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MRI-BASED AND CT-BASED QUANTIFICATION OF GLENOID BONE LOSS AND HILL-SACHS ENGAGEMENT RISK IN ANTERIOR SHOULDER INSTABILITY: A PROSPECTIVE 31-PATIENT STUDY USING THE BEST-FIT CIRCLE AND ADJUSTED GLENOID TRACK CONCEPT

Radiology

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ABSTRACT

Anterior shoulder instability is frequently associated with bipolar structural deficits involving the glenoid rim and the posterolateral humeral head. Accurate quantification of glenoid bone loss and estimation of Hill-Sachs engagement risk are essential for selecting appropriate management and reducing recurrence. This prospective case series evaluated 31 adults with anterior glenohumeral instability imaged between January 2024 and May 2025 using MRI and/or CT. Glenoid bone loss was measured using the best-fit circle method on en-face glenoid reconstructions. The glenoid track (0.83 × glenoid diameter) was adjusted by subtracting the measured defect width. The Hill-Sachs interval was measured and lesions were classified as on-track (HSI ≤ adjusted track) or off-track (HSI > adjusted track). Mean glenoid bone loss was 23.0% (range 10.4–39.2%). Off-track lesions were identified in 25 patients (81%) and on-track in 6 patients (19%). MRI was clinically contributory in 84% of cases by enabling concurrent soft-tissue assessment. Correlation between percentage bone loss and lesion classification was weak (r = 0.25), while correlation between the number of instability episodes and surgical recommendation was mild (r = 0.29). Incorporating bone loss into glenoid track calculation provides a conservative engagement-risk estimate and supports individualized preoperative planning.

KEYWORDS

Glenoid Bone Loss, Hill-Sachs Lesion, Glenoid Track, On-Track/Off-Track, Shoulder Instability, MRI, CT

INTRODUCTION

Anterior glenohumeral instability remains the commonest pattern of shoulder dislocation, particularly in young and physically active individuals. Recurrent instability is driven by a combination of capsulolabral injury and progressive osseous defects. Among the osseous contributors, anterior glenoid bone loss reduces the articular arc and compromises the concavity–compression mechanism, while a Hill-Sachs lesion represents a posterolateral humeral head impaction fracture that may engage the glenoid rim during abduction–external rotation. If these lesions are underestimated, recurrence rates increase and postoperative outcomes may be suboptimal.

Multidetector CT has traditionally served as the reference standard for quantifying bony defects due to its excellent spatial resolution and reliable 3D reconstructions. However, CT provides limited assessment of labral tears, capsular redundancy, marrow edema, and associated rotator cuff pathology, and it exposes patients to ionizing radiation. With wider availability of high-resolution 3T MRI and improved 3D sequences, MRI is increasingly capable of evaluating both soft-tissue and bony anatomy in a single study, which is particularly relevant for younger patients who may undergo repeated imaging.

The glenoid track concept provides a biomechanical framework to predict whether a Hill-Sachs lesion will engage. In its practical imaging application, the track width is estimated as 83% of the intact glenoid diameter. If a Hill-Sachs lesion and its medial extension (the Hill-Sachs interval) lie outside this track, the lesion is termed off-track and has a higher risk of engagement. Because glenoid bone loss effectively narrows the glenoid track, failure to account for the defect may underestimate engagement risk. Prospective Indian data applying a bone-loss-adjusted glenoid track approach remain limited; therefore, this study prospectively applies standardized MRI/CT measurements to quantify bone loss and classify lesions using an adjusted on-track/off-track methodology.

MATERIALS AND METHODS

This prospective observational case series was conducted in the Department of Radio-Diagnosis at MGM Medical College and Hospital, Chhatrapati Sambhajinagar, Maharashtra, India. Thirty-one consecutive patients with clinically and radiologically confirmed anterior shoulder instability presenting between January 2024 and May 2025 were included. Inclusion criteria were age ≥18 years and anterior glenohumeral instability confirmed clinically with supportive imaging. Exclusion criteria included posterior or multidirectional instability, prior surgery or metallic implants in the affected shoulder, and incomplete or poor-quality imaging datasets.

MRI was performed on 1.5T and 3T scanners using axial, coronal, and sagittal proton density and T2-weighted sequences with fat suppression, supplemented by sequences tailored to institutional protocol. CT was acquired using 32-slice and 128-slice multidetector scanners with thin collimation and multiplanar and 3D reconstructions. En-face glenoid reconstructions were used to standardize the measurement plane. Imaging review and measurements were performed on PACS workstations (OsiriX and Medsynapse) using consistent anatomical landmarks.

Glenoid bone loss was quantified by the best-fit circle method. The native inferior glenoid contour was approximated by a circle, yielding the reference glenoid diameter (D). The linear width of the anterior defect (d) was measured along the same plane. Percentage bone loss was calculated as: % bone loss = (d/D) × 100. The glenoid track (GT) was calculated as 0.83 × D. To incorporate bone loss, the adjusted glenoid track was computed as: adjusted GT = (0.83 × D) − d.

The Hill-Sachs interval (HSI) was measured on axial images as the sum of the Hill-Sachs lesion width and the bone bridge between the lesion and the rotator cuff insertion. Lesions were classified as on-track when HSI ≤ adjusted GT and off-track when HSI > adjusted GT. Clinical variables recorded included age, sex, and number of instability/dislocation episodes when available from clinical notes. Data were entered into Microsoft Excel and summarized using descriptive statistics. Pearson correlation coefficients were calculated to explore associations between percentage bone loss and lesion

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category, and between number of episodes and the decision to recommend surgical intervention.

Institutional Ethics Committee approval was not sought because the work was performed as an internal departmental audit using routine clinical imaging without additional interventions. All evaluations adhered to standard departmental imaging protocols.

RESULTS

Thirty-one patients were included (26 males and 5 females). The mean age of the cohort was 44.2 years. The number of recorded instability episodes ranged from 0 to 5. MRI was performed in 23 patients (74%), CT in 26 patients (84%), and both MRI and CT in 18 patients. MRI was considered clinically useful in 26 cases (84%), primarily due to additional depiction of labral and capsuloligamentous abnormalities alongside osseous assessment.

Mean glenoid bone loss across the cohort was 23.0%, with a range of 10.4% to 39.2%. Using the bone-loss-adjusted on-track/off-track classification, 6 patients (19%) were categorized as on-track and 25 patients (81%) as off-track. Surgical intervention was advised in 9 patients (29%), while 22 patients (71%) were managed conservatively based on combined clinical and imaging assessment.

Correlation analysis showed a weak positive correlation between percentage bone loss and lesion classification ($r = 0.25$), indicating that higher bone loss tended to be associated with off-track status but with substantial variability. A mild positive correlation was observed between the number of dislocation episodes and recommendation for surgery ($r = 0.29$), reflecting the influence of clinical history on decision-making in addition to imaging findings.

DISCUSSION

This prospective case series demonstrates the practical value of combining MRI and CT for structured evaluation of bipolar bone loss in anterior shoulder instability. By applying an adjusted glenoid track formula that subtracts measured glenoid bone loss from the calculated track width, we aimed to estimate engagement risk more conservatively and to reduce the chance of under-classifying lesions that may engage.

In our cohort, 81% of patients were classified as off-track using the adjusted method. This proportion is higher than rates often reported when the glenoid track is calculated without defect subtraction, supporting the concept that omission of bone loss can underestimate true engagement risk. Clinically, this matters because off-track lesions have been associated with higher recurrence after isolated soft-tissue stabilization, and they may prompt consideration of bony augmentation procedures or remplissage depending on overall clinical context.

Despite the high proportion of off-track lesions, surgical intervention was advised in only 29% of patients. This highlights that imaging classification is one component of management and must be interpreted alongside symptoms, activity demands, age, recurrence pattern, and patient preference. Some patients with off-track lesions may remain functionally stable or may opt for conservative treatment, whereas others with fewer episodes but high-demand sports participation may be considered for surgery.

MRI was clinically contributory in 84% of cases, reflecting its ability to evaluate associated soft-tissue abnormalities that influence instability, such as Bankart lesions, capsular laxity, and rotator cuff pathology. MRI also avoids ionizing radiation and can be used as a first-line modality in appropriate clinical settings. CT remains indispensable for detailed cortical bone evaluation and for accurate 3D depiction of the glenoid rim in complex cases or when bone block procedures are being considered. In practice, MRI and CT can be complementary, with modality selection tailored to the clinical question, availability, and surgical planning needs.

The weak correlation between bone loss percentage and lesion category underscores the multifactorial nature of engagement. Lesion orientation, humeral head translation, capsulolabral integrity, and dynamic factors during shoulder motion contribute to whether a lesion engages. Similarly, the mild association between recurrence frequency and surgical recommendation reflects the nuanced role of clinical history: repeated instability episodes often indicate failure of conservative measures and may justify operative stabilization, but single-episode patients may still warrant close follow-up if imaging demonstrates high-risk morphology. Standardizing measurement planes and reporting language can also improve communication between radiologists and orthopaedic surgeons, reducing ambiguity during preoperative planning.

Limitations include the single-center design and modest sample size. Measurements were performed by a single observer, so interobserver variability was not assessed. Additionally, postoperative or long-term functional outcomes were not tracked, limiting direct correlation between imaging classification and clinical endpoints. Nevertheless, prospective inclusion of consecutive patients, consistent measurement planes, and standardized formulas strengthen the internal consistency of the study and provide useful regional data.

CONCLUSION

MRI and CT provide complementary roles in the evaluation of anterior shoulder instability. Using the best-fit circle method and bone-loss-adjusted glenoid track assessment, we quantified glenoid bone loss and classified engagement risk using an on-track/off-track framework. Mean glenoid bone loss was 23%, and off-track lesions were prevalent (81%). MRI was clinically useful in most patients, supporting its role as a radiation-free modality for comprehensive evaluation, while CT remains essential for detailed osseous mapping in preoperative settings. Incorporating measured glenoid bone loss into glenoid track calculation may refine risk stratification and support individualized treatment planning.

Table 1: Baseline Patient Characteristics

Variable	Value
Total Patients	31
Mean Age (years)	44.2
Male	26 (84%)
Female	5 (16%)
Episodes Range	0-5

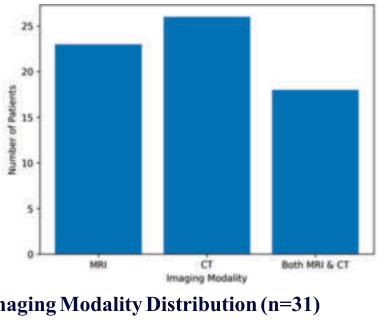

Figure 1: Imaging Modality Distribution (n=31)

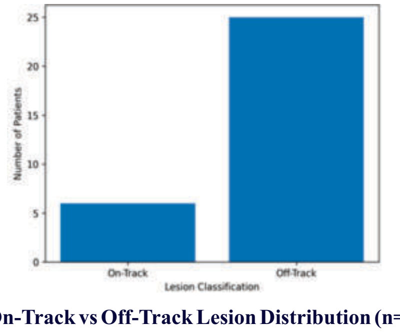

Figure 2: On-Track vs Off-Track Lesion Distribution (n=31)

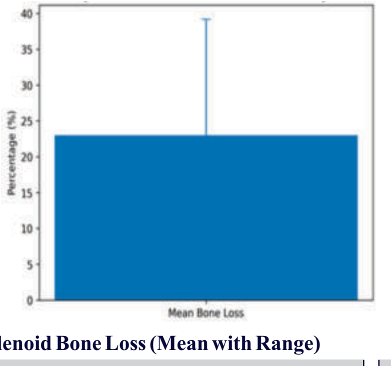

Figure 3: Glenoid Bone Loss (Mean with Range)

Table 2: Correlation Analysis Summary

Variables Compared	Correlation (r)	Strength
Bone Loss vs Lesion Type	r = 0.25	Weak
Episodes vs Surgery	r = 0.29	Mild

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