

# Posterior Displacement and Angulation of Displaced Lateral Clavicle Fractures

## A 3-Dimensional Analysis

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**Background:** The management of lateral clavicle fractures is often challenging because of difficulties in identifying displacement patterns that indicate an unstable fracture.

**Hypothesis:** The aim of this study was to evaluate displacement patterns through analysis using 3-dimensional (3D) rendering software for displaced lateral clavicle fractures. We hypothesized that most displaced lateral clavicle fractures would have posterior displacement and angulation as well as superior displacement of the medial fragment.

**Study Design:** Cross-sectional study; Level of evidence, 3.

**Methods:** Radiographs of 37 displaced lateral clavicle fractures were imported into the 3D rendering software to reconstruct the fracture model. For the computational simulation of fracture reduction, the medial fragment was manipulated and returned into place using the software's moving tools. Two corresponding points were marked between the medial and lateral fragments to measure 3D spatial location in the x-axis (shortening), y-axis (horizontal displacement), and z-axis (vertical displacement). The displacement angle on the cranial view was also measured based on the medial end of the clavicle.

**Results:** There were 32 cases (86.5%) of superior displacement of the medial fragment (mean, 5.8 mm; range, -6.5 to 19.0 mm), 35 cases (94.6%) of posterior displacement of the medial fracture fragment (mean, 8.8 mm; range, -3.2 to 18.3 mm), and 23 cases (62.2%) of distraction of the fracture site (mean, 2.1 mm; range, -9.2 to 12.2 mm). All 37 patients revealed posterior angulation of the fracture site (mean, 8.9°; range, 2.2°-39.4°).

**Conclusion:** Most displaced lateral clavicle fractures have posterior displacement and angulation as well as superior displacement of the medial fragment. Our results revealed that 3D evaluation of lateral clavicle fracture displacement patterns is useful for assessing fracture stability and making treatment decisions.

**Keywords:** lateral clavicle fracture; displacement; pattern; shoulder

Lateral clavicle fractures represent 10% to 30% of all clavicle fractures.<sup>1,9,13,14</sup> Although relatively uncommon compared with shaft fractures, lateral clavicle fractures still represent a diagnostic and therapeutic challenge for shoulder surgeons.<sup>3</sup> Delayed union or nonunion after nonoperative treatment for lateral clavicle fractures is common, especially when the fracture is displaced.<sup>2,7,9,10</sup> The management of lateral clavicle fractures is often challenging because of the difficulties inherent in identifying fracture patterns that imply an unstable fracture.<sup>1</sup>

Neer<sup>5</sup> classified lateral clavicle fractures into 3 types based on the fracture location in relation to the

coracoclavicular ligaments. This classification system has traditionally been used to determine fracture pattern and stability. Neer type I fractures are stable and occur lateral to the coracoclavicular ligaments.<sup>7</sup> Neer type II fractures are usually unstable and characterized by the detachment of the coracoclavicular ligaments from the medial segment.<sup>7</sup> Neer type III fractures involve the articular surface of the acromioclavicular joint.<sup>5</sup> In 1990, Craig<sup>4</sup> added type IV and V fractures to the classification. Type IV fractures involve disruption of the periosteal sleeve in the pediatric population, and type V fractures have only a small inferior cortical fragment that remains attached to the coracoclavicular ligaments.<sup>1</sup> Although these classification systems have been widely used for diagnosis and management of lateral clavicle fractures, one limitation of these classification systems is that fractures are classified using only

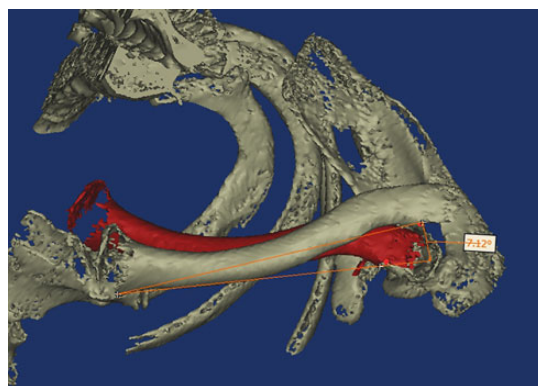
simple coronal assessment. Often, a simple coronal assessment may miss horizontal displacement of the fracture fragment. Although previous studies of lateral clavicle fractures have emphasized vertical displacement of the fracture fragment in the coronal plane, horizontal displacement in the sagittal plane has been underestimated.

Bishop et al<sup>3</sup> emphasized that fracture stability—rather than the Neer classification or the size of the distal fragment—is key in decision making for management of lateral clavicle fractures. Unstable lateral clavicle fractures are more likely to have horizontal displacement as well as vertical displacement of the fracture fragment. Generally, Neer type II fractures are unstable with 28% to 44% of nonunion.<sup>1,2,9,11</sup> Robinson and Cairns<sup>9</sup> reported that of 101 patients, 11 patients had a symptomatic nonunion and 3 patients developed acromioclavicular joint arthritis. This led us to believe that horizontally unstable injuries are missed or underestimated during primary radiologic examinations.

The aim of this study was to evaluate displacement patterns through 3-dimensional (3D) analysis for displaced lateral clavicle fractures. We hypothesized that displaced lateral clavicle fractures would show posterior displacement and angulation as well as superior displacement of the medial fragment.

## METHODS

The study was approved by the institutional review board of our institution. By searching the medical records between 2012 and 2016, we identified radiographs and computed tomography (CT) scans of 37 consecutive patients with displaced lateral clavicle fractures. A displaced lateral clavicle fracture was defined as a medial fracture fragment with  $\geq 5$  mm displacement on plain radiographs at the time of initial injury including an anteroposterior and oblique view of the acromioclavicular joint and an axillary lateral view of the shoulder. Inclusion criteria were acute fracture within 4 weeks after initial trauma, the availability of readable plain radiographs, and CT scans taken at the time of initial injury. Exclusion criteria were nondisplaced or minimally displaced ( $< 5$  mm) fractures, any other combined shoulder injury on the affected side, and a history of shoulder trauma or surgery. The mean age of the patients was  $54.6 \pm 17.2$  years (range, 23–83 years); 23 (62.2%) were men and 14 (37.8%) were women.



**Figure 1.** Through segmentation of the medial clavicular fragment, the medial fragment model was virtually reduced. We identified 2 corresponding points between reduced and non-reduced fragments by using the 4 synchronized windows in the program.

All patients had undergone continuous CT scans (Somatom Definition; Siemens Healthcare) in the supine position at the time of initial injury. The CT data in Digital Imaging and Communications in Medicine format were imported into Mimics software (Materialise Interactive Medical Image Control System) to reconstruct the lateral clavicle fracture models including the scapula and injured clavicle. After obtaining the Mimics files of lateral clavicle fracture models, we performed segmentation of the medial clavicular fragment to extract 3D information using the tools of Mimics software and reconstructed as medial fragment model. The 2 corresponding points of medial and lateral fragment models were marked as red points to analyze the displacement patterns of lateral clavicle fractures and for use as an anatomic reduction guide (Figure 1).

For the computational simulation of anatomic reduction, a 3D medial fragment model was manipulated and returned into place using the software's moving tools and the location of the 2 red points. After the medial fragment was definitively reduced by one of the authors (B.-S.K.), it was verified  $> 2$  times by experienced surgeons (C.-H.C., G.-H.J.). By using the features of a 3D rendering program to allow free 360° rotations with magnification in any plane, we analyzed displacement patterns and measured the difference of the 2 red points between nonreduced and reduced medial fragments in order to assess 3D spatial location on  $x$ -,  $y$ -, and  $z$ -axes in the program (Figure 2). To evaluate the degree of horizontal angulation between 2 medial fragment

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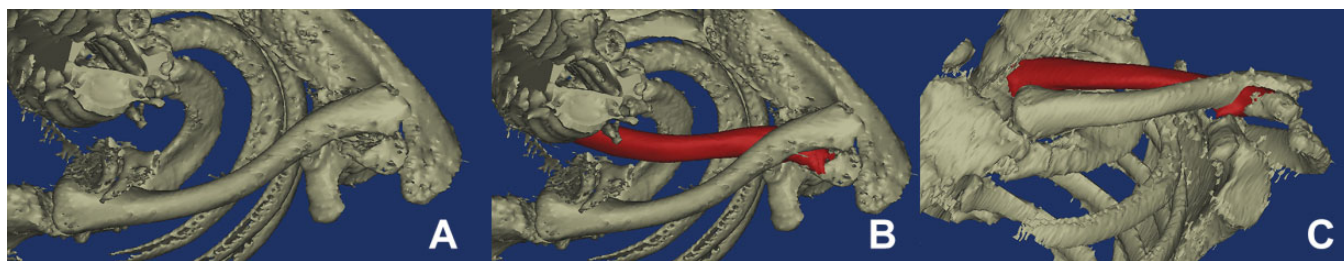
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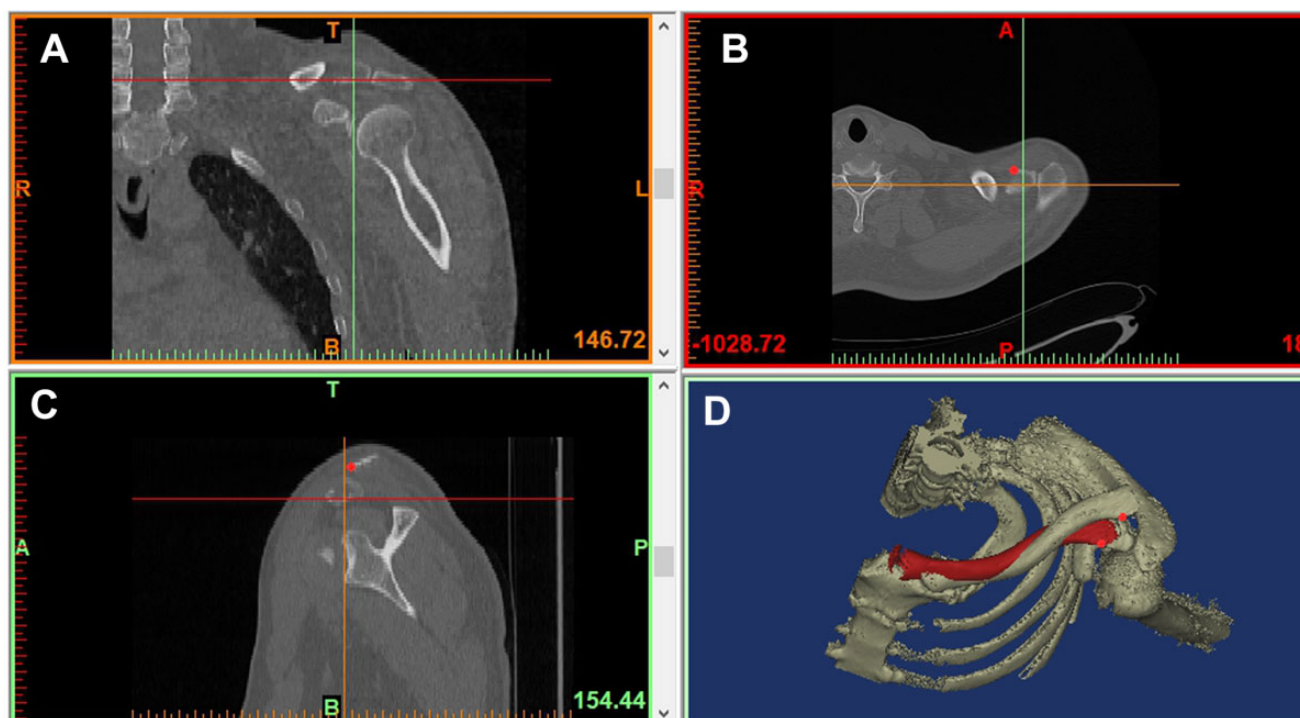
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**Figure 2.** (A) By using the features of a 3-dimensional (3D) rendering program to allow free 360° rotations with magnification in any plane, we performed 3D analysis of displacement patterns. After the lateral clavicular fracture model was anatomically reduced, the angulated deformity of the medial fragment could be assessed in any view including the (B) cranial and (C) anteroposterior views.



**Figure 3.** The degree of anteroposterior displacement between the 2 medial fragment models was measured on the cranial view by comparing the reduced model with the nonreduced model based on the medial end of the clavicle. Two corresponding points (red dots) were indicated using computed tomography images of (A) coronal, (B) axial, and (C) sagittal views, and the degree of displacement and angulation were measured through (D) reconstructed 3-dimensional images in the program.

models on the cranial view, we measured the angle between 2 points based on the medial end of the clavicle (Figure 3).

## RESULTS

### Displacement

We found that 32 (86.5%) and 5 (13.5%) patients had superior and inferior displacement of the medial fracture fragment, respectively. The mean superior displacement of the medial fracture fragment was 5.8 mm (range, -6.5 to 19.0 mm). Furthermore, 35 patients (94.6%) and 2 patients (5.4%) had posterior and anterior displacement of the

medial fracture fragment, respectively. The mean posterior displacement of the medial fracture fragment was 8.8 mm (range, -3.2 to 18.3 mm) (Table 1).

### Distraction/Shortening and Angulation

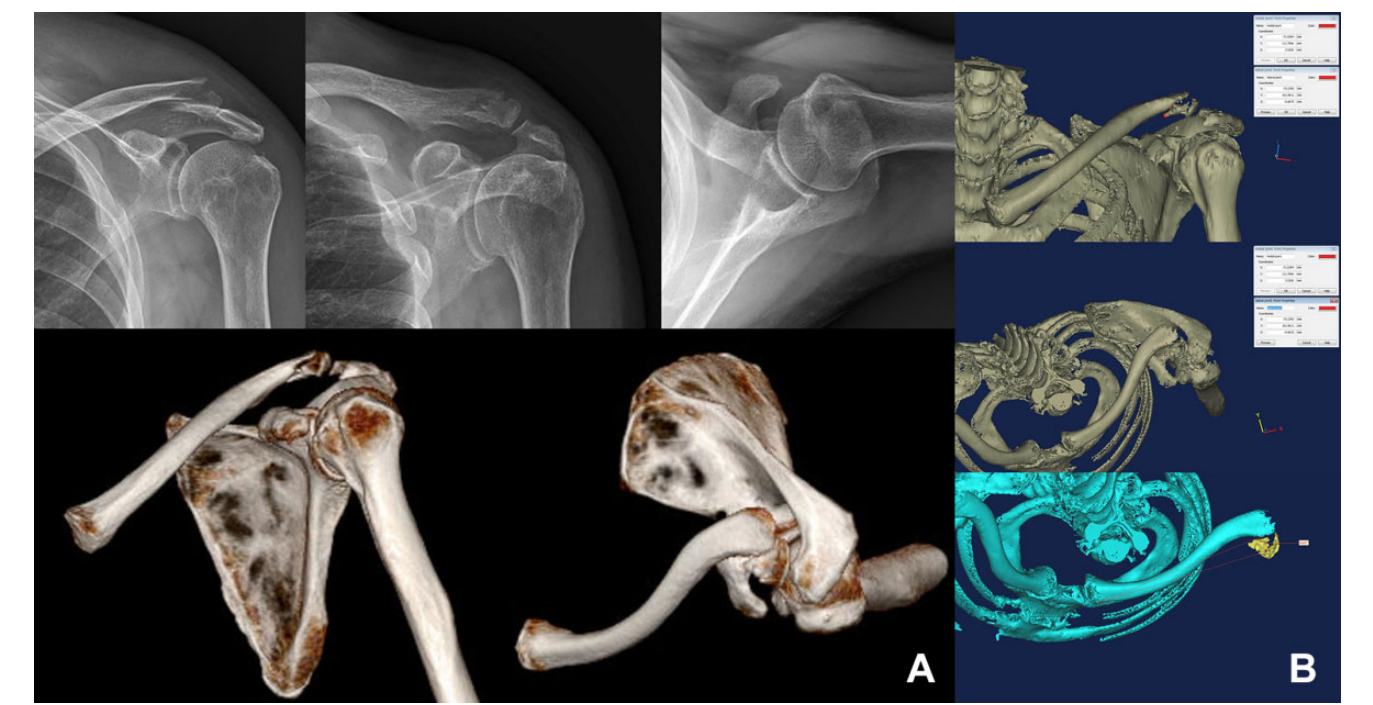
We found that 23 (62.2%) and 14 (37.8%) patients revealed distraction and shortening of the fracture site, respectively. The mean distraction of the medial fracture fragment was 2.1 mm (range, -9.2 to 12.2 mm). All 37 patients revealed posterior angulation of the fracture site. The mean posterior angulation of the fracture site was 8.9° (range, 2.2°-39.4°) (Table 1).



TABLE 1  
Data for 3-Dimensional Analysis of Displacement Patterns for Distal Clavicle Fractures<sup>a</sup>

Patient No.	Displacement, mm			Posterior Angulation, Degree	Patient No.	Displacement, mm			Posterior Angulation, Degree
	x	y	z			x	y	z	
1	0.9	0.6	5.4	2.4	20	2.2	8.7	7.6	4.8
2	9.9	12.6	9.2	25.9	21	-2.1	3.3	17.1	3.0
3	2.8	5.1	4.1	3.6	22	2.2	9.7	4.4	5.0
4	10.2	18.3	-0.9	7.5	23	-4.9	9.9	-0.5	4.0
5	4.7	15.5	7.4	5.5	24	-2.7	6.4	6.3	3.0
6	-1.6	-3.2	11.7	18.7	25	9.5	8.0	-2.8	7.6
7	-1.8	11.6	10.4	6.9	26	6.9	5.9	3.6	7.3
8	6.7	15.8	19.0	5.5	27	3.3	10.6	9.4	5.7
9	-6.6	14.1	0.0	6.6	28	-1.5	9.8	2.3	5.6
10	-3.5	5.0	10.0	6.0	29	-2.9	6.6	3.1	4.6
11	1.1	4.3	6.8	16.2	30	0.5	12.3	7.7	5.6
12	6.0	16.2	7.9	7.1	31	7.2	3.8	-0.9	2.9
13	-0.5	11.4	6.0	15.3	32	-4.9	6.9	5.2	2.8
14	10.4	9.2	-6.5	18.6	33	-0.6	7.3	0.1	2.2
15	-4.2	12.6	3.0	39.4	34	5.6	5.3	6.6	6.6
16	2.8	-0.8	4.9	3.7	35	5.2	5.9	0.6	11.7
17	7.1	8.5	10.1	5.7	36	4.0	7.6	11.0	5.0
18	2.6	17.9	1.9	13.9	37	12.2	16.3	13.3	27.5
19	-9.2	7.8	10.6	6.0					

<sup>a</sup>x-axis, distraction (+) or shortening (-); y-axis, posterior (+) or anterior (-) displacement; z-axis, superior (+) or inferior (-) displacement.



**Figure 4.** Lateral clavicle fracture in the right shoulder of a 71-year-old man. (A) Plain radiographs and 3-dimensional (3D) computed tomography images and (B) simulated images using 3D rendering software.

Case Presentation

A 71-year-old man was evaluated for a lateral clavicle fracture with displacement. Posterior displacement of the

medial fracture fragment was not clearly visible on plain radiographs. 3D CT revealed a displaced lateral clavicle fracture with obvious posterior displacement of the medial fragment (Figure 4). The 3D measurement using Mimics

software revealed 2.2-mm superior and 9.7-mm posterior displacement of the medial fragment with 4.4-mm distraction of the fracture site. The posterior angulation of the fracture site was 5.0°.

## DISCUSSION

The current study demonstrated that most displaced lateral clavicle fractures had posterior displacement and angulation as well as superior displacement of the medial fragment. Our results revealed that the 3D consideration of displacement patterns for lateral clavicle fractures is critical to assess fracture stability and best make treatment decisions.

Stable lateral clavicle fractures generally heal uneventfully and have satisfactory clinical outcomes with nonoperative treatment, whereas unstable lateral clavicle fractures have traditionally been more problematic.<sup>3,6,7,9,10</sup> Because unstable fracture patterns are often associated with longer healing times and notable nonunion rates between 18% and 43% with nonoperative treatment, they are considered the 1 category of clavicle fracture that should be addressed operatively.<sup>2,3</sup> The local osseous and ligamentous anatomic features and deforming forces may result in increased risk of delayed union and nonunion compared with fractures in other parts of the clavicle.<sup>13</sup> However, diagnosis and management of these fractures are often challenging because of the difficulties inherent in identifying a fracture pattern that indicates an unstable fracture.<sup>1</sup> Therefore, understanding these injury patterns and their imaging features may enhance appropriate decision making and management for lateral clavicle fractures.<sup>13</sup>

Management, outcome, and prognosis of lateral clavicle fractures depend on injury to the coracoclavicular ligament and fracture displacement, which makes the fracture unstable.<sup>1,3,7,12</sup> Although the Neer<sup>5</sup> classification system and modified Neer classification system proposed by Craig<sup>4</sup> for lateral clavicle fractures have traditionally been used to determine fracture stability, these classification systems involve simple coronal assessment only. Robinson<sup>8</sup> described that fractures were divided into subgroups A and B depending on displacement (>100% or <100% translation, respectively) of the major fragments for all clavicle fractures. However, Robinson did not mention the direction of displacement. Bishop et al<sup>3</sup> emphasized that fracture stability—rather than the Neer classification system or the size of the distal fragment—is an important component of decision making for the management of lateral clavicle fractures. Use of a simple coronal assessment for displacement pattern risks missing possible horizontal displacement of the fracture fragment. Although most previous studies for lateral clavicle fractures have emphasized vertical displacement of the fracture fragment in the coronal plane, horizontal displacement in the sagittal plane has been underestimated. Determining the fracture patterns and stability that are driving factors for treatment decision making is still difficult.<sup>3</sup>

Plain radiographs can provide valuable information in the assessment of lateral clavicle fractures. Radiographic evaluation includes anteroposterior view, Zanca view, 45° oblique

view, and axillary lateral view of the shoulder joint.<sup>1,3,12</sup> These radiographs can provide an overall assessment of fracture pattern, location, and displacement.<sup>1</sup> Although an axillary lateral view of the shoulder joint is important for assessing fracture patterns of lateral clavicle fractures, it is sometimes difficult to obtain an adequate view for determining horizontal displacement at the time of initial injury because of acute pain. In clinical practice, posterior displacement of a medial fragment may be ignored or underestimated because of projection error or inappropriate positioning of patients for an axillary lateral view. In the patient described in Figure 4, posterior displacement of the medial fracture fragment was not clearly visible on the axillary lateral view of the plain radiograph. However, we confirmed the presence of a displaced lateral clavicle fracture with obvious posterior displacement of the medial fragment using 3D CT. In the current study, we observed that 35 patients (94.6%) had posterior displacement of the medial fracture fragment and greater displacement in the axial plane compared with the coronal plane. The mean superior and posterior displacement of the medial fracture fragment was 5.8 mm and 8.8 mm, respectively. The amount of posterior displacement was more than superior displacement of the medial fragment. All patients revealed posterior angulation of the fracture site, and the mean posterior angulation of the fracture site was 8.9°. Considering our results, we think that inconsistent results and complications after nonsurgical treatment of Neer type II fractures may occur by horizontal displacement that is missed during initial radiologic examination. These results from 3D analysis of displacement patterns for lateral clavicle fracture can help clinicians in assessing fracture stability and determining treatment.

As the current study has shown, CT is needed for a more exact assessment of the severity and direction of lateral clavicle fractures when an unstable fracture is suspected based on plain radiographs. CT allows for an assessment of horizontal instability and the detection of underestimated or misdiagnosed distal clavicle fractures. For the most accurate assessment of the clavicular displacement pattern, CT may be considered in cases with uncertain horizontal displacement. CT also may be used for surgical planning and to determine adequacy of comminuted bone for operative fixation.<sup>13</sup>

This study had several limitations. First, the sample size was small. Second, the patients' position during radiologic examination was different between plain radiographs and CT. Because plain radiographs were taken with patients in the standing position and CT was taken in the supine position, the amount of superior displacement of the medial fragment could have been reduced. Third, the 2 corresponding points of medial and lateral fragment models were marked to analyze the displacement patterns of lateral clavicle fracture and to be used as guides for anatomic reduction. The selection bias of the 2 corresponding points cannot be excluded because of manual marking. Fourth, this study is a 3D reconstruction study using radiographic images, so it will be necessary to accumulate clinical data in the future. Despite these limitations, this is the first study demonstrating significant horizontal displacement of the medial fragment in unstable lateral clavicle fractures.

## CONCLUSION

Most displaced lateral clavicle fractures have posterior displacement and angulation as well as superior displacement of the medial fragment. Our results revealed that the 3D consideration of displacement patterns for lateral clavicle fractures is critical to assess fracture stability and best make treatment decisions.

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