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Comparison of reconstructive procedures for glenoid bone loss associated with recurrent anterior shoulder instability

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Hypothesis: A tibial plafond allograft, iliac crest allograft, and coracoid autograft in a congruent arc Latarjet reconstruction better restore radius of curvature, depth, and surface area for glenoid bone loss in recurrent instability compared with the coracoid autograft in a standard Latarjet reconstruction for anteroinferior glenoid bone loss of the shoulder.

Methods: Three-dimensional shoulder models were generated from bilateral computed tomography scans in 15 patients, who were a mean (standard deviation [SD]) age of 23 (7.7) years, with recurrent anterior shoulder instability and known glenoid bone loss. The surface areas of the glenoid in the involved and contralateral normal shoulder were measured. Virtual surgery was then performed using standard and congruent arc Latarjet reconstruction, tibial plafond, and iliac crest allografts. Grafts were optimally positioned to restore articular congruity and defect fill. Radius of curvature and restoration of glenoid depth were compared with the contralateral glenoid.

Results: Glenoid surface area (11.04% [6.95% SD]) and depth (0.75 [0.57 SD] vs 1.44 [0.65 SD] mm) were significantly reduced ($P < .012$) in the injured glenoid. The mean (SD) coronal plane radius of curvature of the congruent arc Latarjet reconstruction (60.3 [39.0 SD] mm) more closely matched the radius of curvature of the injured glenoid (67.5 [33.2 SD] mm) compared with the other grafts. Restored glenoid depth was greater in the tibial plafond (1.8 [1.1 SD] mm) and iliac crest (2.0 [0.6 SD] mm) allografts compared with other grafts ($P < .002$).

Conclusion: Congruent arc Latarjet reconstruction more closely restores native glenoid coronal radius of curvature, whereas tibial plafond and iliac crest allografts more adequately restore depth compared with standard Latarjet reconstruction.

Level of evidence: Basic Science, Computer Modeling Study.

Keywords: Bone loss; glenoid; instability; shoulder; Latarjet; allograft

The protocol of this study was approved by the University of Michigan Institutional Review Board (Study eResearch ID HUM00051862).

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Unaddressed significant glenoid bone loss is a known risk factor for recurrence and failure after arthroscopic stabilization surgery of the shoulder.[4,12] Several autologous and allograft options for glenoid reconstruction have been described as having favorable clinical outcomes in small case series and technical notes.[1,6,13,16,18] Coracoid-based autograft options include the standard and congruent arc (CA) Latarjet-Patte procedures, whereas allograft options to restore glenoid bone stock include tibial plafond, iliac crest, and glenoid. Although coracoid-based autograft constructs, such as the Latarjet procedure, have shown excellent long-term restoration of shoulder stability and clinical outcomes, questions remain regarding the development of postdislocation arthropathy.[1,10,11,15] The use of an iliac crest allograft or a CA- type Latarjet has been shown to optimally restore glenohumeral contact pressures in a cadaveric model of glenoid bone loss, which theoretically, could be important in the development of arthropathy.[8]

No studies to date, however, have compared all of these graft options with respect to their ability to restore glenoid articular surface congruity, surface area, and radius of curvature. Differences in these parameters may have important implications for glenohumeral kinematics, contact mechanics, and the risk for secondary arthrosis after reconstructive procedures for glenoid bone loss secondary to recurrent anterior instability. Our hypothesis was that tibial plafond allograft, iliac crest allograft, and CA Latarjet reconstruction with coracoid autograft would better restore radius of curvature, surface area, and depth for glenoid bone loss in recurrent shoulder instability compared with the standard Latarjet reconstruction with coracoid autograft.

Materials and methods

Three-dimensional (3D) models of the shoulder were generated from bilateral computed tomography (CT) scans in 15 patients (2 females and 13 males, 6 left and 9 right), who were a mean (standard deviation [SD]) age of 23 (7.7) years, with recurrent anterior shoulder instability, known glenoid bone loss, and an uninjured contralateral shoulder using the Mimics 13.0 computer software program (Materialise, Ann Arbor, MI, USA). This software program uses DICOM (Digital Imaging and Communications in Medicine) data to create a 3D model of the proximal humerus and scapula and has been used in other projects examining anatomic relationships of osseous structures.[3,5] Once created, the model can be rotated and viewed from all angles and can be manipulated and sectioned along cut lines, allowing ‘‘virtual surgery’’ to be performed.

Models and measurements

The surface areas of the injured and contralateral intact glenoid were measured in their entirety with the surface area function in Mimics software, which was then used to precisely calculate the area of bone loss for the injured glenoid. The radius of curvature

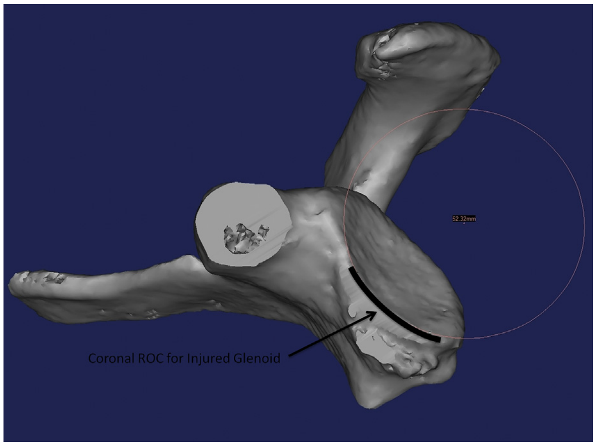

Figure 1 Three-dimensional computed tomography model shows radius of curvature (*ROC*) coronal for a typical bony defect. A best-fit 3-point radius is shown (52.32 mm).

(ROC) was measured along the defect (Fig. 1) using the Mimics 3-point best-fit arc method and was labeled as ROC coronal. We defined a positive coronal ROC as a radius that matched the intact concave glenoid, whereas a negative ROC had the opposite convex curvature. A 3D model for the contralateral, intact shoulder was generated as a control. This intact model was then mirrored to allow for an overlay of the intact glenoid to be superimposed upon the injured glenoid. Point and global registration methods were used to match the contours of the glenoids as closely as possible.

Virtual surgery was then performed to address the bone loss using standard and CA Latarjet reconstruction according to the techniques of Walch[17] and deBeer and Roberts,[6] tibial plafond according to the technique of Provencher et al,[14] and iliac crest according to the technique of Warner et al.[18] Grafts were optimally positioned to restore articular congruity and defect fill while ensuring that no part of the glenoid adjacent graft was proud in relation to the intact glenoid surface, thereby creating an ‘‘idealized’’ surgical model to maximize the potential result with regards to restoration of native anatomy.[8,17]

For the Latarjet-Patte reconstructions, the coracoid was sectioned at the elbow just distal to the insertion of the coracoclavicular ligaments and moved into position in the standard (inferior border in contact with glenoid) or CA (medial border in contact with glenoid) method.[7,9] Slight overlapping of the coracoid and the glenoid was allowed to simulate the use of a saw or burr to optimally smooth the contacting surfaces during surgery. Areas of the articular surface of the coracoid grafts were calculated for each position using the surface area function. The coronal ROC was calculated for each graft position (Fig. 2, *A* and *B*).

For each of the allograft techniques, 20 CT scans of intact pelvic and tibial plafonds were used from a database of high-resolution studies obtained for an evaluation unrelated to the study. CT scans were acquired using a 64-channel high-resolution CT scanner and bone acquisition and standard reformatting algorithms; slice thickness was 0.625 mm.

Pelvis CT scans were reviewed from 20 individuals (mean age, 28.9 [6.9 SD] years) undergoing our typical femoroacetabular impingement imaging protocol, which allowed us to compile 20 CT scans of normal iliac crests. Ankle CT scans obtained for foot trauma not involving the tibial plafond were reviewed from 20 individuals