Osteochondritis dissecans of the capitellum

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Chapter 7

Topographic analysis of 2 alternative donor sites of the ipsilateral elbow

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Topographic analysis of 2 alternative donor sites of the ipsilateral elbow in the treatment of capitellar osteochondritis dissecans

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Abstract

Purpose: To find the best topographic subchondral bone match between the capitellum and 2 proposed alternative donor sites of the ipsilateral elbow for capitellar osteochondral autologous transplantation: the non-articulating part of the radial head and the lateral olecranon tip.

Methods: In our retrospective database, 20 patients with an unremarkable computed tomography scan of the elbow despite clinical suspicion were identified for analysis. Included were patients aged 11 to 20 years with intact osseous structures and a computed tomography slice thickness of 1.25 mm or less. Three-dimensional polygon models were created using a standard predefined threshold, after which 4 articular surface lesions on the capitellum were created: central 40°, central 60°, lateral 40°, and lateral 60°. In addition, 3 donor locations on the non-articulating part of the radial head (diameter, 5 mm) and the lateral olecranon tip (diameter, 3.5 mm) were created. For each of 24 donor-recipient combinations, the donor graft surface was virtually placed on the recipient surface to quantify the mean distance between surfaces.

Results: The group of 20 patients consisted of 16 male and 4 female patients with a mean age of 15.9 years (range, 12-18 years). For a central 40° lesion, the mean distance across all 6 donor-recipient combinations ranged from 0.085 ± 0.023 to 0.118 ± 0.036 mm; for a central 60° lesion, the mean distance ranged from 0.075 ± 0.018 to 0.117 ± 0.062 mm; for a lateral 40° lesion, the mean distance ranged from 0.087 ± 0.030 to 0.182 ± 0.226 mm; and for a lateral 60° lesion, the mean distance ranged from 0.084 ± 0.048 to 0.115 ± 0.045 mm. There were no differences in topographic matching between donor-recipient combinations.

Conclusions: The findings of this study show a less than 0.2-mm difference in the topographic subchondral bone match between 4 common lesion locations on the capitellum and 2 alternative donor sites of the ipsilateral elbow for capitellar osteochondral autologous transplantation: the non-articulating part of the radial head and the lateral olecranon tip.

Clinical Relevance: These findings suggest that the non-articulating part of the radial head and the lateral olecranon tip may potentially be used as a donor source when treating capitellar osteochondritis dissecans.
Introduction

Osteochondral autologous transplantation (OATS) may be indicated in large, unstable capitellar osteochondritis dissecans (OCD) lesions especially with involvement of the lateral wall. It may also be used as a salvage procedure if primary surgical treatment has failed. In OATS a single or multiple cylindrical grafts are harvested from the less weight-bearing parts of the femoral condyle or, to a much lesser extent, from either the fifth or sixth costal-osteocondral junction. The cylindrical plugs, consisting of subchondral bone and hyaline cartilage, are then perpendicularly press fitted into the capitellar defect to attempt to anatomically restore the articular surface. Ideally, the topographic surface of the donor graft will show close similarity with the recipient site and its surroundings. Here, the operating surgeon must take into account several factors including plug contour, cartilage depth, and perpendicular graft placement.

OATS for capitellar OCD has shown promising short-term and intermediate outcomes with regard to elbow function, range of motion, and return to sports. One of the disadvantages of this procedure is the need to harvest grafts from either a healthy knee or rib area in a young athlete and thus the risk of morbidity of the donor site. Multiple studies have reported morbidity after graft harvesting from the knee in the treatment of OCD of the capitellum, knee, and talus including hemarthrosis, anterior knee pain, and instability of the knee. Bexkens et al. reported a donor-site morbidity rate of 7.8% (range, 0%-57%) after knee-to-elbow OATS. Alternative donor sites are needed to avoid violating the integrity of a healthy knee in a young athlete.

The purpose of this study was to find the best topographic subchondral bone match between the capitellum and 2 proposed alternative donor sites of the ipsilateral elbow for capitellar OATS: the non-articulating part of the radial head and the lateral olecranon tip. We hypothesized that both donor sites would show a less than 1-mm difference in topographic matching with the capitellum. In addition, we hypothesized that there would be no difference in topographic matching between both donor sites.

Methods

Patients

After approval from our institutional review board (protocol No. 2009P001019/MGH), a search was performed in the retrospective database of 2 hospitals to identify patients in whom a computed tomography (CT) scan of the elbow was performed between January 2005 and July 2016. This search resulted in 2,135 patients. Within this group, we aimed to identify 20 unremarkable CT scans despite clinical suspicion. The inclusion criteria for this study were (1) patients aged 11 to 20 years; (2) scans that showed an intact
capitellum, radial head, and olecranon; (3) scans made in neutral rotation; and (4) scans with a slice thickness of 1.25 mm or thinner. Excluded from this investigation were (1) patients who had previous elbow surgery; (2) patients with abnormal osseous anatomy (congenital or post-traumatic deformities) on CT; (3) scans of insufficient quality; and (4) scans with intra-articular contrast injection. Forty patients met these criteria. These 40 scans were initially ordered to rule out any fractures or osteochondral lesions of the elbow joint. From this group, we selected 20 patients with the thinnest CT slices for reconstruction of 3-dimensional (3D) polygon models. Patient sex, age, and elbow side at the time of the CT were recorded.

Reconstruction of 3D Models
The original DICOM (Digital Imaging and Communications in Medicine) files of the selected CT scans were obtained through the picture archiving and communication system database. Subsequently, the DICOM files were loaded into InVesalius 3.0 (Centre for Information Technology Renato Archer, Campinas, Brazil), a software platform for the analysis and visualization of medical images and for research in image-guided therapy. CT modeling of the elbow using this technique has been proved to be accurate with high intraobserver and interobserver reliability.11-13 The 3D polygon models of the humerus, radius, and ulna were rendered using a standard predefined threshold (compact bone, child) available in InVesalius (Fig 1).

Figure 1: Three-dimensional polygon model of left elbow. (A) Anterior view. (B) Lateral view.

Lesion Locations at Capitellum
The rendered 3D models were imported into Rhinoceros (Robert McNeel and Associates, Seattle, WA) for further analysis. By use of this software, imaginary articular surface
lesions of 5 mm in diameter at 4 different locations on the capitellum were created: 2 central and 2 lateral lesions, with their centroids located 40° or 60° anteriorly relative to the shaft of the distal humerus (Fig 2). Locations on the capitellum were chosen based on previous descriptions in the literature.9

**Alternative Donor Sites: Non-articulating Part of Radial Head and Olecranon Tip**

Three donor locations of 5 mm in diameter on the surface of the non-articulating part of the radial head were created. These donor locations were located within the radial head “safe zone,” which is the part of the radial head that does not articulate with the proximal radioulnar joint. This zone extends 65° anterior to and 45° posterior to the bisecting reference mark made with the forearm in neutral rotation.14 Two donor locations were located anteriorly to the bisecting mark (40° and 80°) and one was located posteriorly (120°). (A) Anterior view. (B) Lateral view.
In addition, we created 3 donor locations of 3.5 mm in diameter on the surface of the lateral side of the olecranon tip (Fig 4).

Figure 4: Three donor locations were located on the lateral side of the olecranon tip. (A) Lateral view. (B) Anterior view.

Topographic Matching: Capitellum Versus Non-articulating Part of Radial Head and Lateral Olecranon Tip

For each patient, the surface of each donor location was virtually placed on the articular surface of each lesion location on the capitellum. Radial head donor surfaces (5 mm) were placed on 5-mm lesions on the capitellum (Fig 5); olecranon donor surfaces (3.5 mm) were placed on 3.5-mm lesions. This resulted in 24 combinations of the capitellum and radial head or olecranon being tested for each patient (4 recipient locations × 6 donor locations) and 480 combinations in total (24 per patient × 20 patients). The best orientation of the donor surface relative to the surface of the capitellum was found with the use of a surface-to-surface registration technique. Topographic matching of donor-
recipient combinations was determined by calculating the mean distance between both surfaces, which is the average of the local distance from multiple corresponding points in space. A topographic match of 0.0 mm equals a perfect anatomic match.

**Statistical Analysis**
Categorical data were described as absolute numbers with frequencies, and continuous data were displayed as means with standard deviations. Repeated-measures analysis of variance was used to analyze matching differences between donor-recipient combinations. If this led to a significant result, post hoc analysis was performed to identify the donor-recipient combination of greatest congruence by use of the Tukey HSD (honest significant difference) test (STATA, version 13.0; StataCorp, College Station, TX). P < .05 was considered significant. In the post hoc power analysis, a donor-recipient difference of 0.5 mm was regarded as a clinically relevant mismatch. In addition, the largest observed standard deviation of 0.226 mm (olecranon tip 1, lateral 40°) was used. Because there were 6 donor locations, we used an α of .0083 (.05/6) in the post hoc power analysis. By use of a single-group 2-sided t test with a sample size of 20 patients, the study will have over 99% power to detect the difference between a null hypothesis mean of 0.0 mm and an alternative mean of 0.5 mm (nQuery Advisor; Statistical Solutions, Cork, Ireland).

**Results**
The group of 20 patients in whom a CT scan was used for analysis consisted of 16 male and 4 female patients with a mean age of 15.9 years (range, 12-18 years). The right elbow was involved in 13 patients and the left in 7.

Both donor sites, the non-articulating part of the radial head and the lateral olecranon tip, showed a less than 0.2-mm difference in the topographic articular surface match with all 4 locations on the capitellum (Table 1). For a central 40° lesion, the mean distance across all 6 donor-recipient combinations ranged from 0.085 ± 0.023 to 0.118 ± 0.036 mm. For a central 60° lesion, the mean distance across donor-recipient combinations ranged from 0.075 ± 0.018 to 0.117 ± 0.062 mm (Fig 6). For a lateral 40° lesion, the mean distance across all 6 donor-recipient combinations ranged from 0.087 ± 0.030 to 0.182 ± 0.226 mm. For a lateral 60° lesion, the mean distance across all donor-recipient combinations ranged from 0.084 ± 0.048 to 0.115 ± 0.045 mm. There were no significant differences in topographic matching between donor-recipient combinations (P > .05).
Table 1: Summary Statistics of Donor-Recipient Combinations: Capitellum Versus Non-articulating Part of the Radial Head and the Lateral Olecranon Tip*

<table>
<thead>
<tr>
<th>Donor locations</th>
<th>Central 40°</th>
<th>Central 60°</th>
<th>Lateral 40°</th>
<th>Lateral 60°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radial head 40°</td>
<td>0.111 ± 0.053</td>
<td>0.117 ± 0.062</td>
<td>0.118 ± 0.075</td>
<td>0.115 ± 0.045</td>
</tr>
<tr>
<td>Radial head 80°</td>
<td>0.118 ± 0.036</td>
<td>0.114 ± 0.040</td>
<td>0.124 ± 0.025</td>
<td>0.102 ± 0.045</td>
</tr>
<tr>
<td>Radial head 120°</td>
<td>0.107 ± 0.020</td>
<td>0.107 ± 0.033</td>
<td>0.124 ± 0.040</td>
<td>0.105 ± 0.027</td>
</tr>
<tr>
<td>Olecranon tip 1</td>
<td>0.105 ± 0.068</td>
<td>0.096 ± 0.068</td>
<td>0.182 ± 0.226</td>
<td>0.097 ± 0.064</td>
</tr>
<tr>
<td>Olecranon tip 2</td>
<td>0.099 ± 0.065</td>
<td>0.095 ± 0.060</td>
<td>0.102 ± 0.060</td>
<td>0.084 ± 0.048</td>
</tr>
<tr>
<td>Olecranon tip 3</td>
<td>0.085 ± 0.023</td>
<td>0.075 ± 0.018</td>
<td>0.087 ± 0.030</td>
<td>0.084 ± 0.018</td>
</tr>
</tbody>
</table>

NOTE. Data are presented as mean ± standard deviation.
*There were no significant differences in topographic matching between donor-recipient combinations (P > .05).

Figure 6: The distance distribution is shown for donor-recipient matching of a donor graft obtained from the non-articulating part of the radial head, which is superimposed on the capitellum; it is centrally located 60° anteriorly relative to the shaft of the distal humerus. Green indicates a perfect anatomic topographic match. Blue indicates prominence, whereas red and yellow represent penetration into the articular surface of the capitellum.

Discussion

The most important finding of this investigation is that both the non-articulating part of the radial head and the lateral olecranon tip show an appropriate topographic subchondral match with common OCD locations on the capitellum (difference <0.2 mm).
The mean difference in topographic matching between 4 lesion locations (capitellum) and 3 donor locations on the non-articulating part of the radial head ranged from 0.102 ± 0.045 to 0.124 ± 0.040 mm; the mean difference between the same 4 lesion locations and 3 donor locations on the lateral olecranon tip ranged from 0.075 ± 0.018 to 0.182 ± 0.226 mm. No difference in the degree of topographic matching between all 24 donor-recipient combinations was found (P > .05).

Despite promising short-term and intermediate elbow outcomes after OATS in the treatment of capitellar OCD, donor-site morbidity occurs in a significant group of patients.8,9 In this study, we investigated 2 alternative donor sites within the affected elbow to avoid violating the integrity of a patient’s healthy knee or fifth or sixth costal-osteocondral junction when performing OATS. The findings of our study are similar to those of previous studies that investigated the topographic congruence between the capitellar articular surface and common donor locations at the femoral condyle including the trochlea, intercondylar notch, and posterior femoral condyle.16,19 Using a similar technique based on 3D CT, Shin et al.16 found a difference of less than 0.6 mm in topographic congruence across all donor-recipient combinations. These results were based on 5 elbow and 6 knee cadavers with a higher average age (elbow, 23 years; knee, 62 years) than typical patients with capitellar OCD (15 years).9 The lateral trochlea provided the best match.16 Vezeridis and Bae19 investigated topographic similarities of donor-recipient combinations based on the radius of curvature and cartilage depth on magnetic resonance imaging and found a mean difference in curvature that ranged from 0.4 to 1.4 mm across combinations. They concluded that the inferior lateral trochlear ridge should be considered as a donor site for capitellar OATS because of its topographic congruence and accessibility.19 Comparing our findings with those of the aforementioned studies indicates that the non-articulating part of the radial head and the lateral olecranon tip provide a topographic match with the capitellum to the same extent as commonly used donor locations at the femoral condyle.16,19

Previous studies on topographic analysis were based on harvesting a single 10-mm donor graft (78.5 mm²).16,19 In our investigation either a single or multiple grafts, up to 6 in total, could be harvested, which means that defects up to 87.8 mm² (3 grafts × 19.6 mm² + 3 grafts × 9.6 mm²) could be treated. The average number of grafts harvested for capitellar OATS ranges from 1 to 5 (average, 2) and reported graft diameters range from 2.6 to 11 mm.9 The use of a single graft versus multiple grafts remains a subject of debate. Using multiple plugs raises concerns regarding fibrocartilaginous formation between grafts resulting in devitalized cartilage islands, whereas harvesting multiple knee grafts may be associated with a higher risk of donor-site morbidity.10,20 Comparison between these 2 techniques has not been performed for the treatment of capitellar OCD. However, for talar OCD, no difference in clinical outcomes has been reported between single- and double-plug procedures.21
The strengths of our study include using CT scans of patients of the same age and sex (with more male patients than female patients) as in typical OCD cases. Furthermore, because we analyzed the topographic congruence of donor-recipient combinations within a single joint, matching of patients was not needed, given that this is the case when grafts would be harvested from a second joint (e.g., knee-to-elbow OATS). Although the results of this study are promising, further study is needed to find out whether grafts harvested from the radial head or olecranon tip show biological and mechanical properties that are similar to those of the capitellum. Similarly, future research is needed to investigate whether harvesting 1 graft or multiple grafts from both alternative donor sites influences the clinical outcome of the elbow in a negative way.

Limitations
This study should be interpreted by taking into account some limitations. First, assessment of topographic matching of donor-recipient combinations was performed by a 3D CT technique. Because CT does not take into account the articular cartilage, the actual topographic surface of locations of interest may have been slightly different. Second, because topographic surfaces were anatomically analyzed by a 3D CT technique, no conclusions can be drawn on clinical outcomes.

Conclusions
The findings of this study show a less than 0.2-mm difference in the topographic subchondral bone match between 4 common lesion locations on the capitellum and 2 alternative donor sites of the ipsilateral elbow for capitellar OATS: the non-articulating part of the radial head and the lateral olecranon tip.
References


