

Repair of an Anteroinferior Glenoid Defect by the Latarjet Procedure: Quantitative Assessment of the Repair by Computed Tomography

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Purpose: The purpose of this study was to determine quantitatively whether the Latarjet procedure (coracoid transfer to the glenoid) is sufficient to restore a significant defect area of the glenoid. **Methods:** Fourteen cadaveric shoulders were used (mean age, 76 years; range, 72 to 87 years). An anteroinferior glenoid defect was created and then the coracoid osteotomized to its angle and transferred to the defect. A 3-dimensional computed tomography scan was used to calculate the surface area of (1) the intact glenoid, (2) the osteotomized glenoid, and (3) the reconstructed glenoid. **Results:** The mean area of the intact inferior glenoid was $734 \pm 89 \text{ mm}^2$. After creation of the defect, the surface area of the glenoid was reduced significantly to $523 \pm 55 \text{ mm}^2$ ($P = .011$). The mean defect area was $28.7\% \pm 6\%$ of the intact glenoid. After coracoid transfer, the mean surface area of the reconstructed glenoid was $708 \pm 71 \text{ mm}^2$ but it was not significantly smaller than that of the intact glenoid ($P = .274$). The mean surface area of the coracoid that was used to repair the defect was $198 \pm 34 \text{ mm}^2$, or $27\% \pm 5\%$ of the intact glenoid. **Conclusions:** In our cadaveric model, a mean 29% defect size of the inferior glenoid was restored to normal after coracoid transfer by use of the Latarjet procedure. **Clinical Relevance:** In the clinical scenario, the existence of a glenoid bone defect of more than 25% to 30% is very rare in patients with anterior shoulder instability. Therefore, when clinically indicated, large bony defects of the anterior glenoid can be adequately treated by the Latarjet procedure.

A significant glenoid bone defect results in a loss of concavity of the glenoid and subsequently affects shoulder stability.¹⁻⁴ According to some biomechanical studies, containment of the humeral head is reduced when an anteroinferior glenoid defect is present

and therefore the shoulder is significantly less resistant to forces that cause dislocation.⁵⁻⁸ Although the definition of a large- or critical-sized defect is not clear, it is generally accepted that patients with bone loss of the inferior glenoid between 20% and 30% have a high recurrence rate after Bankart repair and that a bone grafting procedure is required in these patients to restore osseous and shoulder stability.^{5,6,8,9} According to Itoi et al.,⁶ an osseous defect with a width of 21% of the glenoid length is "critical" to cause anteroinferior instability. Lo et al.⁹ reported that bone loss of at least 25% to 27% of the inferior glenoid (inverted-pear glenoid) significantly decreases the articular arc available to support the humeral head and shoulder instability that occurred under these conditions even after Bankart repair.

According to many studies, when a large glenoid defect is present, a bone grafting procedure is neces-

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sary to restore glenohumeral stability and prevent future recurrences of dislocations.¹⁰⁻¹³ Today, there are several methods to address glenoid bone deficiency: bone grafting by use of iliac crest graft,¹⁴ autologous bone grafting from the ipsilateral acromion,¹⁵ allogeneic bone grafting,¹⁶ and transfer of the coracoid to the glenoid (Latarjet procedure).^{17,18} The major advantages of the Latarjet procedure are the extension of the concavity of the glenoid's bony articular arc (bone effect) and the creation of a sling effect of the transferred conjoint tendon (muscle-tendon effect). In addition, the coracoid bone graft does not create donor-site problems like the iliac bone graft, and at least part of its vascularity remains intact because of the soft-tissue attachments. Therefore a lower complication rate, like bony nonunion, is expected with the Latarjet procedure.

Various methods to evaluate the amount of glenoid bone loss have been described. An arthroscopic technique using the bare spot of the glenoid as a reference point to assess the defect has been reported by Burkhart et al.¹⁹ However, other authors have shown that this method is not reliable to quantify bone loss of the glenoid.²⁰ The ratio of the defect to the glenoid length (the length between the supraglenoid tubercle and the infraglenoid tubercle) has also been used to estimate the size of the glenoid defect. However, computed tomography (CT) is currently widely accepted as being a more accurate method of assessing osseous defects of the glenoid.²¹

The purpose of this study was to determine whether the surface area of the glenoid is sufficiently repaired with the Latarjet procedure, by use of an inferior glenoid bone defect cadaveric model and 3-dimensional (3D) CT for imaging and quantitative analysis. Our hypothesis was that coracoid transfer to the glenoid would have the ability to restore a large antero-inferior glenoid defect.

METHODS

This study included 14 cadaveric shoulders (10 male and 4 female cadavers) (mean age, 76 years; range, 72 to 87 years). The inclusion criterion for these specimens was no evidence of glenohumeral arthritis or other bony lesions during radiographic evaluation or direct inspection. The shoulders were thawed overnight before use, and all soft tissues including the labrum were removed to expose the glenoid. In addition, disarticulation of the humerus was performed. An oblique osteotomy from approximately the mid-glenoid notch to the 6-o'clock position ac-

ording to Lo et al.⁹ was then created to simulate a large antero-inferior defect of the inferior glenoid. We chose this type of osteotomy because its reproducibility was very high by use of specific landmarks (mid-glenoid notch and 6-o'clock position). To simulate the bony part of the Latarjet procedure, the coracoid was osteotomized just anterior to its base with the use of an angled saw. Next, fixation of the coracoid to the glenoid was performed with 1 cannulated 3.5-mm screw by rotating the coracoid 90° and placing the inferior surface (which was previously decorticated) against the glenoid.

CT Protocol and Measurements

A 16-row multislice CT scanner (Light Speed; GE Medical Systems, Milwaukee, WI) was used for all examinations. The cadaveric shoulders were placed in the center of the scanner's bore. A continuous scan was obtained from the upper margin of the acromioclavicular joint to the inferior scapular angle, with a field of view of 15 × 15 cm, collimation of 16 × 0.625 mm, and short pitch of 0.562 (5.62 mm per rotation). The tube parameters were 120-kV peak and 200 mA. The acquisition matrix was 512 × 512. The 3D reconstructions were created from the axial data set with a soft-tissue algorithm, and all evaluations were performed on a commercially available external workstation (Advantage Windows, version 4.1; GE Healthcare, Buckinghamshire, England).

The oblique sagittal plane was used for measurements because it allows a direct view of the glenoid fossa. Then, the surface of the inferior glenoid, which can be approximated to a true circle, was manually drawn and calculated as described by Sugaya et al.²² (Fig 1). Two Kirschner wires were placed at the 6-o'clock position and the mid-glenoid notch to determine precisely the osteotomy area before the osteotomy was performed (Fig 2). Our aim was to create a 25% to 30% defect size of the inferior glenoid in every case. These Kirschner wires served as guide-wires to perform the osteotomy. After the osteotomy, the surface area of the osteotomized glenoid was calculated (Fig 3). The percentage of the glenoid defect was calculated as a ratio of the area of the osteotomized segment to the area of the inferior glenoid according to Sugaya et al. Finally, the surface area of the coracoid fragment (after fixation) and the reconstructed glenoid was calculated (Figs 4 and 5). The region of interest was drawn manually for assessment of the area under different circumstances (intact glenoid, after osteotomy, and after repair). The measure-

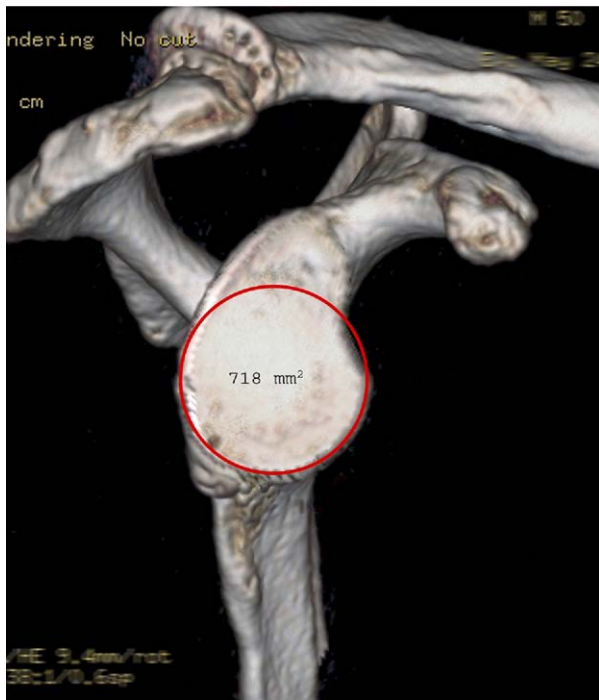


FIGURE 1. Volume-rendering 3D reconstructed image from a cadaveric shoulder showing that the normal glenoid has a pear-like shape. The inferior glenoid, which is the region of interest and approximates a true circle, was drawn manually, and the surface area was measured.

ments of these parameters were performed by the same investigator. Reproducibility was assessed in 10 paired measurements performed on the same day, 5 on 1 intact glenoid and 5 on 1 repaired glenoid, by another musculoskeletal radiologist with more than 20 years of experience.

Statistical Analysis

A paired Student *t* test was used to compare the surface area of the intact glenoid with that of the osteotomized and reconstructed glenoids. $P < .05$ was considered statistically significant. Pearson correlation coefficients and coefficients of variation were used to test the reproducibility of measured areas.

RESULTS

The mean area of the intact inferior glenoid was $734 \pm 89 \text{ mm}^2$ (range, 676 to 821 mm^2). After creation of the defect, the surface area of the glenoid was reduced significantly ($P = .011$) to $523 \pm 55 \text{ mm}^2$ (range, 398 to 547 mm^2). The mean defect area was $211 \pm 32 \text{ mm}^2$ (range, 178 to 232 mm^2), or $28.7\% \pm$

6% of the intact glenoid. After coracoid transfer, the mean surface area of the reconstructed glenoid was $708 \pm 71 \text{ mm}^2$ (range, 654 to 758 mm^2), but it was not significantly smaller than that of the intact glenoid ($P = .274$). The mean surface area of the coracoid that was used to repair the defect was $198 \pm 34 \text{ mm}^2$ (range, 164 to 224 mm^2), or $27\% \pm 5\%$ of the intact glenoid. After the reconstruction, there was a decrease of $26 \pm 16 \text{ mm}^2$ (range, 8 to 44 mm^2), or $3.5\% \pm 2\%$ of the surface of the inferior glenoid. The reproducibility of the measured areas, expressed as the percent coefficients of variation, did not exceed 2.5% (range, 0.5% to 2.5%) for the intact glenoid, 2.2% (range, 0.5% to 2.2%) for the osteotomized glenoid, and 2.4% (range, 0.5% to 2.4%) for the reconstructed glenoid.

DISCUSSION

Bone loss of the anteroinferior glenoid is a common finding in patients with anterior instability.²²⁻²⁵ According to biomechanical studies, a large glenoid defect significantly decreases anterior stability.⁵⁻⁸ Although the definition of a large or critical glenoid defect is not clear in the literature, it is generally accepted that bone loss averaging 25% to 30% cannot

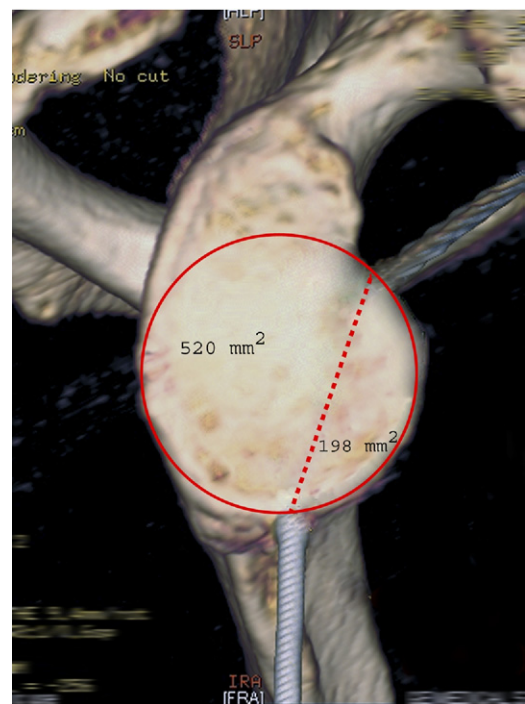


FIGURE 2. Two Kirschner wires were placed in the 6-o'clock position and in the mid-glenoid notch to determine the osteotomy area precisely. In this case it is 27.5% of the inferior glenoid.

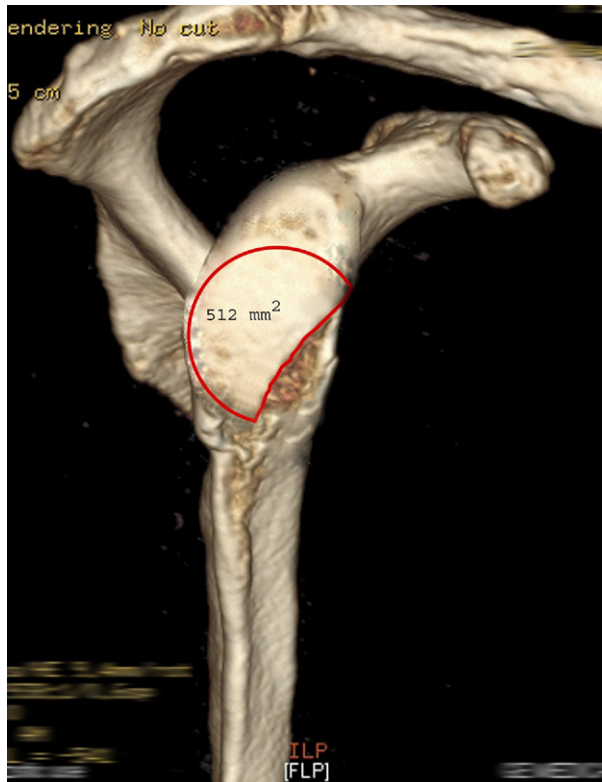


FIGURE 3. Glenoid after an osseous defect was artificially created. The region of interest was drawn over the remaining inferior glenoid, and the surface area was measured.

be addressed by soft-tissue repair only.⁸⁻¹¹ In a clinical study, Burkhart and De Beer²⁶ reported that in patients with significant bone loss of the anteroinferior glenoid (inverted-pear glenoid), arthroscopic Bankart repair results in a high recurrent dislocation rate (61%). Therefore a bony procedure to repair the glenoid defect and increase glenohumeral stability is recommended in these cases.

One of the most popular procedures to repair a glenoid bone defect is the Latarjet procedure, which was first described by Latarjet in 1954.²⁷ However, no previous reports in the literature have discussed whether the size of the coracoid graft is large enough to repair a large glenoid defect. The findings of our study show that the coracoid transfer to the glenoid defect is an excellent method to restore the surface area of the inferior glenoid when a large defect (28% of the intact glenoid) is present. In our cadaveric model the surface area of the reconstructed glenoid was slightly decreased, in comparison to the intact glenoid, after coracoid transfer, when the defect is between 25% and 30%. In the clinical setting the

existence of a glenoid bone defect of more than 30% is very rare or almost impossible.^{22,25} Therefore, in the clinical scenario, the surgeon can address every glenoid bone defect with the Latarjet method according to our results. From a biomechanical point of view, according to Montgomery et al.,⁷ a bone graft of 6 mm in width would be ideal when a glenoid defect is present. However, they did not quantitatively calculate their repair like in our study. On the basis of our quantitative assessment, there is no need for the surgeon to calculate the surface area of the coracoid graft because he or she can expect an almost full repair of a 25% to 30% glenoid defect when using the Latarjet procedure. Therefore this study shows that the Latarjet procedure is an excellent method to repair a large anteroinferior glenoid defect (when present) in patients with anterior instability. However, it is not clear from the literature whether the Latarjet procedure is indicated in cases of small glenoid bone defects or what the critical amount of bone loss is for a bone grafting procedure. Chuang et al.²³ used the glenoid index (ratio of the maximum inferior diameter of the injured glenoid to the maximum inferior diameter of



FIGURE 4. Volume-rendering 3D reconstructed image after reconstruction procedure. The region of interest was drawn over the coracoid process, and the surface area of the coracoid fragment was calculated.



FIGURE 5. Volume-rendering 3D reconstructed image after reconstruction procedure. The surface of the repaired inferior glenoid area was assessed and compared with the intact inferior glenoid (circle). In this case there was almost complete restoration (5% reduction of initial area) according to the measurements.

the uninjured contralateral glenoid), which was calculated preoperatively using 3D CT, to determine whether the Latarjet procedure is needed. If the glenoid index was less than 0.75, the patient was accurately (96%) predicted to benefit from the Latarjet procedure and not an arthroscopic Bankart repair.

The stabilizing effect of the Latarjet procedure is a combination of (1) extension of the glenoid's articular arc (bone effect) and (2) tensioning of the transferred conjoint tendon in the abduction and external rotation position (muscle-tendon effect).²⁸ In our study only the ability of the procedure to rebuild a deficient glenoid was investigated. Therefore the question of whether the bone or the muscle-tendon effect is more important cannot be answered based on our results. Wellmann et al.²⁹ in their biomechanical study found that in the presence of a glenoid defect, the Latarjet procedure was more effective at restoring anterior instability in comparison to a structural bone graft. This means that both mechanisms are probably responsible for the excellent stabilizing effect of this operation.²⁸ Another advantage of the Latarjet proce-

cedure is that the coracoid bone graft does not create donor-site problems like the iliac bone graft.³⁰ Furthermore, in comparison to the iliac bone graft and allograft, the coracoid graft preserves at least part of its vascularity because of the soft-tissue attachments. Therefore a lower complication rate (though not documented), like bony nonunion, is expected with the Latarjet procedure. On the other hand, disadvantages of the Latarjet procedure include potential injury to the musculocutaneous nerve, difficulties in revision surgery, and a nonanatomic procedure. The distortion of the local anatomy by placing a large bone piece in the anterior part of the glenoid is probably responsible for the arthritis that occurred after the Latarjet procedure in a long-term follow-up study.¹⁸

A 3D CT scan was used to calculate the surface area of the glenoid (intact, osteotomized, and reconstructed) in our study. CT is widely accepted as being a more accurate method of assessing osseous abnormalities, especially of the glenoid.^{21,31} Technologic advances, such as multidetector scanners capable of volume imaging with isotropic reconstructions, have resulted in an ongoing interest regarding accurate preoperative planning.³² Various reports have addressed the problem of accurate assessment of the osseous defect using CT.^{21-23,25,32} Sugaya et al.,²² using multidetector scanners, tried to assess the size of the defect and to classify this as an adjunct to preoperative planning. Their assumption that the inferior portion of the pear-shaped glenoid contour can be approximated to a true circle was also used in our study. Chuang et al.²³ have shown that 3D CT scans are 96% accurate in predicting whether to perform an arthroscopic Bankart repair or open Latarjet procedure. Because the overall prevalence of osseous defects in patients with anterior shoulder instability has been recognized in the literature, the role of CT in studying these patients has evolved.^{21-23,32} We believe that our approach using 3D CT is the most accurate method to quantitatively assess the effect of the Latarjet augmentation procedure on repair of an osseous glenoid defect.

A limitation of our study is related to the manually drawn measurements. However, this method is more accurate than other imaging methods, and it is easily reproducible with any multidetector scanner. In addition, its reproducibility is high, not exceeding 2.5%, because the osseous boundaries can be easily recognized. Another limitation is the location of the glenoid defect, which was created in an anteroinferior position in our cadaveric model. According to many recent studies, the location of the defect is anterior rather anteroin-

ferior.^{23,25} However, we chose this type of osteotomy because its reproducibility was very high using specific landmarks (mid-glenoid notch and 6-o'clock position).⁹

CONCLUSIONS

In our cadaveric model, a mean 29% defect size of the inferior glenoid was restored to normal after coracoid transfer by use of the Latarjet procedure.

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