Morphological and Dynamic Evaluation of the Glenoid Track with 3D Modeling Software: Case Report

Ewerton Borges de Souza Lima[1] Guilherme Augusto Stirma[1] Paulo Santoro Belangero[1] Carlos Vicente Andreoli[1] Alberto de Castro Pochini[1] Benno Ejnisman[1]

[1] Discipline of Sports Medicine and Physical Activity, Department of Orthopedics and Traumatology, Sports Traumatology Center, Universidade Federal de São Paulo, São Paulo, SP, Brazil

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Address for correspondence Ewerton Borges de Souza Lima, MD, MsC, MBA, Discipline of Sports Medicine and Physical Activity, Department of Orthopedics and Traumatology, Sports Traumatology Center, Universidade Federal de São Paulo, São Paulo, SP, Brazil (e-mail: ewertonbslima@gmail.com).

Abstract

Introduction Anterior glenohumeral dislocation (AGHD) often entails humeral and glenoid bone loss. While CT is standard, its static nature limits evaluation of dynamic engagement; three-dimensional dynamic analysis (3DDA) may better depict glenoid-track mechanics and aid planning.

Case Report A 35-year-old man presented after an assault with right AGHD. He had positive apprehension/relocation/surprise tests; CT showed a large posterosuperior Hill-Sachs without anterior glenoid fracture, and MRI confirmed an anteroinferior labral injury. CT DICOM data were imported into InVesalius and Rhino to build a 3D model of the glenoid, humerus, and coracoid. The humerus coordinate system was rotated to simulate abduction (0–90°) and external rotation (0–90°), testing 16 shoulder positions to identify the point of engagement. Coracoid dimensions measured 5.5 mm (height) × 6.6 mm (width); adding these to the glenoid-track calculation predicted 17.21 mm with classic Latarjet and 18.31 mm with congruent-arc. A classic Latarjet procedure with two cannulated screws and washers was selected. The patient had no complications, returned to activities, and at two years scored ASES 87 and WOSI 39.

Conclusion 3DDA clarified off-track behavior across functional ROM and quantified required graft size, directly informing the choice of coracoid bone-block and yielding a stable, functional shoulder. As a non-invasive adjunct that reuses existing CT data, 3DDA appears practical for refining indications and technique selection in AGHD.

Keywords

- anterior shoulder instability
- glenoid track
- hill-sachs lesion
- latarjet procedure
- 3D dynamic modeling

Introduction

Anterior glenohumeral dislocation (AGHD) is a common orthopedic injury and often results in bone damage in the glenoid and humeral head. Measuring this bone loss is of great importance for deciding on surgical treatment.[1] Computed tomography (CT) is the current standard method for measuring it,[2] but it only provides a two-dimensional and static image that is not ideal for interpreting the dynamics of the joint.[3] The use of the three-dimensional dynamic analysis (3DDA) within a software provides a solution to this problem, as it allows better interpretation of bone losses and facilitates preoperative planning.[4]

The present study describes a 3DDA for therapeutic decision-making in the case of AGHD. This manuscript was written in accordance with CARE guidelines for case

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Fig. 1 Computed tomography of the Hill-Sachs lesion. (A) Coronal section; (B) Sagittal section; (C) Axial section.

reporting. The patient signed the informed consent form, and the study was approved by the Research Ethics Committee under number 56193922.3.0000.5505.

Case Report

A 35-year-old male patient was a victim of physical aggression and presented with deformity, pain, and functional impairment in the right shoulder. AGHD was diagnosed, and closed reduction was performed. He had complete passive and active range of motion (ROM). There were no neurological injuries or signs of ligament hyperlaxity. Apprehension, relocation, and surprise tests were positive. Shoulder CT (►**Fig. 1**) showed joint congruency and the presence of a large posterosuperior humeral head depression (Hill-Sachs lesion). There was no anterior glenoid fracture (Bone Bankart Lesion). Magnetic resonance showed an anteroinferior labral injury without associated tendon injuries.

Three-Dimensional Dynamic Analysis

To plan the appropriate surgical technique for treating the shoulder instability, it was decided to do the 3DDA, which would allow the evaluation of the bone injury and the joint movement in different positions during the functional shoulder ROM.

To reconstruct the 3D model, CT images in DICOM format were transferred to the software InVesalius (Renato Archer Information Technology Center, Campinas - SP, Brazil) and Rhino 7 (Robert McNeel & Associates, Seattle - WA, USA), in which a complete dynamic anatomical analysis of the glenoid, humerus, and coracoid process was possible.

We mathematically rotated the local coordinate system of the humerus, centered in the humeral head, using a sequence of XY (►**Video 1**), which represented abduction/adduction and rotations: X = Rotation around the X axis of the scapula, represents abduction/adduction of the humerus; Y = Rotation around the Y axis, representing axial rotation. Functional shoulder ROM was defined as abduction 0-90 (x-axis), external rotation 0-90 (y-axis). We tested a total of 16 shoulder positions (►**Fig. 2**).

Video 1

Demonstration of three-dimensional dynamic analysis in 3D modeling software. Assessment of the position of the Hill-Sachs lesion in relation to the anterior edge of the glenoid, after simulated positioning of the coracoid graft (classic Latarjet technique). Online content including video sequences viewable at: https://www.thieme-connect.com/products/ejournals/html/10.1055/s-0045-1812882.

Decision Making

The height of the coracoid was 5.5 mm, and the width was 6.6 mm. Adding these measures to the glenoid track calculation, the treatment by the classic Latarjet technique would reach 17.21mm and the congruent "C" arch technique 18.31mm (►**Figs. 3** and **4**). It was then opted for treatment using the classic Latarjet technique, with two canulated screws and washers.

No complications were identified during the follow-up. The patient recovered well, returning to his activities without complaining of instability or new episodes of dislocation. Two years after the surgery, his ASES score was 87 and his WOSI score was 39.

Discussion

AGHD is a common disorder and, when the dislocation recurs, anterior glenohumeral instability develops, which affects around 2% of the general population. The presence of an associated bone injury increases the risk of instability and treatment failure using the capsulolabral repair technique. In these cases, surgical treatment using the bone block technique may be indicated.[1]

The treatment of Hill-Sachs defects with an intact glenoid rim remains controversial. Although studies have shown the role these defects play in perpetuating instability, consensus on the critical values of the defects and the best treatment options is lacking. Of the possible procedures, remplissage

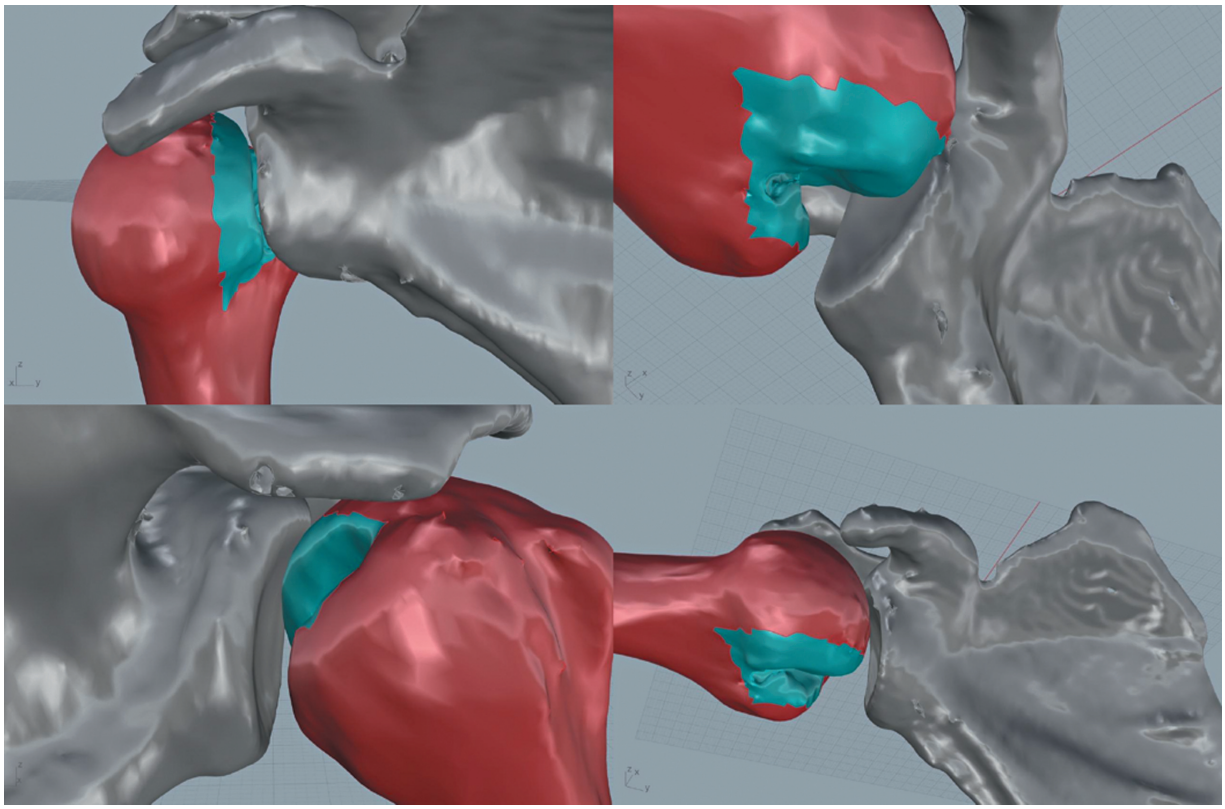

Fig. 2 Three-dimensional reconstruction with dynamic analysis of the shoulder in different positions of abduction and lateral rotation, demonstrating the relationship between the Hill-Sachs lesion and the anterior edge of the glenoid.

and the Latarjet procedure are the most performed. Studies of the biomechanical effects of remplissage and Latarjet procedures in the treatment of a moderately sized Hill-Sachs defect with an intact glenoid rim have demonstrated that they improve joint stability, reducing the overall frequency of dislocation, while having minimal effect on ROM. Overall shoulder without difference between both surgeries.[5]

The indication for surgical treatment with the bone block technique is based, among other criteria, on the presence of an off-track lesion, according to the GT concept, experience, and surgeon preference. GT consists of studying the dynamic interaction between bone loss in the proximal humerus and glenoid, which, depending on the location and size of the lesion, makes the joint unstable.[6]

Our case report demonstrated that the dynamic simulation of the interaction between bone lesions was an important tool for surgical decision-making. The simulation identified the shoulder positions in which engagement occurred and made it possible to measure the necessary size of the graft to choose the best bone block technique.

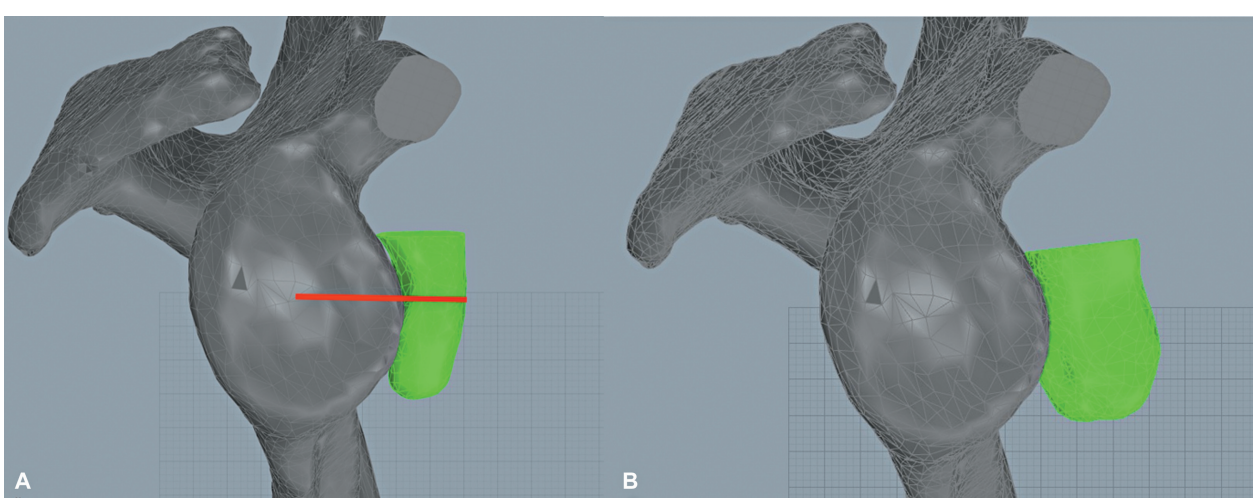

Fig. 3 Three-dimensional reconstruction of two coracoid graft positioning options for applying the bone block technique. (A) Classic Latarjet; (B) Latarjet using the congruent arc technique.

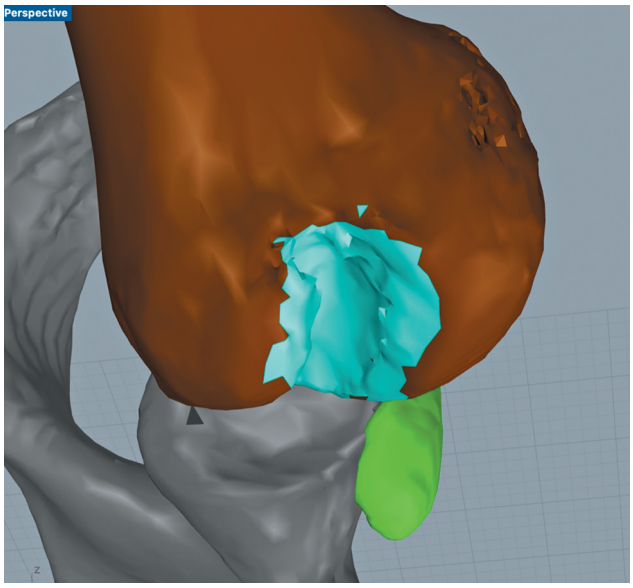

Fig. 4 Three-dimensional reconstruction with dynamic analysis demonstrating the restoration of the glenoid track through fixation of the coracoid graft using the Latarjet technique. Shoulder positioning in 90° abduction + 90° lateral rotation.

Before the simulation was carried out, a bone block using the Eden-Hybinette technique had been established as the technique to be performed. However, after the dynamic study and measurement in 3D software, the Latarjet technique was indicated for the procedure. The study demonstrated, relating the size of the graft and the different positions of the shoulder, that, with the coracoid graft, the off-track injury was corrected.

The width of the glenoid path observed in much of the literature is analyzed in only one position of the arm (90° of abduction and maximum external rotation).[7] The present study dynamically used the range of 0° to 90° of abduction and external rotation of 0° to 90°; thus, we were able to achieve more precise and detailed measurements of the glenoid track.

Preoperative planning of the Latarjet procedure, with 2D tomography, provides precise measurements of the width of the coracoid and glenoid with satisfactory inter- and intra-observer reliability. However, some studies have questioned the accuracy of CT and 3D-CT in measuring bone defects, showing a high level of variability and low interobserver reliability.[8–10] Given that static CT and 3D-CT measurements can be imprecise in quantifying bone loss, three-dimensional dynamic analysis emerges as a viable and accurate alternative to visualize the anatomy of the injury and shoulder movement, assisting in therapeutic decisions.

The case report presented in detail the practical application of a new tool that can be useful in diagnosis and therapeutic decision-making in cases of shoulder instability. Dynamic three-dimensional analysis is a non-invasive tool and does not require additional radiation, as it is just a complementary step in which CT images are used to create a three-dimensional model for analysis. Therefore, we believe it is a useful and risk-free tool for the patient and the healthcare professional. 3D reconstruction with the aid of modeling software are images acquired from tomography that generate various anatomical positions; however, the influence of each individual's ligament laxity or muscular action, factors that influence the translation and rotation of the glenohumeral joint, are not measured or recreated. Therefore, in the same way that biomechanical studies are limited in relation to in vivo studies, image reconstruction studies where we modify the images have these limitations that must be considered, in addition to the lack of clinical images, the short follow-up time, and the lack of objective assessments regarding pain, functionality, and patient satisfaction.

Conflict of Interest

All authors declare no conflict of interest related to this article. This study did not receive funding from public, private, or non-profit sectors.

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