Surgery Article

HAND
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DOI: 10.1177/1558944717745662
hand.sagepub.com

Comparison of Exposure in the Kaplan Versus the Kocher Approach in the Treatment of Radial Head Fractures

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Abstract

Background: The aim of this study was to compare the complete visible surface area of the radial head, neck, and coronoid in the Kaplan and Kocher approaches to the lateral elbow. The hypothesis was that the Kaplan approach would afford greater visibility due to the differential anatomy of the intermuscular planes. **Methods:** Ten cadavers were dissected with the Kaplan and Kocher approaches, and the visible surface area was measured in situ using a 3-dimensional digitizer. Six measurements were taken for each approach by 2 surgeons, and the mean of these measurements were analyzed. **Results:** The mean surface area visible with the lateral collateral ligament (LCL) preserved in the Kaplan approach was 616.6 mm^2 in comparison with the surface area of 136.2 mm^2 visible in the Kocher approach when the LCL was preserved. Using a 2-way analysis of variance, the difference between these 2 approaches was statistically significant. When the LCL complex was incised in the Kocher approach, the average visible surface area of the Kocher approach was 456.1 mm^2 and was statistically less than the Kaplan approach. The average surface area of the coronoid visible using a proximally extended Kaplan approach was 197.8 mm^2. **Conclusions:** The Kaplan approach affords significantly greater visible surface area of the proximal radius than the Kocher approach.

Keywords: coronoid, elbow, radial head, Kaplan approach, Kocher approach, posterior interosseous nerve

Introduction

In the treatment of radial head and neck fractures, the modified Kocher approach and the Kaplan approach are the 2 most common approaches used for access to the lateral elbow.[3] The Kocher approach centers on the posterolateral elbow and exploits the oblique interval between the anconeus and the extensor carpi ulnaris (ECU).[12] The standard Kocher approach involves incision of the lateral collateral ligament (LCL) to gain access to the radial head. However, the modified Kocher approach preserves the lateral ulnar collateral ligament (LUCL) by anterior retraction of the ECU. A capsulotomy can be then made anterior to the LUCL in order to preserve this important structure.[8,9,13] For distal extension of this approach, the radial collateral ligament (RCL)–annular ligament complex must be incised.

The Kaplan approach starts more anterior to the Kocher interval, between the extensor digitorum communis (EDC) and the extensor carpi radialis brevis (ECRB).[11] This allows a capsulotomy through the annular ligament anterior to the RCL-LUCL complex as well as distal extension without further compromise to the LCL and without extensive retraction. Despite these advantages to the Kaplan approach, some surgeons prefer to avoid it due to the proximity of the posterior interosseous nerve (PIN).[2,6,18,22]

The radial head is the most commonly fractured element in the adult elbow, and the fracture fragments are often anterior.[20] The radial head becomes a critical factor in elbow stability, especially if the coronoid is fractured as in the case of a terrible triad injury. Likewise, the coronoid is increasingly important for stability as other soft tissue and bony constraints are compromised around the elbow.[15,19] Therefore, coronoid fractures often need to be addressed concurrently with radial head fractures. If the radial head is not excised, access to the coronoid can be challenging. Alternative approaches, such as a separate medial incision, indirect posterior to anterior fixation, and extensile

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Supplemental material is available in the online version of the article.

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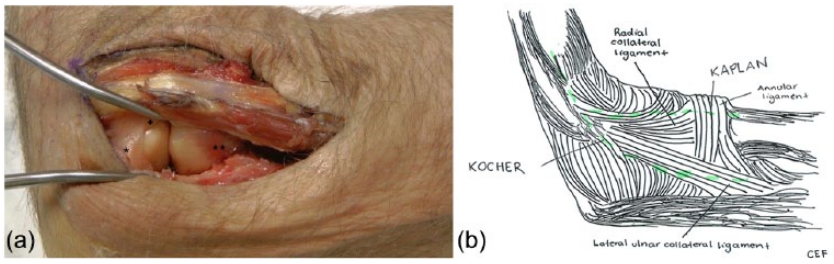

Figure 1. (a) Photo and (b) drawing of the dissection noting local anatomy: * denotes the lateral ulnar collateral ligament, ** denotes radial head, and + denotes radial collateral ligament retracted anteriorly.
Source. Figure 1b drawing courtesy of Christina Freibott (CEF).

approaches involving detachment of the extensor tendon complex, have been described for coronoid fixation in conjunction with the posterolateral Kocher approach. Therefore, it would be advantageous to explore ways to improve the visualization from the lateral capsulotomy used for the approach to the radial head, to possibly avoid additional dissection or as a tool for visualization when performing indirect posterior to anterior fixation.

The aim of this study was to compare the visible surface area of the radial head, neck, and coronoid in the Kocher and the Kaplan approaches. The hypothesis is that the more anterior Kaplan approach between the EDC and ECRB offers better exposure of the radial head, radial neck, and the coronoid than the posterolateral Kocher approach through the anconeus-ECU interval.

Materials and Methods

Ten fresh-frozen upper extremity cadavers were thawed to room temperature and dissections were performed under supervision from the senior author. First, a skin incision was made centered over the lateral epicondyle and then extended proximally up the humerus 2 cm and distally down the forearm 5 cm centered over the radiocapitellar joint. Next, either the Kaplan or the Kocher approach was performed depending on the specimen. Alternating the order of approach for dissection was done to control for any differences in tissue pliability.

The dissection for the modified Kocher approach was performed by finding the fat stripe at the anterior edge of the distinctly oblique anconeus muscle, and incising the interval between the anconeus and ECU from the lateral epicondyle to 4 cm distal to the radiocapitellar joint. Incision through the annular ligament and an anterior capsulotomy was performed to expose the proximal radius. Measurements of the surface area exposed were taken with a 3-dimensional (3-D) digitizer as described below. The RCL and accessory LCL were then incised and the Kocher interval approach was extended distally until limited by the anconeus, and the surface area of the proximal radius exposed was then measured and recorded.

The dissection for the Kaplan approach was performed by finding the interval between the EDC and ECRB, which was at the midpoint of the anterior radial head and typically found about 1.5 cm anterior to the Kocher interval. The capsule was then incised anterior to the RCL and LUCL, through the annular ligament (Figure 1). The proximal posterior edge of the superficial head of the supinator was elevated subperiosteally off of the radius and reflected anteriorly as a sleeve. The visible surface area of the radius was then measured with the 3-D digitizer as described below. After measurement of the surface area, the PIN was identified by direct dissection within the supinator muscle belly in all instances to confirm its location and preserved continuity. Distance from the radiocapitellar joint to the PIN was then measured and recorded.

The coronoid was exposed by extending the Kaplan deep dissection anterior to the origin of the ECRB, up between the brachioradialis and triceps muscle. The anterior joint capsule was elevated off of the anterior surface of the humerus in this plane. The surface area of the coronoid was then measured with the 3-D digitizer, and the majority of the origin of the common extensor tendons was not disturbed. From the Kocher interval, by contrast, it was not possible in this study to visualize the coronoid from the posterolateral starting point on the radial head and neck because the LCL was intact.

The visible surface area was measured in situ using a needle-point stylus attached to a 3-D digitizer[1] (Microscribe G2X, Solution Technologies Inc, Oella, Maryland) with the forearm in neutral and self-retaining retractors in place (Figure 2). The same retractors set at maximal tension were used in each case. The visible borders of the exposed surface were carefully traced following the outline defined by the muscle and bone edges. The accuracy of the tactile 3-D digitalization for capturing surface area with this technique has been reported as <0.3 mm, making it quite accurate.[1] Three measurements were made of all areas by both surgeons. The 6 topographical measurements were then processed in Rhinoceros software, and then the mean was used to create a digital rendering of the surface

Figure 2. Photo demonstrating cadaver set up with the Microscribe 3-dimensional digitizer.

area as well as to calculate the mean exposed area for each exposure (v5, McNeel software, Seattle, Washington). An analysis of variance (ANOVA) analysis was then used to compare the mean visible surface area of the proximal radius in the following approaches: Kocher approach with the LCL preserved, Kocher approach with the LCL incised, and the Kaplan approach. The Kocher approach was performed first on 5 of the cadavers, while the Kaplan approach was performed first on the other 5 cadavers. After measurement of the area of the first approach, the second approach was then performed so that both the Kaplan and Kocher approaches were performed in all 10 cadavers. The coronoid was not visible from any of these approaches, so the extensile Kaplan approach was performed, as described above, after all measurements were taken for the standard Kaplan and Kocher approaches, and the visible surface area of the coronoid was recorded. The level of significance was set at $p < .05$.

Results

The precision of the surface area measurements made by the investigators using the 3-D digitizer was ± 27 mm^2. The overall precision of 27 mm^2 was computed as the mean of all standard deviations for both experimenters. The intraclass correlation coefficient was excellent and was calculated to be 0.85. The intraobserver reliability was taken as the mean of all standard deviations by individual experimenter and was 29 mm^2 for Experimenter 1 and 24 mm^2 for Experimenter 2. The interrater reliability was 0.51.

The mean surface area of the radius visible for each measurement taken on all the cadavers in the Kaplan approach was 616.6 mm^2 ± 68.1 mm^2 (Figure 3 and Supplemental Figure S1) and was 456.1 mm^2 ± 25.5 mm^2 in the Kocher approach with the RCL incised (Figure 4). Using a 2-way ANOVA, the difference between these 2 approaches was statistically significant ($p < .05$). With the RCL intact, the average visible surface area of the radius was 136.2 mm^2 ± 31.1 mm^2 in the limited Kocher approach (Figure 5) and was statistically less than the other approaches. Average surface area of the coronoid visible from the proximally extended Kaplan approach was 197.8 mm^2 ± 48.4 mm^2 (Figure 6), but the coronoid was not visible from the Kocher approach at all (Table 1).

The PIN was 3.95 cm ± 0.55 mm from the radiocapitellar joint in the Kaplan approach on average and was entirely contained within the supinator muscle (Figure 7). There were no instances of visible injury to the nerve during dissection using subperiosteal elevation of the supinator muscle.

Discussion

This study showed that the Kaplan approach affords significantly greater visible surface area of the proximal radius than the Kocher approach, with or without the LCL complex intact. The Kaplan approach is more anterior between the EDC and the ECRB. The posterior edge of the supinator can be elevated off of the radius as a periosteal sleeve that is reflected anteriorly to contain and protect the PIN as it travels through the supinator muscle.[10] The distal extension of the Kaplan approach in this study was limited to 4 cm distal from the radiocapitellar joint in order to be consistent with the distal extension of the Kocher approach previously described, but as long as the PIN is identified and protected, there is no limit to the distal extension of the Kaplan approach into the forearm as it is a continuation of the Thompson approach to the dorsal radius. The current study compared the surface area of the radial head, neck, and shaft exposed in the two approaches for internal fixation or replacement and illustrated how the oblique angle of the anconeus limits distal exposure relative to the more anterior Kaplan approach and how this anatomy would be a disadvantage for internal fixation or replacement.

This study corroborated some of the findings of another recent study, but there were some differences.[5] Desloges et al reported on the percentage of the radial head articulation that was exposed in 2 lateral approaches to the elbow, rather than the visualized surface area of the radial head and proximal shaft. The approaches used in that study were also slightly different from the present study, in that the EDC splitting approach rather than the Kaplan approach was used. In that study, they similarly found that the more anterior approach, the EDC split, offered more visible articular surface area than the posterolateral modified Kocher approach.

Coronoid fractures are often seen in conjunction with radial head fractures and can compromise elbow stability if not

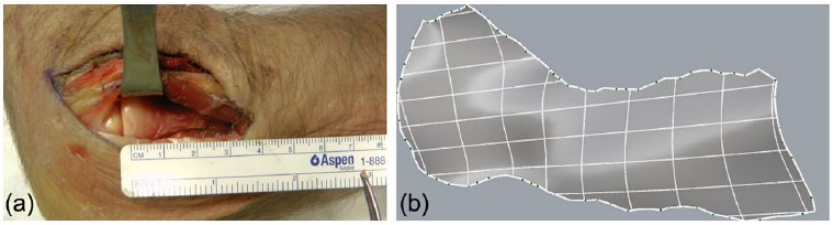

Figure 3. (a) Photo of the area visible from the Kaplan approach and (b) a digital rendering of the mapped surface area.

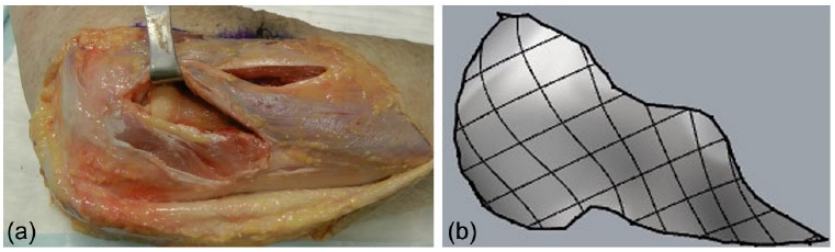

Figure 4. (a) Photo of the area visible from the extended Kocher approach with the radial collateral ligament incised and (b) a digital rendering of the mapped surface area.

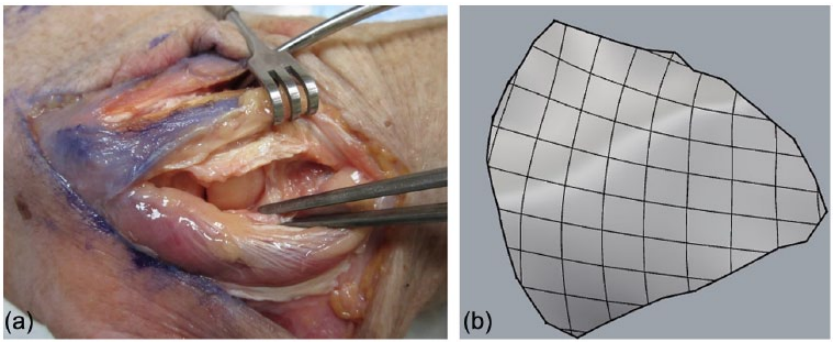

Figure 5. (a) Photo of the area visible from the limited Kocher approach with the radial collateral ligament intact and (b) a digital rendering of the mapped surface area.

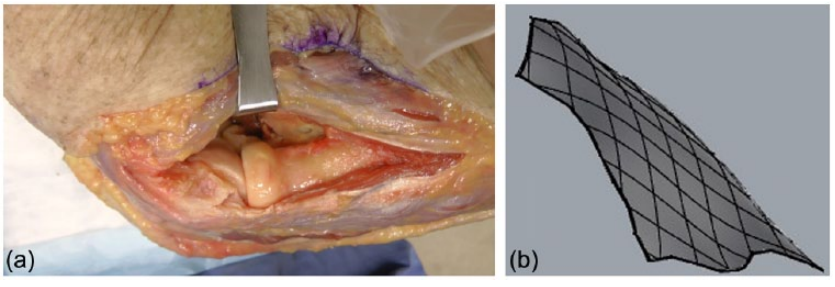

Figure 6. (a) Photo of the area of the coronoid visible from the proximally extended Kaplan approach and (b) a digital rendering of the mapped surface area. The tendon origin of the extensor digitorum communis is preserved, while the extensor carpi radialis brevis is divided and reflected anteriorly.

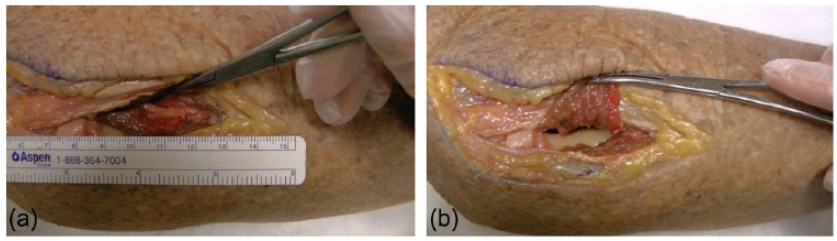

Figure 7. The posterior interosseous nerve was 3.95 cm ± 0.55 mm on average from the radiocapitellar joint in the Kaplan approach (a) and was located within the belly of the supinator muscle (b).

Table 1. Surface Area Visible of the Proximal Radius and Coronoid in the Kaplan, Kocher and Limited Kocher Approaches.

Approach	Surface area of the radius (mm^2)	SD	*P* value*	Coronoid exposure
Kaplan	616.6	± 68.1		197.8 mm^2 ± 48.4[a]
Kocher	456.1	± 25.5	*P* < .01	N/A
Limited Kocher	136.2	± 31.1	*P* < .01	N/A

**P* value reported for difference between the Kaplan approach and the others tested.
[a]Visible from the Kaplan approach extended proximally.

addressed concurrently.[15,19] In this study, almost 88% of the coronoid was visible from the Kaplan approach with the radial head intact by elevating the capsule off of the distal humerus and proximal ulna through the existing capsulotomy, but it was not visible from the Kocher interval, as it was too posterior and the LCL was intact.[14] Other authors have also described exposure of the coronoid from a lateral elbow approach but used different techniques. To expose the coronoid from the lateral side of the elbow, Desloges et al detached the EDC, the ECRB, the extensor carpi radialis longus, and the brachioradialis to achieve this through the extended EDC splitting approach, and they detached the ECU, EDC, and ECRB from the lateral epicondyle in the extended Kocher approach.[5] However, these and similar approaches which detach the extensor origin potentially further destabilize the elbow.[4,9,17] Other authors have acknowledged that the coronoid is not well visualized from the posterolateral Kocher approach without extensor detachment and therefore make a separate medial approach to the coronoid in cases where the radial head is not excised through the Kocher interval.[3,7,16] In contrast, the current study demonstrates substantial visualization of the coronoid using the Kaplan approach without disruption of the LCL or extensor mechanism even with the radial head intact.

The PIN was found to be 4 cm from the radiocapitellar joint on average in the Kaplan approach with the forearm in neutral rotation. This distance correlates with other studies.[18] This distance has been shown to be about 1 cm farther from the radiocapitellar joint in the Kocher approach.[6,22] However, the relationship of the PIN with forearm rotation is nearly eliminated in the case of radial neck fractures.[2] Therefore, the authors recommend visualization and protection of the PIN. The PIN in this study was always within the supinator muscle and was not visibly damaged when the proximal posterior edge of the muscle was elevated from the radial periosteum. However, traction injury could not be assessed. Further, the surgeon must be aware of anatomical variation in the course of the nerve.

A limitation of this study includes the small sample size. However, the level of significance and the post hoc power analysis confirm that the sample size was sufficient. When outlining the visualized surface area, we were limited by the ability to access the area with the stylus of the 3-D digitizer, which is similar to a ballpoint pen. However, we believe that this technique is clinically relevant as it simulates intraoperative access with instruments and is more accurate than other techniques which have relied on methylene blue staining or overlaying mesh to cut out to match and measure. Of course, absolute visualization may be less in a clinical scenario than in cadavers, but this interference should be consistent between both approaches used in the study. Tissue pliability may also be different with multiple approaches performed sequentially in the same specimen; however, the order of approaches was alternated to minimize bias and this was reflected in the excellent reliability coefficient of the measurements and high overall study precision. In addition, forearm rotation was not performed in this study but would be possible during surgery if desired once a stable construct was obtained.

This study showed that the Kaplan approach to the proximal radius, between the EDC and the ECRB, is valuable for maximizing visualization of the proximal radius and coronoid while preserving the LCL and extensor attachment. The Kaplan approach is the most extensile approach and affords greater visibility over the posterolateral Kocher approach,

which is limited by the oblique angle of the anconeus interval relative to the forearm and radius. The PIN lies within the boundaries of this approach, and the nerve can be visualized and protected within the supinator as the muscle is elevated subperiosteally from the proximal radius.[21] Proximal extension of Kaplan approach via the relatively anterior capsulotomy made in the EDC-ECRB interval also affords good visibility of the coronoid process from the lateral elbow even when the radial head is intact, without destabilizing the elbow.

In summary, this study demonstrated that the Kaplan approach affords significantly greater visible surface area of the proximal radius than the Kocher approach.

Acknowledgment

The authors acknowledge Charlie Yongpravat for his assistance with technical support.

Ethical Approval

Ethical approval was not sought as this is a cadaveric study.

Statement of Human and Animal Rights

This article does not contain any studies with human or animal subjects.

Statement of Informed Consent

Informed consent was not sought as this is a cadaveric study.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This study was funded by a research grant (Grant ID:13-002) from the Orthopaedic Scientific Research Foundation (OSRF).

References

1. Boldt F, Weinzierl C, Hertrich K, et al. Comparison of the spatial landmark scatter of various 3D digitalization methods. *J Orofac Orthop*. 2009;70(3):247-263. doi:10.1007/s00056-009-0902-2.
2. Calfee RP, Wilson JM, Wong AH. Variations in the anatomic relations of the posterior interosseous nerve associated with proximal forearm trauma. *J Bone Joint Surg Am*. 2011;93(1):81-90. doi:10.2106/JBJS.I.01242.
3. Cheung EV, Steinmann SP. Surgical approaches to the elbow. *J Am Acad Orthop Surg*. 2009;17(5):325-333.
4. Cohen MS, Hastings H II. Rotatory instability of the elbow. The anatomy and role of the lateral stabilizers. *J Bone Joint Surg Am*. 1997;79(2):225-233.
5. Desloges W, Louati H, Papp SR, et al. Objective analysis of lateral elbow exposure with the extensor digitorum communis split compared with the Kocher interval. *J Bone Joint Surg Am*. 2014;96(5):387-393. doi:10.2106/JBJS.M.00001.
6. Diliberti T, Botte MJ, Abrams RA. Anatomical considerations regarding the posterior interosseous nerve during posterolateral approaches to the proximal part of the radius. *J Bone Joint Surg Am*. 2000;82(6):809-813.
7. Garrigues GE, Wray WH III, Lindenhovius AL, et al. Fixation of the coronoid process in elbow fracture-dislocations. *J Bone Joint Surg Am*. 2011;1993(20):1873-1881. doi:10.2106/JBJS.I.01673.
8. Husband JB, Hastings H II. The lateral approach for operative release of post-traumatic contracture of the elbow. *J Bone Joint Surg Am*. 1990;72(9):1353-1358.
9. Imatani J, Ogura T, Morito Y, et al. Anatomic and histologic studies of lateral collateral ligament complex of the elbow joint. *J Shoulder Elbow Surg*. 1999;8(6):625-627.
10. Jockel CR, Zlotolow DA, Butler RB, et al. Extensile surgical exposures of the radius: a comparative anatomic study. *J Hand Surg Am*. 2013;38(4):745-752. doi:10.1016/j.jhsa.2012.12.029.
11. Kaplan EB. Surgical approaches to the proximal end of the radius and its use in fractures of the head and neck of the radius. *J Bone Joint Surg*. 1941;23:86.
12. Kocher T. Operations at the elbow. In Kocher T, ed. *Text-Book of Operative Surgery*. New York, NY: Macmillan; 1911:313
13. Mansat P, Morrey BF. The column procedure: a limited lateral approach for extrinsic contracture of the elbow. *J Bone Joint Surg Am*. 1998;80:1603-1615.
14. Matzon JL, Widmer BJ, Draganich LF, et al. Anatomy of the coronoid process. *J Hand Surg Am*. 2006;31(8):1272-1278. doi:10.1016/j.jhsa.2006.05.010.
15. O'Driscoll SW, Jupiter JB, Cohen MS, et al. Difficult elbow fractures: pearls and pitfalls. *Instr Course Lect*. 2003;52:113-134.
16. Ring D, Jupiter JB. Surgical exposure of coronoid fractures. *Tech Shoulder Elbow Surg*. 2002;3(1):48-56. doi:10.1097/00132589-200203000-00010.
17. Ruchelsman DE, Tejwani NC, Kwon YW, et al. Open reduction and internal fixation of capitellar fractures with headless screws. Surgical technique. *J Bone Joint Surg Am*. 2009;91(Suppl 2, Pt 1):38-49. doi:10.2106/JBJS.H.01195.
18. Schimizzi A, MacLennan A, Meier KM, et al. Defining a safe zone of dissection during the extensor digitorum communis splitting approach to the proximal radius and forearm: an anatomic study. *J Hand Surg Am*. 2009;34(7):1252-1255. doi:10.1016/j.jhsa.2009.04.026.
19. Schneeberger AG, Sadowski MM, Jacob HA. Coronoid process and radial head as posterolateral rotatory stabilizers of the elbow. *J Bone Joint Surg Am*. 2004;86:975-982.
20. Tornetta P, Hochwald N, Bono C, et al. Anatomy of the posterior interosseous nerve in relation to fixation of the radial head. *Clin Orthop Relat Res*. 1997(345):215-218.
21. van Leeuwen DH, Guitton TG, Lambers K, et al. Quantitative measurement of radial head fracture location. *J Shoulder Elbow Surg*. 2012;21(8):1013-1017. doi:10.1016/j.jse.2011.08.056.
22. Witt JD, Kamineni S. The posterior interosseous nerve and the posterolateral approach to the proximal radius. *J Bone Joint Surg Br*. 1998;80(2):240-242.