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BASIC SCIENCE

Three-dimensional suitability assessment of three types of osteochondral autograft for ulnar coronoid process reconstruction

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Background: Osteochondral autografts with use of the olecranon tip, lateral radial head, or proximal radial head have been employed for coronoid process reconstruction. However, it is unclear which autograft is most suitable for coronoid articular configuration. We assessed 3-dimensional articular facet suitability of 3 osteochondral autografts for coronoid process reconstruction.
Methods: We performed 3-dimensional computed tomography of 20 elbows to compare the articular facet configuration between the coronoid process and the ipsilateral olecranon tip, lateral radial head, and proximal radial head. We measured the area of the proximity region ($\leq$2.0 mm) between the articular facets of the coronoid process and 3 osteochondral autografts, the covering rate defined as the percentage area of the coronoid articular facet occupied by the proximity region, the location of the proximity region center, and the percentage of the removed ulnohumeral articular facet.
Results: The covering rate was significantly higher with an olecranon graft than with radial head grafts. The regional center of a proximal radial head graft was significantly medial compared with that of olecranon and lateral radial head grafts. The olecranon graft used an average of 13.8% of the ulnohumeral articular facet.
Conclusions: An olecranon graft was most suitable for defects of the coronoid process involving the tip, and a proximal radial head graft was most suitable for defects of the coronoid process involving the anteromedial rim. The use of an olecranon graft for reconstruction of 50% of the height of the coronoid process does not cause concern for gross elbow instability.
Level of evidence: Level III, Diagnostic Study.

Keywords: Coronoid process; olecranon graft; radial head graft; three-dimensional analysis; reconstruction

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Surgical treatment of persistent posterior elbow dislocation after comminuted fractures of the coronoid process is challenging. When the loss of the coronoid process causes elbow dislocation and instability, coronoid process reconstruction with autografts should be considered. Autografts

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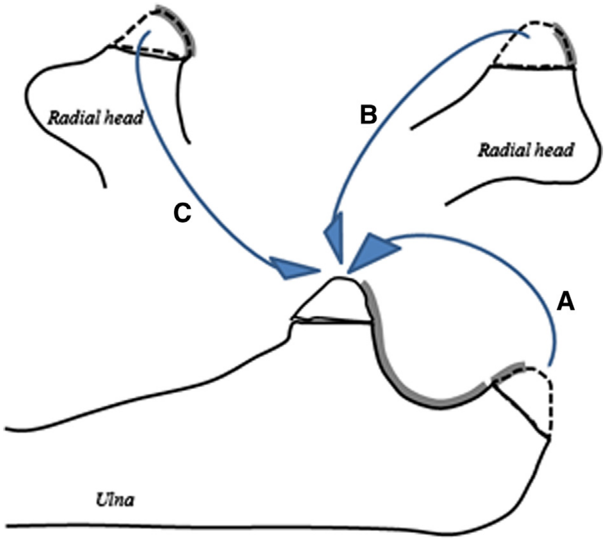

Figure 1 A schema of 3 osteochondral bone grafts using the olecranon (**A**), lateral radial head (**B**), and proximal radial head (**C**) is shown.

have been harvested from the radial head,[16,18] olecranon,[10] iliac crest bone,[4,7] tibia,[9] and distal humerus.[14] The radial head and olecranon have especially been used as osteochondral bone grafts and are more beneficial than a simple bone graft without cartilage (Fig. 1). Moritomo et al[10] used the ipsilateral olecranon tip as an osteochondral autograft to reconstruct the coronoid process in patients with persistent elbow dislocation. van Riet et al[18] described use of the lateral articular facet of the radial head, and Ring et al[16] used the proximal articular facet of the radial head. However, it is unknown which of these osteochondral grafts is most suitable as a substitute for coronoid articular configuration.

The coronoid articular facet articulates with the trochlea of the humerus and has a convex lateral surface and concave medial surface. The convex surface appears to match the articular facet of the olecranon and the lateral facet of the radial head, whereas the concave surface matches the proximal facet of the radial head (Fig. 2). Because of the differences in the shapes of the olecranon, coronoid, and radial head, the portion that each graft can reconstruct on the coronoid articular facet may differ.

Although a radial head graft is often harvested from the discarded fragment followed by a radial head arthroplasty to reconstruct the coronoid process,[16,18] the olecranon graft is harvested from the ipsilateral olecranon tip without reconstruction of the olecranon tip.[10] Therefore, the consequences of olecranon resection need to be considered. Some biomechanical studies have concluded that the extent of olecranon resection influences elbow stability.[1,2] However, the extent of olecranon resection required for coronoid process reconstruction remains unknown.

We hypothesized that the olecranon graft would be most suitable for defects of the coronoid process including the tip without causing gross instability. This study aimed to evaluate the suitability of 3 osteochondral grafts by measuring the area and location of the proximity region between the normal and reconstructed articular facets of the coronoid process and to measure the percentage of the ulnohumeral articular facet of the ulna occupied by the resected olecranon articular facet.

Materials and methods

We studied 20 forearms (8 right and 12 left) in 20 subjects (10 women and 10 men; mean age, 37 years; range, 16-66 years). All subjects initially presented to our hospital with contralateral forearm disorders, such as upper extremity fracture malunions, ulnocarpal impaction syndrome, or distal radioulnar joint instability. We used only computed tomography (CT) data from the normal side in this study, although we performed bilateral CT scans for comparison.

Both forearms, from elbow to wrist, were scanned by CT (helical CT, LightSpeed Ultra16; General Electric, Waukesha, WI, USA; slice thickness, 1.25 mm). Data were saved in the Digital Imaging and Communications in Medicine format and sent to a computer. We transferred the digital data to Bone Viewer (Orthree, Osaka, Japan), extracted regions of the radius and ulna in all slice images semiautomatically by segmentation, created 3-dimensional (3D) models of the radius and ulna, and visualized these images with Bone Simulator (Orthree, Osaka, Japan). The previous accuracy analysis of 3D bone models, which was constructed from CT data with 0.625-mm thickness by use of our original computer program, showed that the mean error was 0.45 mm.[13]

The cutting plane of the coronoid process was defined as a plane parallel to the posterior flat spot on the olecranon and at 50% of the height of the coronoid process (Fig. 3). The coronoid region was defined as the anterior part of the ulnohumeral articular facet of the original ulna divided by the cutting plane.

We simulated 3 different osteochondral autografts: olecranon, lateral radial head, and proximal radial head. For the olecranon graft, a second ulna model was duplicated from the original, and the olecranon tip of the duplicated model was flipped around and superimposed on the corresponding part of the coronoid process of the original model (Fig. 4, *A*). For the lateral and proximal radial head grafts, the lateral and proximal sides of the articular facets of the radial head were respectively superimposed on the corresponding part of the coronoid process (Fig. 4, *B, C*).We investigated the proximity region with a distance of $\leq$2.0 mm between the articular surfaces of the coronoid region and the grafts by a proximity mapping method[5,6,11] (Fig. 5). The articular facet area was calculated by selecting all individual surface triangles with use of Magics RP (Materialise, Leuven, Belgium). The covering rate was calculated by the following equation:

$$\text{Covering rate} = \frac{\text{Area of proximity region}}{\text{Area of coronoid region}} \times 100\ (\%)$$

We also investigated the resection region at the time of olecranon graft harvest and calculated the resection area by dividing the ulnohumeral articular facet area by the cutting plane. The resection rate was defined by the following equation:

$$\text{Resection rate} = \frac{\text{Resection area}}{\text{Ulnohumeral articular facet area}} \times 100\ (\%)$$

We also investigated the location of the proximity region center to clarify the characteristics of each osteochondral graft.