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CORONOID RECONSTRUCTION WITH AN OSTEOCHONDRAL RADIAL HEAD GRAFT

Running title: Radial head graft for coronoid deficiency

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1 **ABSTRACT**

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

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

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

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

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

23 **Treatment study, level of evidence IV.**

24 **INTRODUCTION**

25 The coronoid process has a key role in elbow stability^{5, 6, 16-18, 30} and its injuries are
26 associated with complications relating to instability or incongruity^{20, 26-29}. In the setting of
27 chronic coronoid deficiency the surgeon may have to deal with persistent dislocation and/or early
28 degenerative changes. Chronic deficiency can be due to malunion/nonunion of a coronoid
29 fracture or even loss of bone fragments that may have been discarded during the previous
30 surgical treatment²⁴. In all these chronic scenarios, usually the coronoid fragment size and
31 quality are not sufficient to allow revision of the fixation. Coronoid hypoplasia or dysplasia can
32 also occur from injury to the coronoid during development, as may occur with a childhood
33 dislocation.

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

39

40 **Surgical technique**

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

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47 a prosthesis), the graft can be autogenous; otherwise an allograft can be used. The radius is lined
48 up with the ulna such that the articular surface of the radial head, which would normally
49 articulate with the radial notch of the ulna, lies where the original coronoid was and is tangential
50 to the surface of the trochlea. This typically requires the radius to be tilted slightly as shown in
51 Figure 1. A cut is made part way across the radial head/neck in line with the flat surface of the
52 coronoid bed. Before completing that cut, the portion of the radial head that projects anteriorly
53 out into the brachialis is trimmed off. This renders the graft less bulky and easier to place. Then
54 the initial osteotomy at the head/neck junction is completed. The graft can be placed in two
55 different positions. For a deficiency of the tip of the coronoid, it articulates with the central
56 concave portion of the trochlea (Fig 2A). If the deficiency involves the anteromedial coronoid²⁰,
57 the graft can be placed more medially so that it articulates with the medial portion of the trochlea
58 (Fig 2B). In order to correctly position the graft, the elbow is flexed at 90° and the ulna must be
59 firmly compressed against the humerus for anatomic reduction. The graft is compressed against
60 the trochlea and fixed temporarily with a K-wire from its anteromedial side. Typically two
61 retrograde screws and one antegrade screw are used. A targeted guide is used to fix the graft with
62 the two retrograde 3.5 lag screws (one lateral and one centro-medial) through the ulna from its
63 subcutaneous border. One screw is inserted directly on the border of the ulna, the other on the
64 lateral side of the border (the medial side is steeper). Directing the screws parallel to the articular
65 surface or in a slight distal to proximal orientation reduces the risk of hitting the trochlear
66 surface. The medial edge of the graft is trimmed off so that it does not extend medially into the
67 flexor-pronator origin. Then the antegrade headless screw is placed from the anteromedial side
68 into the ulna (Fig 3). Once the graft has been secured and confirmed so that it articulates well
69 with the trochlea, the rest of the procedure can be completed (e.g. radial head replacement or

70 lateral collateral ligament reconstruction). Primarily, we suggest that the coronoid has to be
71 addressed as first step²³. The fixation is adequately rigid that a hinged external fixator is not
72 needed.
73 Postoperatively the patient is immobilized for 3 weeks in a cast to protect the ligament
74 reconstruction. A removable splint, taken off to do gentle range of motion (ROM) exercises in
75 the overhead position, is used for 3 weeks further. The patient typically weans off the splint over
76 the next 6 week, depending on stability and mobility of the elbow.

77

78 Clinical cases

79 Case 1

80 A 20-year-old female Paralympic swimmer was treated at our institution for chronic
81 coronoid deficiency due to hypoplasia or dysplasia of the coronoid, chronic posterior subluxation
82 of the radial head with both varus posteromedial rotatory instability (PMRI) and recurrent
83 posterolateral rotatory instability (PLRI). The patient, affected by an unspecified chromosomal
84 abnormality, had bilateral lateral condyle fractures at about age 5 and then developed bilateral
85 instability treated 4 years later with bilateral lateral collateral ligament (LCL) reconstructions
86 which were revised 7 years later for recurrent dislocations. At the time of our evaluation she
87 complained of recurrent left elbow dislocations, pain and limitation of motion. On physical
88 examination alignment was normal and the ROM was 40°-120° of flexion (the lack of extension
89 was partially due to the patient's fear of elbow dislocation). Her posterolateral rotatory
90 apprehension test¹⁹ was dramatically positive, but it was impossible to perform the PLRI tests
91 because of her guarding. The posterolateral rotatory drawer test²¹ on the opposite elbow was
92 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 2²⁰ coronoid nonunion (Fig
115 5A) associated with recurrent PLRI. Upon presentation to our institution she had 10° of cubitus

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

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

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

133

134 Case 3

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

139 left hand in order to prevent these painful episodes. The dysplasia resulted from repeated
140 subluxations and dislocations during development following an injury at age 6 that left her with a
141 coronoid malunion. The nature of the injury was not clear, as her parents were not available. On
142 physical examination, she had moderate cubitus varus and full ROM, but guarded against letting
143 the elbow fully extend. She had markedly positive signs for PLRI, including dramatically
144 positive posterolateral rotatory apprehension sign, posterolateral rotatory drawer test, lateral
145 pivot-shift test and chair test⁹. There were both varus laxity and pseudolaxity due to combined
146 lateral soft tissue laxity and medial bone deficiency. The elbow was so unstable that she
147 dislocated spontaneously while performing the MRI (Fig 6B). CT scan showed dysplasia of the
148 coronoid with complete anteromedial deficiency, shallow trochlear notch of the ulna, posterior
149 subluxation of a dysplastic radial head with angulation of the radial neck, posterior capitellar
150 impaction defect and a shallow dysplastic radial notch of the ulna.

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

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

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162 9/10 on the SOD scale. Physical examination revealed a negative posterolateral rotatory
163 apprehension sign, lateral pivot-shift test and chair test. Posterolateral rotatory drawer testing
164 revealed mild laxity similar to that in the opposite elbow and the motion was 10°-150° of flexion
165 and 80°-80° of pronation-supination.

166

167

168 **DISCUSSION**

169 Coronoid deficiency, both in the acute and chronic setting, is challenging even for the
170 most experienced orthopedic surgeon. This paper describes the senior author's surgical technique
171 and the midterm outcomes of three patients who underwent this type of treatment. Each patient
172 regained a stable pain-free elbow with functional ROM and union of the graft documented by CT
173 scan without evidence of graft resorption or degenerative changes. Although various methods for
174 coronoid reconstruction have been reported, the results have been unpredictable and sometimes
175 poor^{23, 25, 32} leading some authors to question the role of a bone graft²⁵. This is the first report that
176 incorporates CT scanning to determine bone healing. Some authors showed only x-rays in which
177 it is difficult to assess bone union^{4, 15} and other authors admitted they were unable to comment on
178 union of the graft in the absence of CT scans²⁴. Other authors did not even mention union of the
179 graft to the ulna^{11, 12, 22}. We strongly believe that, for a coronoid reconstruction to be successful,
180 the graft must not resorb and that the risk of resorption is lower if the graft heals.

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

191 ROM. Van Riet, et al.³², reported on 6 patients, treated with the first version of the senior
192 author's technique, with a mean follow-up of 64 months. All the patients had persistent posterior
193 subluxation with coronoid deficiencies or non-fixable nonunions. Results were excellent in 1,
194 good in 2, fair in 1 and poor in 2 patients. The graft definitely resorbed in one patient, although
195 graft union was difficult to assess on plain radiographs. Three patients required additional
196 surgery (one LCL reconstruction, one skin release of irritated external fixator pin sites, one total
197 elbow arthroplasty 7 years after surgery). Ring, et al.²⁴, reported 8 patients who underwent
198 surgical reconstruction, after acute/subacute trauma, with the concave proximal articular surface
199 of the radial head. The coronoid fracture involved between 30% and 100% of its height: 4
200 patients had a terrible triad injury (all with a coronoid tip fracture²⁰) and 4 had a posterior
201 olecranon fracture-dislocation (all with a basal coronoid fracture²⁰). The length of follow-up was
202 not specified. The 4 patients with terrible triad injuries were rated excellent. Of the 4 basal
203 coronoid deficiencies, 1 was rated good and 3 fair. Three of the patients with posterior olecranon
204 fracture-dislocations had persistent ulnohumeral subluxation.

205 The technique used in our patients differs from that reported by Ring, et al.²⁴, in several
206 aspects. The main difference is the graft orientation. Ring reproduces the most medial portion of
207 the coronoid taking advantage of the concavity of the proximal surface of the graft.

208 Alternatively, we placed the annular convex surface of the radial head against either the central
209 concave surface or the medial portion of the trochlea. Neither technique completely restores the
210 native shape of the coronoid, but stability appears to be accomplished with either method. Ring
211 fixes the graft with only one screw. We use 3 screws at different angles to achieve rigid fixation,
212 including in the anteromedial portion, which bears more load in varus. Ring suggests that the
213 lateral exposure is adequate to place the graft and the added medial dissection is not worthwhile.

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

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

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

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

249

250 **CONCLUSION**

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

255

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335

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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Figure 2
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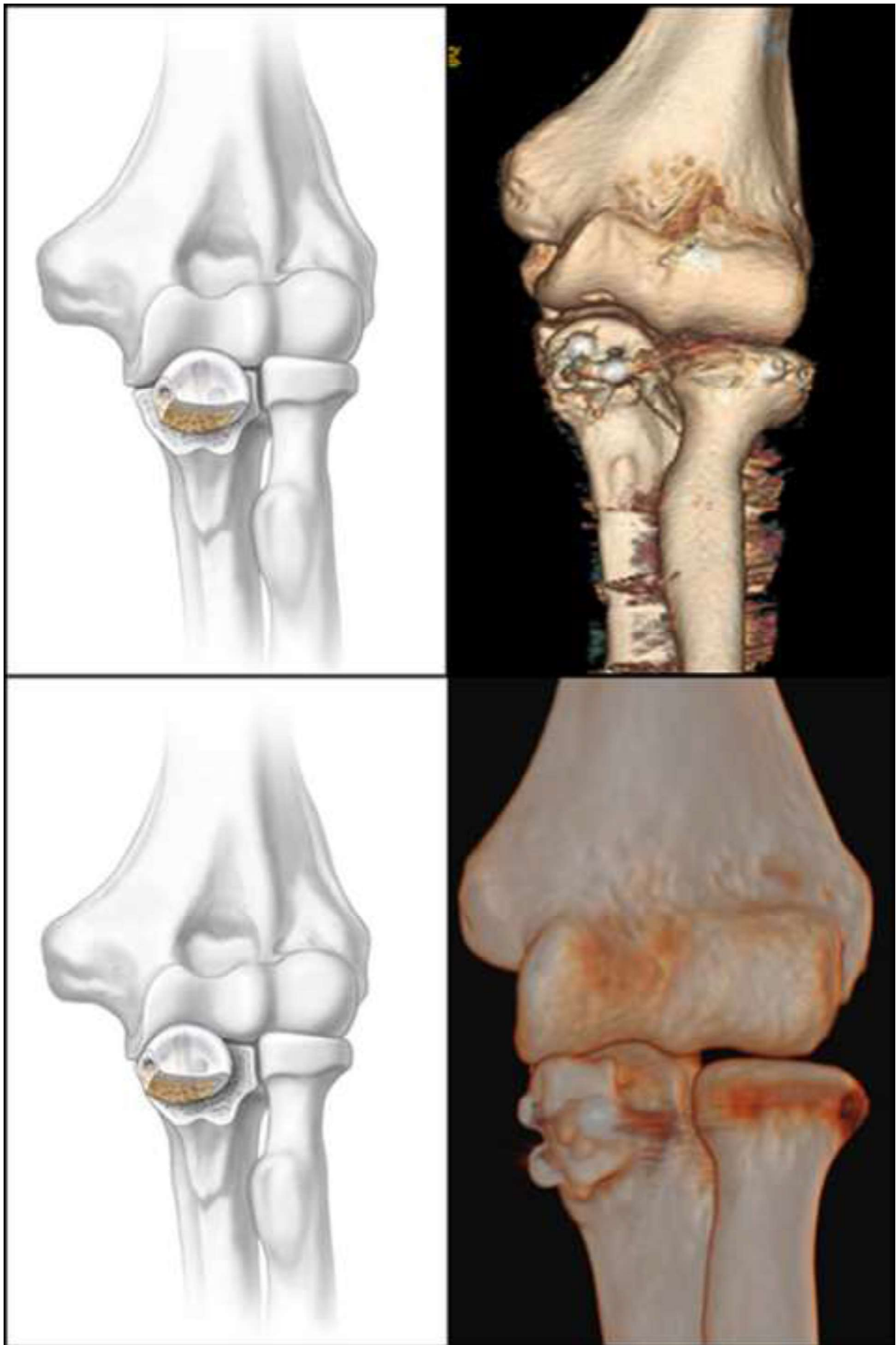


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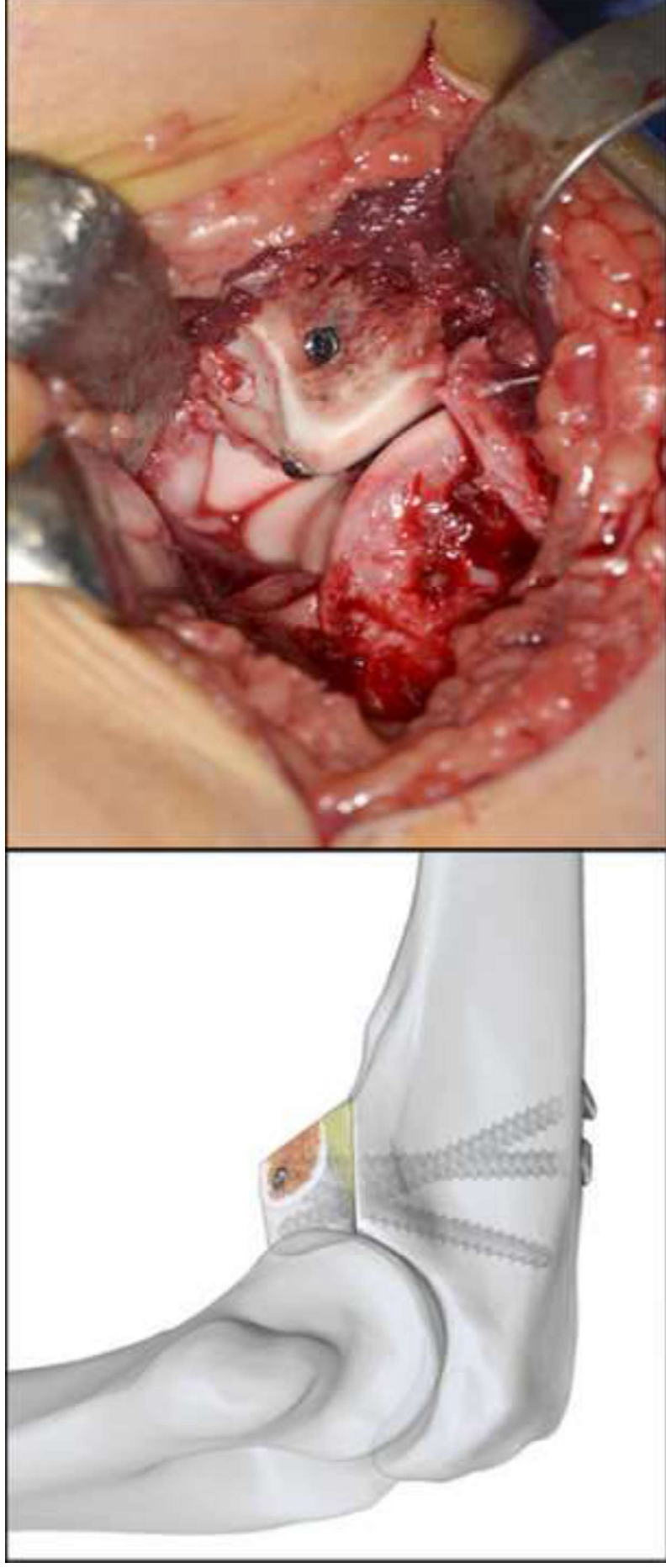


Figure 4
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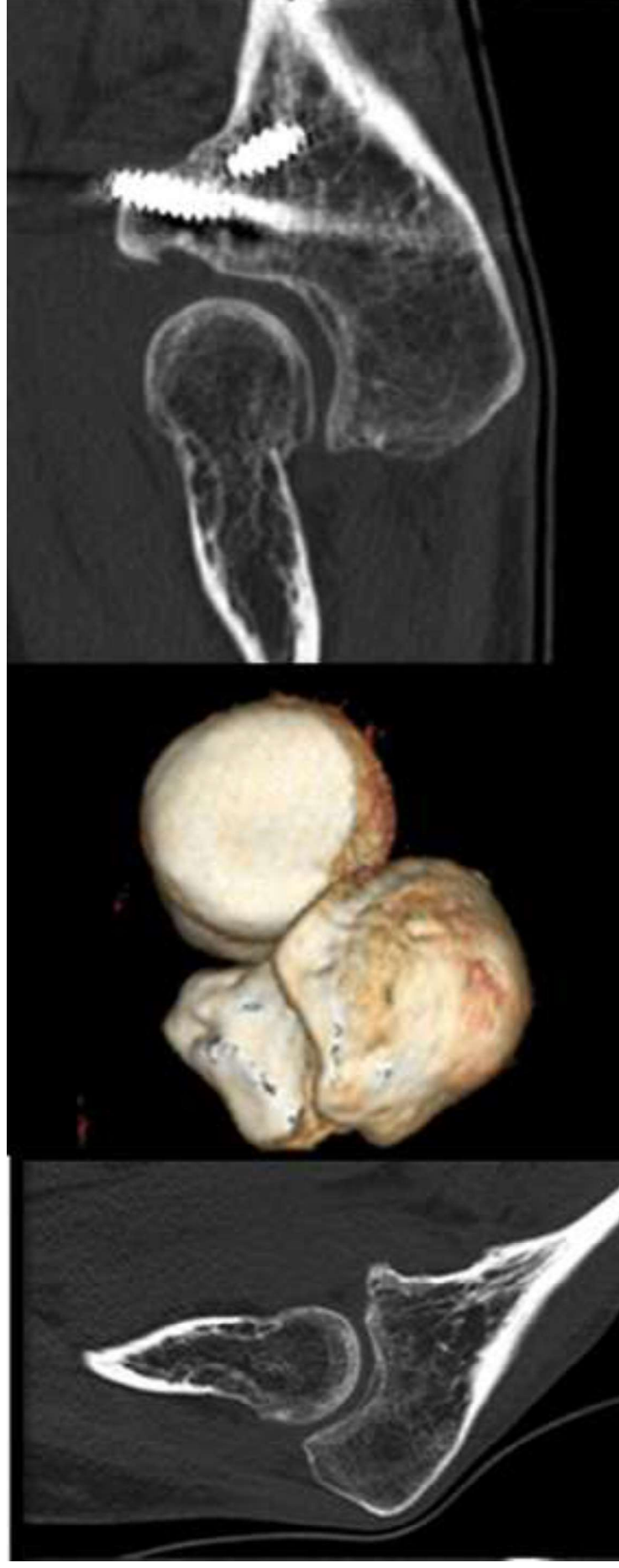


Figure 5
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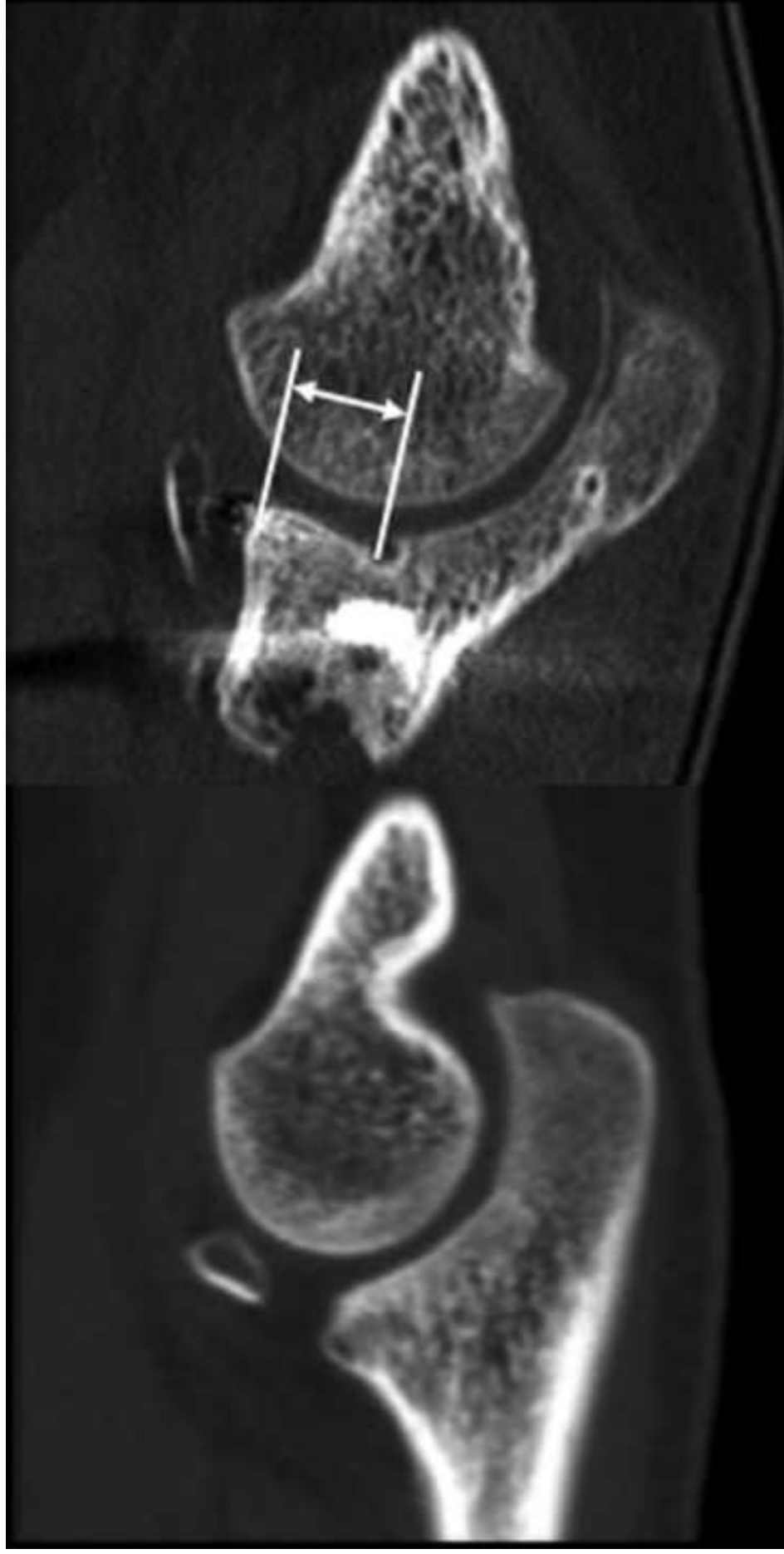


Figure 6
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