SCIENTIFIC ARTICLE

Regional Variations in Cartilage Thickness of the Radial Head: Implications for Prosthesis Design

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Purpose To characterize the regional variations in cartilage thickness around the radial head.

Methods We dissected 27 cadaveric radii and scanned them with computed tomography in neutral position. Three-dimensional cartilage and subchondral bone surface models were generated from computed tomography scans and 2 independent observers processed them through a computer program to obtain cartilage thickness measurements. These measurements were taken at 41 predetermined landmarks around the periphery of the radial head and within the articular dish.

Results At the periphery of the radial head, cartilage was thickest in the posteromedial region. Thickness values within the articular dish were similar but increased toward the rim. Regional variations within the rim (range, 0.76−1.73 mm) were also detected with the thickest region located anteriorly and thinnest region laterally. In addition, cartilage was significantly thicker in male relative to female specimens.

Conclusions Regional variations in cartilage thickness are present around the periphery and rim and within the articular dish of the radial head.

Clinical relevance Cartilage thickness across the articular dish may contribute to dish depth and the radius of curvature. This may be clinically important for the design of anatomic implants, because accounting for such subtle contours could help to restore radiocapitellar concavity-compression stability better. *(J Hand Surg Am. 2015;40(12):2364−2371. Copyright © 2015 by the American Society for Surgery of the Hand. All rights reserved.)*

Key words Articular cartilage, implant, radial head, radial head arthroplasty.

Additional material is available online.

RADIAL HEAD FRACTURES ARE THE most prevalent fractures of the elbow[1,2] and account for approximately 75% of all proximal forearm injuries.[3] As such, the complex anatomy of the proximal radius has been studied extensively to improve the development of replacement implants.[4−8] Most investigators have focused on characterizing the dimensions of the radial head using various techniques, specimens, or models but have placed little to no emphasis on the contribution of cartilage to the radial head shape. Characterizing the regional variations in cartilage thickness could enhance our understanding of and potentially improve the quality of implants for arthroplasty.

Radial head implants vary widely in their approximation of the native radial head geometry[6,9] because designs can be based on osseous specimens,[10] whole bone specimens,[7,11,12] or measurements taken from computed tomography (CT) images.[6,7] For implants generated using whole bone and osseous specimens or single CT images, investigators have characterized

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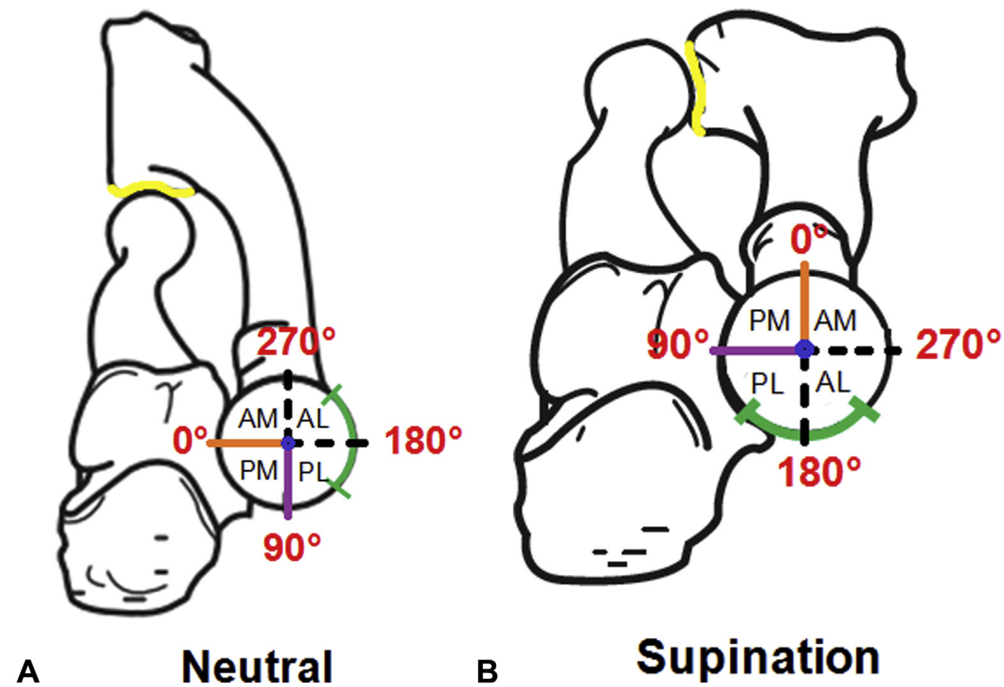

FIGURE 1: A Axial view of a representative proximal right radial head relative to the ulna in neutral position (orientation in which the radii were scanned), demonstrating radial head quadrants. **B** Rotating the foream into supination; the quadrants also rotate 90°. The yellow line represents the sigmoid notch of the radius located distally; the orange and purple lines represent x and y axes, respectively, whereas the blue dot depicts the z axis. The green line represents the nonarticulating region of the radial head. AM, anteromedial; PM, posteromedial; AL, anterolateral; PL, posterolateral.

parameters such as the maximum diameter and the height of the radial head. However, such measurements are typically performed at one location and do not account for all of the subtle contours of the radial head. In contrast, reverse engineering is a promising technique that may capture these topographic variations in dimension, allowing accurate and personalized implants to be generated based on a patient's CT scans. This method involves creating 3-dimensional models of the intact joint based on CT scans of a patient's subchondral bone to create a solid replacement implant for the opposing fractured joint.[13,14] Such measurements do not account for cartilage, however, because this tissue is radiolucent when surrounded by synovial fluids and soft tissue that exhibit a similar radiodensity.[15] Therefore, characterizing the distribution of cartilage thickness across the radial head may provide a generalized correction for its contribution, which could be used alongside personalized subchondral bone measurements during implant design by reverse engineering. Such implants may be better able to restore elbow kinematics, because previous investigators have reported the mechanical advantages of using anatomically correct prostheses.[5,11,16]

The purpose of this study was to determine the distribution of radial head cartilage thickness. We hypothesized that there would be notable regional variations in cartilage thickness, which might have clinical implications for implant design.

MATERIALS AND METHODS

Cadaveric specimens

We dissected 61 radii from embalmed upper limbs and denuded them of all soft tissue. Of these, 27 radii (44%) showed no visible signs of fracture or cartilage deformation and thus were investigated (14 males and 13 females, aged 49–99 years; 13 right and 14 left radii).

Computed tomography and image processing

The radial heads were rehydrated in normal saline for 24 hours before scanning.[15] The 27 radii were scanned in air using a Discovery CT750 HD scanner (GE Medical Systems, Pewaukee, WI) with the following parameters: 120 kV, 50 mA, and 0.625 mm slice thickness. Specimens were scanned in neutral position to ensure that all points of measurement were consistent. Neutral position was defined as having the radial styloid process perpendicular to the CT scanner bed.

The CT images of the 27 radii were then imported into Mimics 14.12 (Materialise, Leuven, Belgium) and the subchondral bone and cartilage geometries