizes with diameters of 19 and 22 mm. Furthermore, 2 stem sizes are available, with diameters of 8 and 6.5 mm, respectively, and lengths of 60 and 55 mm, respectively.

To assess the relationship between the tilt angle of the bipolar head and radiocapitellar instability, the tilt angle and radiocapitellar subluxation were measured on a lateral radiograph of the elbow taken at the latest follow-up. The lateral radiograph of the elbow was taken with the elbow flexed to 90° and the forearm in neutral rotation. The X-ray beam was centered perpendicular to the elbow. The measurements were performed on digital radiographs using an imaging software.

The tilt angle of the bipolar head was defined as the angle between the mobile radial head and the stem of the prosthesis. The tilt angle was measured on lateral X-ray by drawing a line through the bottom of the radial head and another line along the collar of the stem. The tilt angle of the bipolar head was measured at the point of intersection of the 2 lines (Figure 1). Instability or subluxation of the radiocapitellar joint was measured using the radiocapitellar distance. We modified the method of measurement of the radiocapitellar distance described by Coonrad et al. and Yian et al. as follows (14, 15). A horizontal line (A) was drawn from the center of the bipolar head on the surface at the top. The line was parallel to the long axis of the stem. Another line (B) was drawn from the center of the capitellum parallel to line (A). The vertical distance (D) between the lines (A) and (B) was then measured as the radiocapitellar distance (Figure 1). The magnification

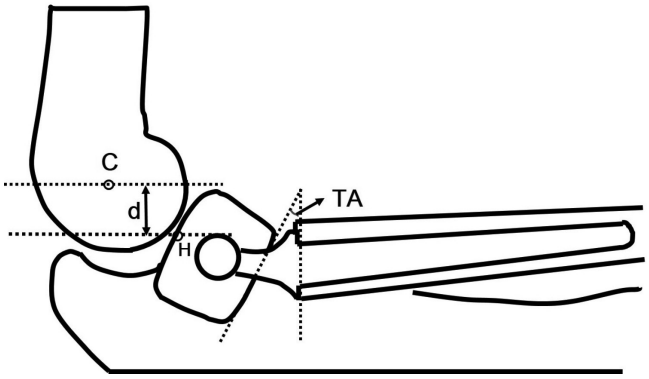

Figure 1. Measurement of the tilt angle and radiocapitellar distance
C: center of the capitellum; d: radiocapitellar distance (mm); H: center of the radial head surface; TA: tilt angle

HIGHLIGHTS

- Tilt of the bipolar head is commonly observed on postoperative radiographs, especially in cases of complex elbow injury.
- An increase in the tilt angle of the bipolar radial head prosthesis was accompanied by an increase in posterior subluxation of the radial head prosthesis.
- The tilt angle of the bipolar radial head can be used as a radiological indicator of radiocapitellar instability.

Table 1. Patient's demographics and radiologic measurements

Sex	Age (years)	Diagnosis	Tilt angle (°)	RC distance (mm)
F	38	RHF, ED	25.5	14.8
F	43	RH nonunion	22.2	6.1
M	23	RHF, Triceps tendon rupture	17.8	9.3
F	45	RHF, ED	0.6	1.1
M	64	RHF, OF, ED	33.4	15.5
M	27	RHF, ED	24.5	9.3
F	57	TT	15.2	8.5
M	62	RHF, OF, ED	7.9	2.7
F	58	RHF, OF, ED	8.2	5.1
F	34	TT	22.6	9.4
F	33	TT	9.9	3.1
F	77	RHF, OF, ED	11.3	2.1
F	70	TT	20.4	7.6
M	23	TT	14.6	7.8
M	24	RHF, OF, ED	0.6	2.0
M	43	RHF, ED	26.7	12.6
F	62	RH fracture, MCL rupture	11.7	5.6
M	41	RHF, OF, ED	21.3	17.0
F	72	RHF, OF, ED	22.0	9.7
M	30	TT	33.4	15.4
M	41	RHF, OF, ED	28.6	11.6
F	63	TT	0.7	0.7
M	28	TT	25.3	10.2
M	39	TT	8.5	5.0
M	45	RHF, Essex-Lopresti injury	28.0	13.0
M	49	TT	5.4	1.2
F	64	TT	11.4	3.9
M	68	RHF, ED	34.6	14.2
Mean	47.3		17.6	8.0

RHF: radial head fracture; RH: radial head; ED: elbow dislocation; OF: olecranon fracture; TT: terrible triad; MCL: medial collateral ligament; RC: radiocapitellar

of the distance was recalculated by measuring the known head diameter.

Statistical analysis

Intra- and interobserver reliability was calculated using Intraclass Correlation Coefficients (ICCs) with 95% confidence intervals. All the measurements were performed independently by 2 observers, and each observer repeated the measurement after an interval of 2 weeks. Interobserver reliability was based on the first trial of measurements to avoid training bias. The ICC was graded as follows: <0.40, poor; 0.41-0.60, fair; 0.61-0.80, good; and 0.81-1.00, excellent. The association between the tilt angle of the bipolar head and the

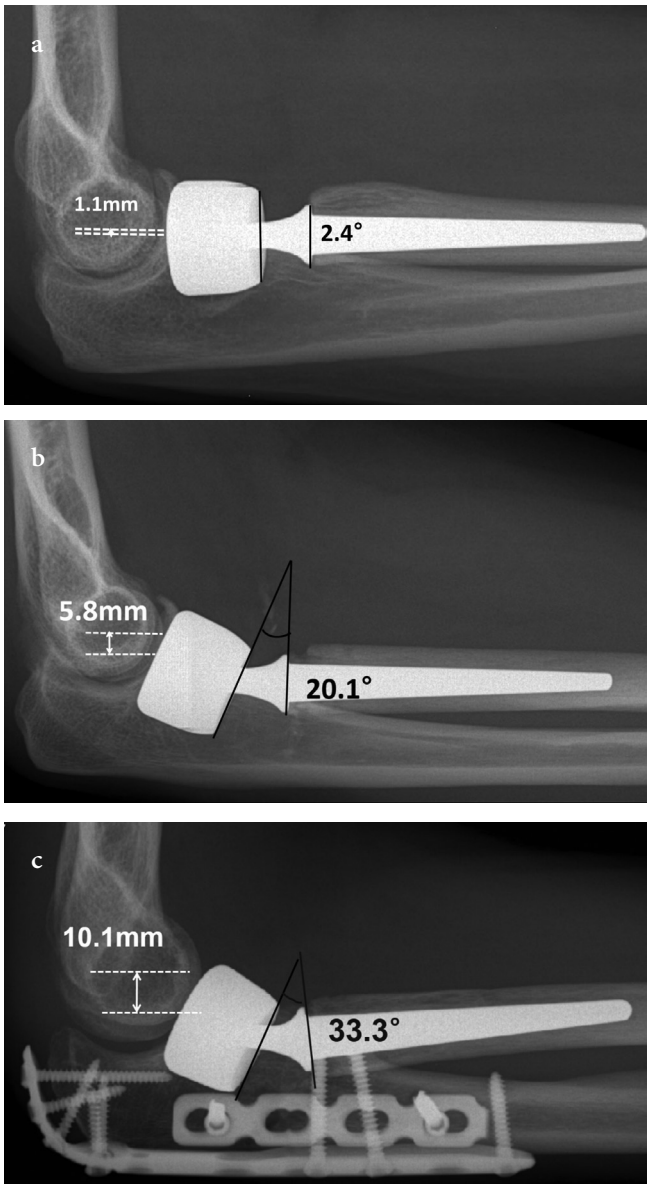

Figure 2. a-c. Radiographs of the elbow showing (a) a tilt angle of 2.4° and radiocapitellar distance of 1.1 mm, (b) a tilt angle of 20.1° and radiocapitellar distance of 5.8 mm and (c) a tilt angle of 33.3° and radiocapitellar distance of 10.1 mm

radiocapitellar distance was assessed using a nonparametric measure of correlation (Pearson's rank correlation). Statistical analyses were performed using the Statistical Package for Social Sciences version 20.0 software (IBM SPSS Corp.; Armonk, NY, USA).

Results

For the reliability of the measurements, there was an excellent intra- and interobserver reliability for measurements of the tilt angle and the radiocapitellar distance. The ICC for interobserver reliability of the tilt angle was 0.93, and ICCs for intraobserver reliability for the 2 observers were 0.96 and 0.97, respectively. The ICC for interobserver reliability of the radiocapitellar distance was 0.87, and the ICCs for intraobserver reliability for the 2 observers were 0.91 and 0.93, respectively. The mean values of the tilt angle and the radiocapitellar distance were used in the final analysis.

The mean tilt angle was 17.6°±10.2° (range, 0.6°-34.6°), and the mean distance between the center of the capitellum and the center of the prosthetic radial head was 8.0±5.0 mm (range, 0.6–17.0 mm) (Figure 2). Pearson's correlation was used to assess the relationship between the tilt angle and the radiocapitellar distance. The correlation coefficient of 0.77 with P<0.001 revealed the strong positive and statistically significant correlation between the 2 variables (Figure 3).

Discussion

Radial head arthroplasty has evolved over time from the use of silicone prostheses to metallic unipolar and bipolar prostheses. The clinical outcomes of bipolar prosthesis placement have been satisfactory and comparable to the monoblock radial head replacements (8, 16). The bipolarity of the head allows automatic positioning and improved congruency of the head against the humerus and reduces stress at the implant–bone interface, thereby decreasing the contact pressure on the capitellar cartilage, an advantage over the monopolar prosthesis. Although the advantages of the bipolar radial head implant are obvious, it predisposes the implant to the risks of dislocation and disengagement (10, 13). Brinkman et al. reported 2 cases of reoperation because of subluxation of the implant out of 11 cases with bipolar radial head prostheses (17). Recently published studies focusing on the complications of radial head prostheses observed no differences between different types of prosthesis regarding complications (18, 19). However, disassembly of the radial head was found only in patients who received bipolar prostheses.

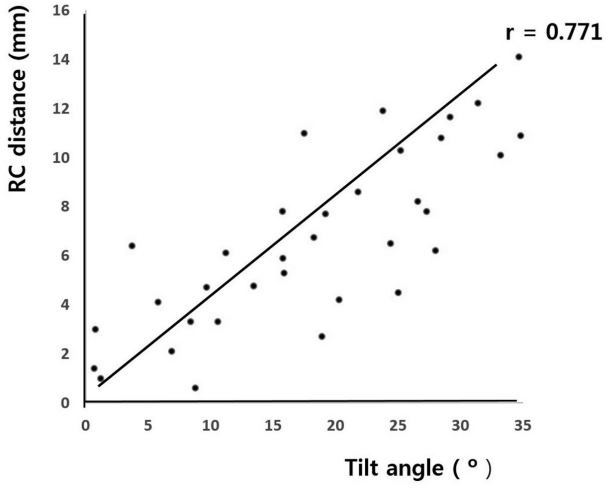

Figure 3. Correlation graphs showing a strong positive correlation between the tilt angle and radiocapitellar distance
r: Pearson correlation coefficient; RC: radiocapitellar

The radiocapitellar joint plays an important role in the maintenance of elbow stability in cases of compromised primary stabilizers, as observed for fracture dislocations of the elbow. Radiocapitellar stability depends on concavity compression forces, which are the functions of radiocapitellar contact (20). The effect of the radial head designs on the stability of the radiocapitellar joint has been studied biomechanically (12, 13). Moon et al. demonstrated that the monopolar metallic head and the native radial head behaved similarly concerning resistance to radiocapitellar subluxation (13). However, they reported that the bipolar head behaved in a manner entirely opposite to that of the native and monopolar heads and actually facilitated subluxation. They explained that tilting of the bipolar head occurred by initial joint subluxation. If the compression forces acted continuously on an inclined joint surface, the joint reaction force aggravated subluxation. In our radiological study, tilting of the bipolar head, ranging from slight to the maximum possible limit, was observed in all the patients, and a strong correlation was found between the tilt angle of the radial head and radiocapitellar subluxation. These findings support the idea that the mobility of the head, as noted for the bipolar design prosthesis, has an adverse effect on the concavity compression mechanism of the radiocapitellar stability. Clinically, once the limit of the bipolar tilt is reached, slippage or partial disengagement of the component can occur. This might happen under any unbalanced or eccentric loads applied to the surface of the mobile head (7, 9).

It would be clinically important to establish a possible correlation of the radiocapitellar distance as an associated sign of clinical instability after radial head arthroplasty. To our knowledge, studies to identify the threshold of the radiocapitellar distance implying clinical instability have not been reported. A biomechanical study with a cadaveric model showed that more than 4 mm posterior subluxation of the radial head could affect the radial head contact area and pressures (21). Another radiological study with 10 elbow dislocations described significant ulnohumeral joint instability

when the ulnohumeral distance was greater than or equal to 4 mm (14). Our data showed two-third of the patients had a radiocapitellar distance of more than 4 mm. This finding does not provide the threshold value of the radiocapitellar distance in defining instability. However, it is noteworthy that the radiocapitellar subluxation is common, and the distances vary from 1 to 17 mm after radial head arthroplasty. Our results support those of Yian et al., who found that more than half of their cadaveric specimens showed a significant amount of radiocapitellar subluxation after radial head arthroplasty (15).

Limitations of our study included the use of a single radiograph for measuring the tilt angle and the radiocapitellar distance. Various degrees of elbow flexion and forearm rotation might have affected the variables in this study. However, a standard lateral X-ray of the elbow joint is the most commonly used, and clinical interpretation is more useful and straightforward (14, 15). Next, our cases consisted of various injury patterns and types of management in addition to bipolar radial head arthroplasty. Associated soft tissue injuries and fractures and their management could contribute to radiocapitellar stability. It is possible that different types of elbow injury remain unstable until the constraint structures, including the radial head, are restored completely. Finally, radiologic instability might not be related to the clinical condition. Further studies about correlation between the tilted bipolar angle and clinical instability might be necessary.

In conclusion, our study demonstrated a strong correlation between the tilt angle of the radial head and radiocapitellar subluxation in patients who underwent bipolar radial head arthroplasty. An increase in the tilt angle of the bipolar radial head prosthesis was accompanied by an increase in the posterior subluxation of the radial head prosthesis. Our results also suggested that the tilt angle of the bipolar radial head prosthesis can be used as a radiological indicator of radiocapitellar instability.

Ethics Committee Approval: Ethics committee approval was received for this study from the Korea University Guro Hospital Institutional Review Board with reference number KUGHI3211.

Informed Consent: Informed consent was exempted from the IRB because of retrospective radiologic analysis.

Author Contributions: Concept - J.G.M.; Design - J.G.M.; Supervision -J.G.M.; Materials - Y.J.J., J.H.K., M.J.L.; Data Collection and/or Processing - Y.J.J., J.H.K., M.J.L.; Analysis and/or Interpretation - M.J.L., H.D.L.; Literature Search - J.H.K., M.J.L; Writing Manuscript - J.G.M., Y.J.J., J.H.K.; Critical Review - J.G.M., H.D.L.

Conflict of Interest: The authors have no conflicts of interest to declare.

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