Coronoid reconstruction with an osteochondral radial head graft

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CORONOID RECONSTRUCTION WITH AN OSTEOCHONDRAL RADIAL HEAD GRAFT

Running title: Radial head graft for coronoid deficiency

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No disclosures for any author related to the subject of this paper.

This study was not supported by any outside funding or grants. The Mayo Clinic IRB that convened on October 10, 2011 approved the project, entitled "General Radiologic Patterns of Elbow Injury." (IRB protocol number 11-002988).

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ABSTRACT

Background. Chronic coronoid deficiency can occur subsequent to coronoid fracture malunion/nonunion or to coronoid hypoplasia or dysplasia resulting from injury during development. Several surgical options have been described to treat this difficult condition, but results are equivocal. We hypothesized that a modified coronoid reconstruction using a radial head osteochondral graft could restore elbow stability and congruity and that a technique involving rigid internal fixation would promote graft union.

Methods. The coronoid was reconstructed using an osteochondral fragment from a frozen allograft radial head in 3 young patients affected by complex posttraumatic elbow instability and incongruity due to coronoid deficiency. To promote bone healing, the fragment was kept as large as could be fitted in place, the cut surface compressed onto the remaining coronoid was as large as possible, the medial portion of the radial head (containing dense bone) was used and 3 lag screws were inserted in different directions.

Results. At a mean follow-up of 26 months all 3 patients achieved a painless, congruent stable joint, with a functional range of motion. CT scans performed 3 months after surgery showed complete union of the graft in all the patients. Each patient rated himself as either "Almost normal" or "Greatly improved" on the Subjective Outcome Determination scale.

Conclusion. Coronoid reconstruction with a radial head osteochondral allograft was successful in restoring stability and function in chronically unstable elbows with coronoid deficiency. Strong fixation using a large segment of the medial radial head achieved rapid graft healing.

Keywords: coronoid deficiency, posttraumatic elbow instability, posttraumatic elbow incongruity, coronoid reconstruction, osteochondral graft, radial head, graft union.

Treatment study, level of evidence IV.

INTRODUCTION

The coronoid process has a key role in elbow stability[5, 6, 16-18, 30] and its injuries are associated with complications relating to instability or incongruity[20, 26-29]. In the setting of chronic coronoid deficiency the surgeon may have to deal with persistent dislocation and/or early degenerative changes. Chronic deficiency can be due to malunion/nonunion of a coronoid fracture or even loss of bone fragments that may have been discarded during the previous surgical treatment[24]. In all these chronic scenarios, usually the coronoid fragment size and quality are not sufficient to allow revision of the fixation. Coronoid hypoplasia or dysplasia can also occur from injury to the coronoid during development, as may occur with a childhood dislocation.

Various techniques for coronoid reconstruction using bone or osteochondral grafts have been described[2-4, 7, 10-12, 14, 15, 22, 24, 25, 31-33], although no clear evidence exists to establish superiority of any particular technique. The aim of this paper is to describe our current surgical technique to reconstruct the coronoid and to describe the mid-term results of three patients treated with this technique.

Surgical technique

Usually a medial skin incision is made, looking for any branches of the medial antebrachial cutaneous nerve and trying to preserve them. A medial Hotchkiss approach is made through the anterior three-quarters of the common flexor pronator origin and down onto the anterior bundle of the medial collateral ligament. The capsule is opened and the coronoid is exposed. The coronoid bed is then prepared with a microsagittal saw, making a flat surface onto which the graft can be placed. Whenever the patient's radial head has to be excised (e.g. to place

a prosthesis), the graft can be autogenous; otherwise an allograft can be used. The radius is lined up with the ulna such that the articular surface of the radial head, which would normally articulate with the radial notch of the ulna, lies where the original coronoid was and is tangential to the surface of the trochlea. This typically requires the radius to be tilted slightly as shown in Figure 1. A cut is made part way across the radial head/neck in line with the flat surface of the coronoid bed. Before completing that cut, the portion of the radial head that projects anteriorly out into the brachialis is trimmed off. This renders the graft less bulky and easier to place. Then the initial osteotomy at the head/neck junction is completed. The graft can be placed in two different positions. For a deficiency of the tip of the coronoid, it articulates with the central concave portion of the trochlea (Fig 2A). If the deficiency involves the anteromedial coronoid[20], the graft can be placed more medially so that it articulates with the medial portion of the trochlea (Fig 2B). In order to correctly position the graft, the elbow is flexed at 90° and the ulna must be firmly compressed against the humerus for anatomic reduction. The graft is compressed against the trochlea and fixed temporarily with a K-wire from its anteromedial side. Typically two retrograde screws and one antegrade screw are used. A targeted guide is used to fix the graft with the two retrograde 3.5 lag screws (one lateral and one centro-medial) through the ulna from its subcutaneous border. One screw is inserted directly on the border of the ulna, the other on the lateral side of the border (the medial side is steeper). Directing the screws parallel to the articular surface or in a slight distal to proximal orientation reduces the risk of hitting the trochlear surface. The medial edge of the graft is trimmed off so that it does not extend medially into the flexor-pronator origin. Then the antegrade headless screw is placed from the anteromedial side into the ulna (Fig 3). Once the graft has been secured and confirmed so that it articulates well with the trochlea, the rest of the procedure can be completed (e.g. radial head replacement or

lateral collateral ligament reconstruction). Primarily, we suggest that the coronoid has to be addressed as first step[23]. The fixation is adequately rigid that a hinged external fixator is not needed.

Postoperatively the patient is immobilized for 3 weeks in a cast to protect the ligament reconstruction. A removable splint, taken off to do gentle range of motion (ROM) exercises in the overhead position, is used for 3 weeks further. The patient typically weans off the splint over the next 6 week, depending on stability and mobility of the elbow.

Clinical cases

Case 1

A 20-year-old female Paralympic swimmer was treated at our institution for chronic coronoid deficiency due to hypoplasia or dysplasia of the coronoid, chronic posterior subluxation of the radial head with both varus posteromedial rotatory instability (PMRI) and recurrent posterolateral rotatory instability (PLRI). The patient, affected by an unspecified chromosomal abnormality, had bilateral lateral condyle fractures at about age 5 and then developed bilateral instability treated 4 years later with bilateral lateral collateral ligament (LCL) reconstructions which were revised 7 years later for recurrent dislocations. At the time of our evaluation she complained of recurrent left elbow dislocations, pain and limitation of motion. On physical examination alignment was normal and the ROM was 40°-120° of flexion (the lack of extension was partially due to the patient's fear of elbow dislocation). Her posterolateral rotatory apprehension test[19] was dramatically positive, but it was impossible to perform the PLRI tests because of her guarding. The posterolateral rotatory drawer test[21] on the opposite elbow was positive. CT scan revealed a severely deficient hypoplastic coronoid (Fig. 4A,B), a significant

93 degree of joint dysplasia and chronic posterior subluxation of the radial head, which was
94 deformed and tilted.

95 Surgery was performed through both the previous lateral incision and a medial Hotchkiss
96 approach. A frozen radial head osteochondral allograft (Fig. 4C) was used to reconstruct the
97 absent anteromedial coronoid as described above. The tilt and dysplastic shape of the radial head
98 was corrected by an intra-articular opening wedge osteotomy of the anterior half of the radial
99 head, and held open with a slice of cancellous bone allograft. The posterior subluxation of the
100 radial head on the capitellum was corrected by an anterior opening wedge ulnar osteotomy that
101 was fixed with a 6-hole locking plate. The dysplastic posterior rim of the radial notch was
102 restored by a soft tissue notchplasty using a portion of the gracilis allograft. The LCL was then
103 reconstructed with a gracilis allograft.

104 The patient returned to swimming 3 months after surgery when x-rays and CT scan
105 showed union of both the osteotomies and the graft (Fig 4C). Thirty-one months after surgery the
106 patient had no pain and scored herself as “Almost Normal” (9/10) on the Summary Outcome
107 Determination (SOD) scale[1, 8]. The ROM was 30°-140° of flexion and 65°-90° of
108 pronation/supination. Radiographs showed the elbow to be congruent with no evidence of graft
109 resorption or degenerative changes.

110

111 Case 2

112 Two years following trauma to the left elbow, resulting in an isolated coronoid fracture
113 that was treated non-surgically, a 14-year-old female gymnast presented with painful
114 posteromedial rotatory instability due to an anteromedial subtype 2[20] coronoid nonunion (Fig
115 5A) associated with recurrent PLRI. Upon presentation to our institution she had 10° of cubitus

varus, full elbow motion and positive posterolateral rotatory drawer and lateral pivot-shift tests for PLRI.

A medial Hotchkiss approach was made to the coronoid nonunion, which was identified and mobilized but not big enough to be fixed. A frozen radial head allograft was used to reconstruct the coronoid process as described above. Through a lateral Kocher skin incision the LCL was reconstructed with a split semitendinosus allograft.

At 3 months after surgery the elbow was stable and pain-free, the ROM was 20° to 110° of flexion and the CT scan revealed that the radial head allograft was healed and ulnohumeral congruity had been restored (Fig 5B). Twenty-one months after surgery the patient underwent removal of the two retrograde screws which continued to bothered her on the subcutaneous border of the ulna: then the elbow was pain-free and the ROM was 0° to 125° degrees of flexion. Radiographs performed just before screw removal showed the elbow joint to be congruent without resorption or degenerative changes. The nonunited coronoid fragment that had been displaced anteriorly was prominent and presumably impinging against the humerus in flexion, but the patient did not wish to have surgery to remove it or to improve motion. Twenty-four months after surgery the patient had no pain and scored herself as “Greatly improved” (8/10) on the SOD scale.

Case 3

A 25 year-old woman was referred for treatment of severe recurrent PLRI and PMRI associated with coronoid and radial head dysplasia (Fig 6A). The instability episodes happened dozens of times per day, each time she fully extended the elbow or tried to push with the outstretched hand, and were painful and disabling. She had learned to minimize the use of her

left hand in order to prevent these painful episodes. The dysplasia resulted from repeated subluxations and dislocations during development following an injury at age 6 that left her with a coronoid malunion. The nature of the injury was not clear, as her parents were not available. On physical examination, she had moderate cubitus varus and full ROM, but guarded against letting the elbow fully extend. She had markedly positive signs for PLRI, including dramatically positive posterolateral rotatory apprehension sign, posterolateral rotatory drawer test, lateral pivot-shift test and chair test[9]. There were both varus laxity and pseudolaxity due to combined lateral soft tissue laxity and medial bone deficiency. The elbow was so unstable that she dislocated spontaneously while performing the MRI (Fig 6B). CT scan showed dysplasia of the coronoid with complete anteromedial deficiency, shallow trochlear notch of the ulna, posterior subluxation of a dysplastic radial head with angulation of the radial neck, posterior capitellar impaction defect and a shallow dysplastic radial notch of the ulna.

A medial Hotchkiss approach was made, the coronoid nonunion was identified and excised and a radial head allograft was used to reconstruct the coronoid process. Through a lateral Kocher approach, the defect in the capitellum was filled with the remaining portion of the allograft radial head and fixed with 2 screws. Finally the LCL was reconstructed with a split semitendinosus allograft.

A CT scan taken 6 months postoperatively (Fig 6C) revealed complete union of the allograft radial head to the coronoid and incorporation of the allograft in the posterior capitellum. Two years after surgery the patient underwent removal of the retrograde screw which continued to bother her on the subcutaneous border of the ulna. At most recent follow-up, 26 months postoperatively (Fig 6D), she was pain-free with no symptoms of instability nor had she experienced any instability episodes since her surgery. She rated herself as “Almost normal” and

9/10 on the SOD scale. Physical examination revealed a negative posterolateral rotatory apprehension sign, lateral pivot-shift test and chair test. Posterolateral rotatory drawer testing revealed mild laxity similar to that in the opposite elbow and the motion was 10°-150° of flexion and 80°-80° of pronation-supination.

DISCUSSION

Coronoid deficiency, both in the acute and chronic setting, is challenging even for the most experienced orthopedic surgeon. This paper describes the senior author's surgical technique and the midterm outcomes of three patients who underwent this type of treatment. Each patient regained a stable pain-free elbow with functional ROM and union of the graft documented by CT scan without evidence of graft resorption or degenerative changes. Although various methods for coronoid reconstruction have been reported, the results have been unpredictable and sometimes poor[23, 25, 32] leading some authors to question the role of a bone graft[25]. This is the first report that incorporates CT scanning to determine bone healing. Some authors showed only x-rays in which it is difficult to assess bone union[4, 15] and other authors admitted they were unable to comment on union of the graft in the absence of CT scans[24]. Other authors did not even mention union of the graft to the ulna[11, 12, 22]. We strongly believe that, for a coronoid reconstruction to be successful, the graft must not resorb and that the risk of resorption is lower if the graft heals.

Among the surgical options in the literature, the techniques involving allograft or residual autogenous osteochondral portions of the radial head are the most commonly reported to treat coronoid deficiency[2, 3, 7, 11, 13, 24, 25, 32]. Esser, et al.[7], described a 31-year-old patient with a posterior dislocation and comminuted fractures of the radial head and proximal ulna, including a basal transolecranon fracture of the coronoid. The coronoid was reconstructed using the concave proximal articular surface of the radial head. At 6 months follow-up, the elbow was pain-free and stable, lacking 8° of extension. Chen, et al.[3], reported a case of neglected posterior elbow dislocation whose deficient coronoid was reconstructed with a fragment of patient's excised radial head. The authors did not describe details concerning orientation or fixation of the graft. At 3 months follow-up the patient reported improvement, but with residual limitation of elbow

ROM. Van Riet, et al.[32], reported on 6 patients, treated with the first version of the senior author's technique, with a mean follow-up of 64 months. All the patients had persistent posterior subluxation with coronoid deficiencies or non-fixable nonunions. Results were excellent in 1, good in 2, fair in 1 and poor in 2 patients. The graft definitely resorbed in one patient, although graft union was difficult to assess on plain radiographs. Three patients required additional surgery (one LCL reconstruction, one skin release of irritated external fixator pin sites, one total elbow arthroplasty 7 years after surgery). Ring, et al.[24], reported 8 patients who underwent surgical reconstruction, after acute/subacute trauma, with the concave proximal articular surface of the radial head. The coronoid fracture involved between 30% and 100% of its height: 4 patients had a terrible triad injury (all with a coronoid tip fracture[20]) and 4 had a posterior olecranon fracture-dislocation (all with a basal coronoid fracture[20]). The length of follow-up was not specified. The 4 patients with terrible triad injuries were rated excellent. Of the 4 basal coronoid deficiencies, 1 was rated good and 3 fair. Three of the patients with posterior olecranon fracture-dislocations had persistent ulnohumeral subluxation.

The technique used in our patients differs from that reported by Ring, et al.[24], in several aspects. The main difference is the graft orientation. Ring reproduces the most medial portion of the coronoid taking advantage of the concavity of the proximal surface of the graft. Alternatively, we placed the annular convex surface of the radial head against either the central concave surface or the medial portion of the trochlea. Neither technique completely restores the native shape of the coronoid, but stability appears to be accomplished with either method. Ring fixes the graft with only one screw. We use 3 screws at different angles to achieve rigid fixation, including in the anteromedial portion, which bears more load in varus. Ring suggests that the lateral exposure is adequate to place the graft and the added medial dissection is not worthwhile.

This might be possible if only one screw is being used, but, in our experience, it is easier to ensure correct position and orientation of the graft and accomplish rigid fixation through a medial approach. Ring suggests that the hinged external fixator should not be omitted. Previously, we used an external fixator at the end of this procedure, but we no longer do so for three reasons. First, improved fixation of the graft makes it less important. Second, it adds time to the operation. Third, pin site problems may occur with hinged fixators at the elbow.

The technique we describe is the result of the senior author's experience in coronoid reconstruction over the course of many years and with many types of autogenous and allogenic grafts. These have included bicortical and tricortical iliac crest, olecranon tip, radial head, coronoid and femoral head. Based on our clinical experience thus far, we believe the radial head shows the most promise. It is osteochondral and provides a large enough piece of good quality bone that can be rigidly fixed. It also can be prepared with a wide flat surface in contact with the ulna. This affords excellent initial stability, which also favors bone union. Either its convex or concave surface can be used; it can be easily harvested often without performing an additional approach; it can be used both as an allograft and as an autograft. The use of the radial head has already been previously described by the senior author[23, 32], but the unpredictable outcomes lead him to modify the technique. Initially, an oblique osteotomy of the graft was performed such that it was tilted distally and the graft was placed so that the lateral surface of the head/neck junction would articulate against the trochlea. The position of the graft in the mediolateral plane can vary depending on the type of coronoid deficiency: in cases of a deficient anteromedial coronoid it might be more important to support the medial side of the joint instead of reconstructing the coronoid tip. With the current technique the graft is placed so that the medial articular cartilage portion of that radial head articulates against the trochlea and the graft is tilted slightly in the

opposite direction. These modifications were made to permit the use of a larger piece of bone that would permit improved fixation and a larger surface area of contact with the native ulna, thereby hopefully improving the likelihood of bone union. We believe that graft resorption is unlikely if bone union is accomplished and the graft is subjected to loading. Also, the medial portion of the graft typically shows higher bone quality and it is characterized by articular cartilage. The technique has now been standardized and 3 screws inserted with different directions are used. Proof of this concept is provided by the CT scans showing complete bony union 3 months postoperatively in all 3 cases with this technique.

This report has limitations. It includes only 3 patients and they were young: further investigations are needed to evaluate graft healing in older patients whose bone quality is lower. Also, the elbows did not have degenerative changes at the time of reconstruction, even though such degenerative changes are often present in cases of coronoid deficiency.

CONCLUSION

Coronoid reconstruction has to be considered as a salvage procedure when the coronoid is deficient. Our clinical results and documented rapid complete union of the graft to the remaining coronoid support the use of the convex articular surface of the radial head allograft as a valid option.

REFERENCES

1 Blonna D, Lee GC, O'Driscoll SW. Arthroscopic Restoration of Terminal Elbow Extension In High Level Athletes. Am J Sports Med 2010;38:2509-2515. 10.1177/0363546510376727

2 Bopp F, Tielemann FW, Holz U. [Elbow dislocation with fracture of the coronoid process and comminuted fracture of the radius head]. Unfallchirurg 1991;94:322-324.

3 Chen CY, Chao EK, Lee SS. Augmentation of elbow stability with radial head transfer: a case report and review of the literature. Changgeng Yi Xue Za Zhi 1996;19:83-89.

4 Chung CH, Wang SJ, Chang YC, Wu SS. Reconstruction of the coronoid process with iliac crest bone graft in complex fracture-dislocation of elbow. Arch Orthop Trauma Surg 2007;127:33-37. 10.1007/s00402-006-0198-2

5 Closkey RF, Goode JR, Kirschenbaum D, Cody RP. The role of the coronoid process in elbow stability. A biomechanical analysis of axial loading. J Bone Joint Surg Am 2000;82-A:1749-1753.

6 Doornberg J, Ring D, Jupiter JB. Effective treatment of fracture-dislocations of the olecranon requires a stable trochlear notch. Clin Orthop Relat Res 2004:292-300.

7 Esser RD. Reconstruction of the coronoid process with a radial head fragment. Orthopedics 1997;20:169-171.

8 Finkbone PR, O'Driscoll SW. Box-loop ligament reconstruction of the elbow for medial and lateral instability. J Shoulder Elbow Surg 2015;24:647-654. 10.1016/j.jse.2014.12.008

9 Gardner RC. Tennis elbow: diagnosis, pathology and treatment. Nine severe cases treated by a new reconstructive operation. Clin Orthop Relat Res 1970;72:248-253.

10 Hall RM. Recurrent posterior dislocation of the elbow joint in a boy. J Bone Joint Surg Br 1953;35-B:56.

11 Kalicke T, Muhr G, Frangen TM. Dislocation of the elbow with fractures of the coronoid process and radial head. Arch Orthop Trauma Surg 2007;127:925-931. 10.1007/s00402-007-0424-6

12 Kohls-Gatzoulis J, Tsiridis E, Schizas C. Reconstruction of the coronoid process with iliac crest bone graft. J Shoulder Elbow Surg 2004;13:217-220.

13 Meeder PJ, Holz U. [Replacement-plasty of the coronoid process in unstable elbow joint dislocations with avulsion fracture of the coronoid process and radius head crush fracture]. Aktuelle Traumatol 1985;15:89-90.

14 Milch H. Bilateral recurrent dislocation of the ulna at the elbow. J Bone Joint Surg Am 1936;18:777-780.

15 Moritomo H, Tada K, Yoshida T, Kawatsu N. Reconstruction of the coronoid for chronic dislocation of the elbow. Use of a graft from the olecranon in two cases. J Bone Joint Surg Br 1998;80:490-492.

16 Morrey BF, An K-N. Articular and ligamentous contributions to the stability of the elbow joint. Am J Sports Med 1983;11:315-319.

17 Morrey BF, An KN. Stability of the elbow: osseous constraints. J Shoulder Elbow Surg 2005;14:174S-178S. 10.1016/j.jse.2004.09.031

18 [redacted]

19 [redacted]

20 [redacted]

21 [redacted]

22 Okazaki M, Takayama S, Seki A, Ikegami H, Nakamura T. Posterolateral rotatory instability of the elbow with insufficient coronoid process of the ulna: a report of 3 patients. J Hand Surg [Am] 2007;32:236-239.

23 [redacted]

24 Ring D, Guss D, Jupiter JB. Reconstruction of the coronoid process using a fragment of discarded radial head. J Hand Surg Am 2012;37:570-574. 10.1016/j.jhsa.2011.12.016

25 Ring D, Hannouche D, Jupiter JB. Surgical treatment of persistent dislocation or subluxation of the ulnohumeral joint after fracture-dislocation of the elbow. J Hand Surg [Am] 2004;29:470-480.

26 Ring D, Jupiter JB. Fracture-dislocation of the elbow. J Bone Joint Surg Am 1998;80:566-580.

27 Ring D, Jupiter JB. Fracture-dislocation of the elbow. Hand Clin 2002;18:55-63.

28 Ring D, Jupiter JB, Zilberfarb J. Posterior dislocation of the elbow with fractures of the radial head and coronoid. J Bone Joint Surg Am 2002;84-A:547-551.

29 Saati AZ, McKee MD. Fracture-dislocation of the elbow: diagnosis, treatment, and prognosis. Hand Clin 2004;20:405-414. 10.1016/j.hcl.2004.06.005

30 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-A:975-982.

31 Silveira GH, Bain GI, Eng K. Reconstruction of coronoid process using costochondral graft in a case of chronic posteromedial rotatory instability of the elbow. J Shoulder Elbow Surg 2013;22:e14-18. 10.1016/j.jse.2013.01.015

32 [redacted]

33 Wainwright D. Recurrent dislocation of the elbow-joint. Proc R Soc Med 1947;40:885.

336 **LEGENDS**

337 Fig. 1. The medial articular portion of the radial head is placed tangential to the trochlear
338 surface. To restore the tangent of the coronoid, the radial head is tilted slightly proximally.
339 Fig. 2. Two options for the positioning of the graft in the medio-lateral plane. A: the graft
340 articulates with the central concave portion of the trochlea. B: the graft articulates with the
341 medial portion of the trochlea.
342 Fig. 3. Illustration (A) and intraoperative photograph (B) showing the fixation of the graft (with
343 two retrograde screws and one headless anteromedial screw). The graft was trimmed to remove
344 the distal and anteromedial prominences.
345 Fig. 4. Case 1. A-B: preoperative CT scan showing a deficient hypoplastic coronoid. C: 3-
346 months postoperative CT scan revealing ulnohumeral congruity and graft healing.
347 Fig. 5. Case2. A: preoperative CT scan reveals an Anteromedial coronoid fracture with
348 involvement of the tip. B: 3-months postoperative CT scan revealing ulnohumeral congruity and
349 graft healing; the arrows indicate the height of the graft.
350 Fig. 6. Case 3. A: preoperative x-rays; note the absence of any subchondral line indicating a
351 severe coronoid deficiency. B: preoperative MRI showing spontaneous posteromedial rotatory
352 dislocation. C: 6-months postoperative CT scan revealing ulnohumeral congruity and graft
353 healing. D: radiographs showing the maintenance of joint reduction and the absence of
354 degenerative changes.
355

Figure 1

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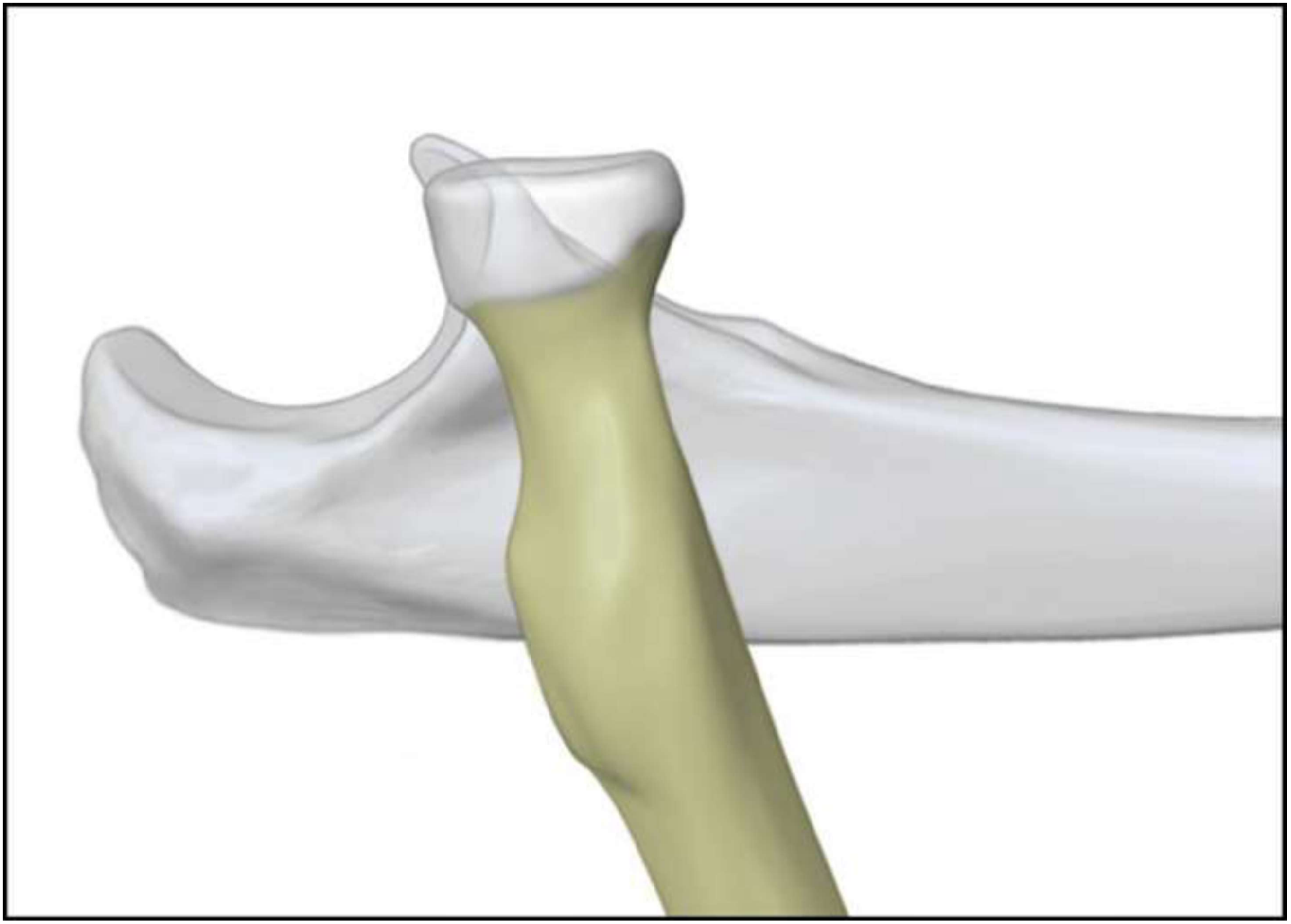

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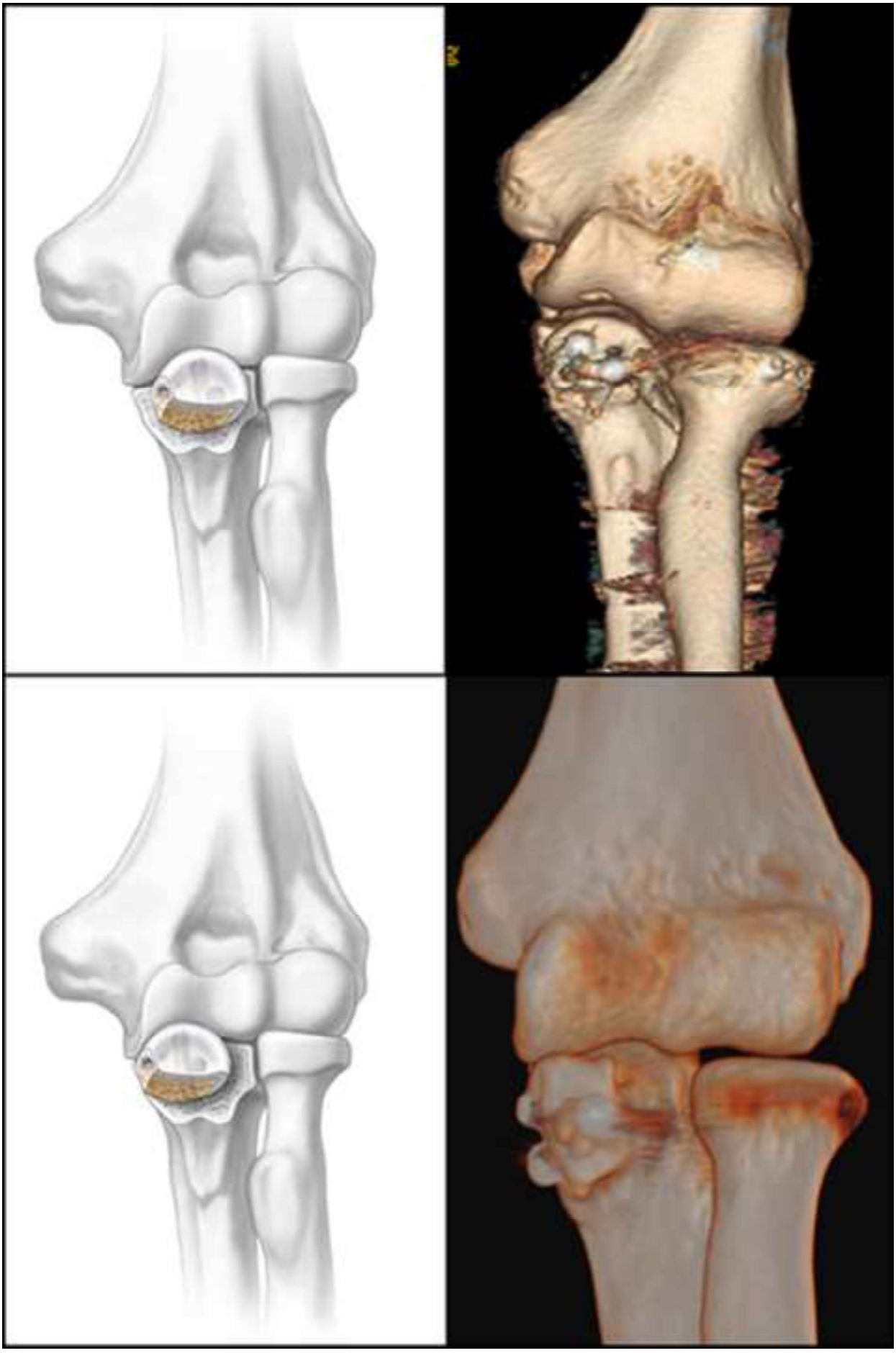

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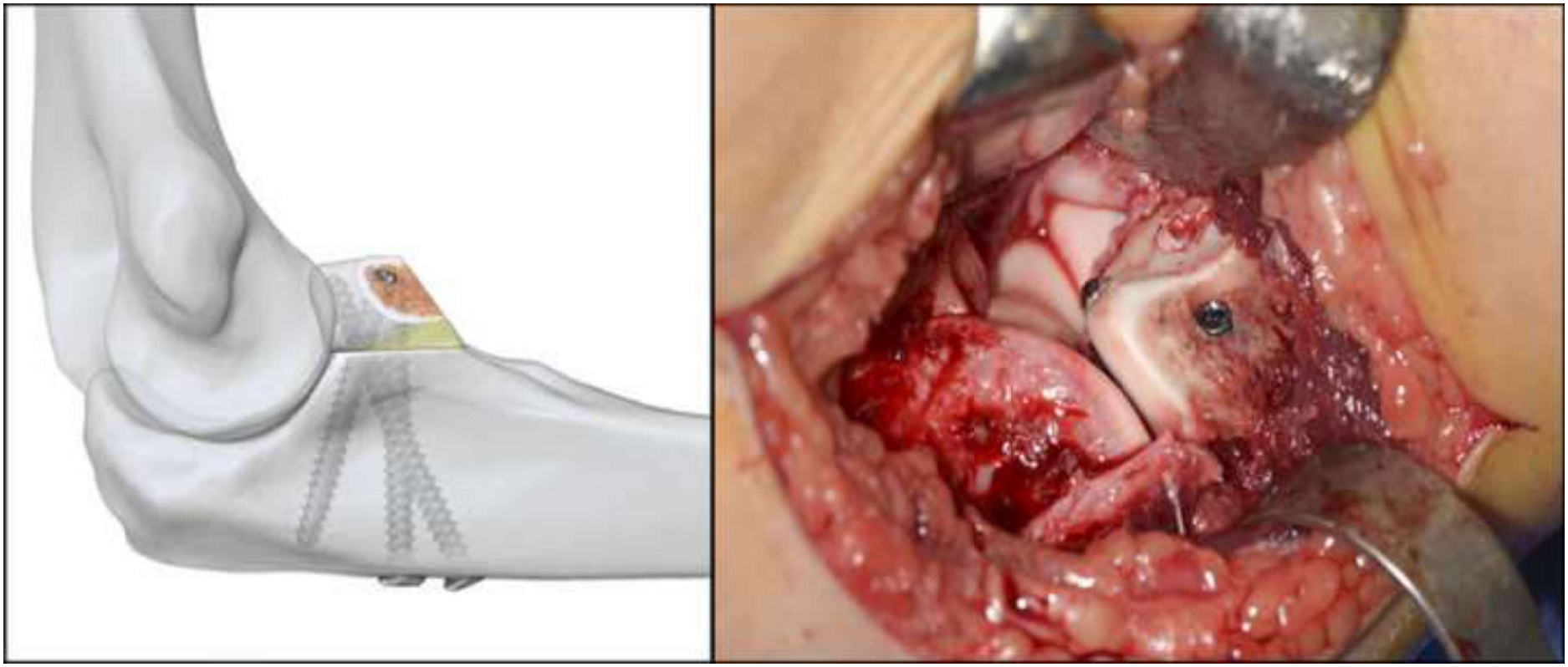

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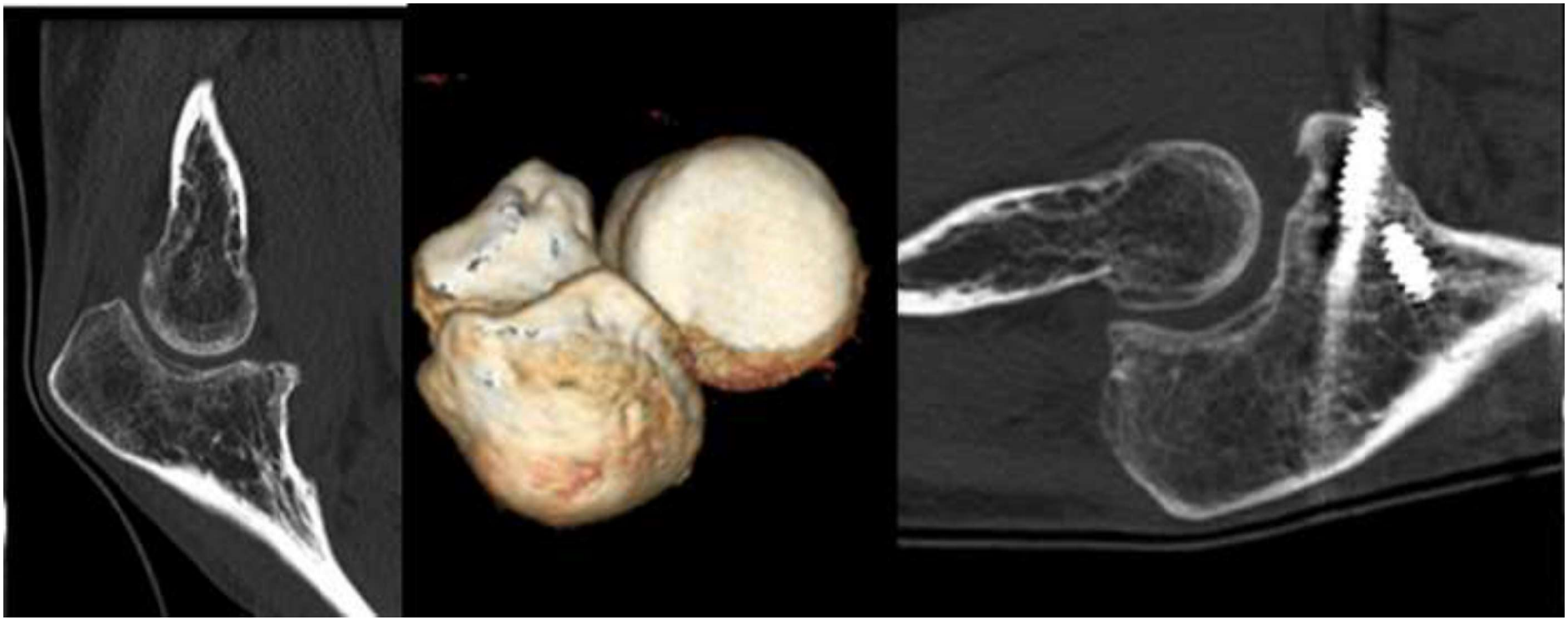

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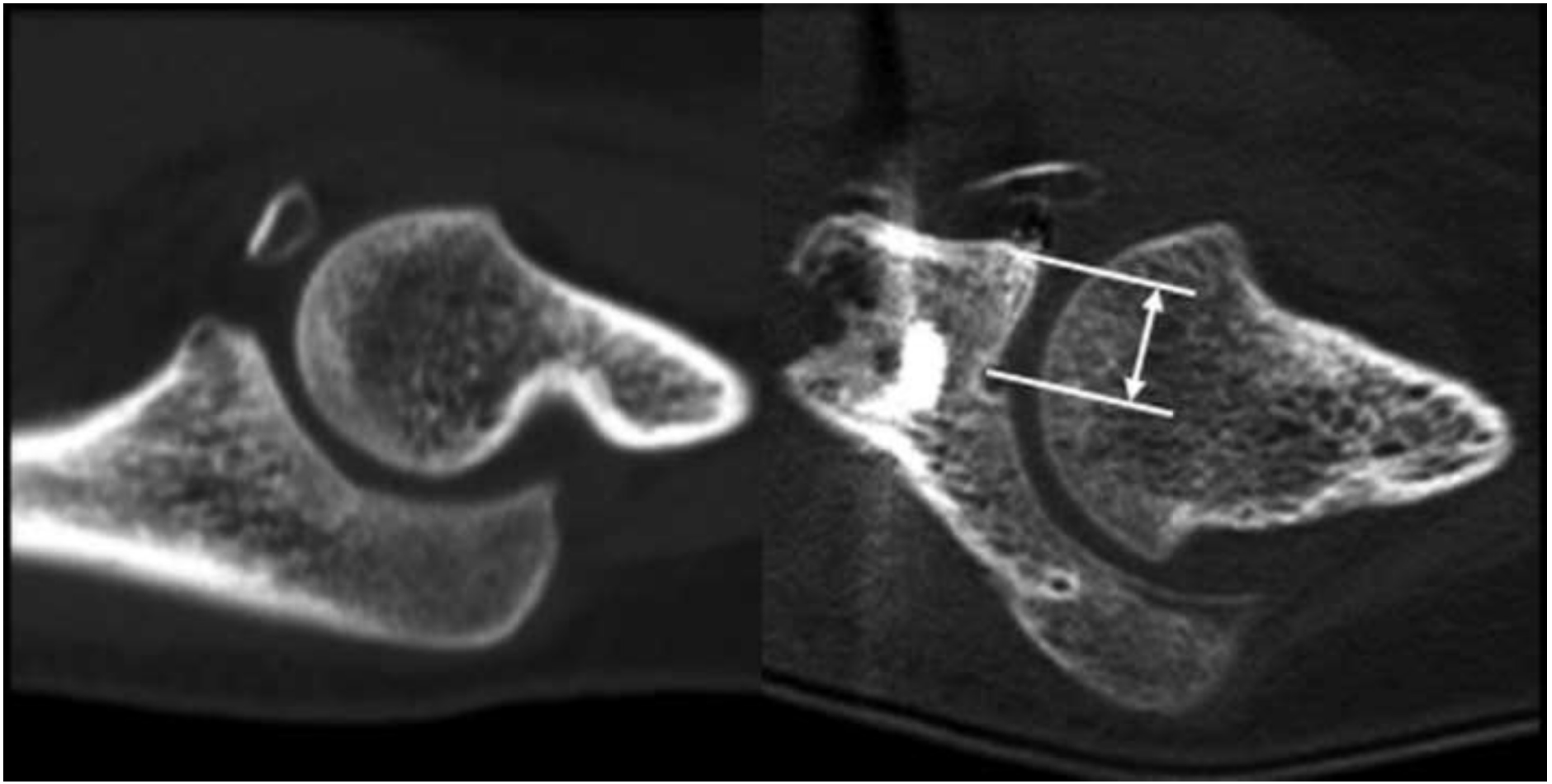

Figure 6

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