Chapter 27

Trauma Mechanisms and Injury Classification

Sampat Dhumbre Patil

27 Trauma Mechanisms and Injury Classification

Introduction

Calcaneal fractures comprise 60% of tarsal fractures and 1 to 2% of all fractures.[1] There is a broad spectrum of fracture types and fracture patterns of the calcaneum. It is a significant cause of morbidity and 80 to 90% injuries occur in men in their prime working years.[2] Many patients are unable to return to the pre-injury occupation.[3]

Mechanism of Injury

Calcaneal fractures are high-energy trauma usually due to fall from a height or road traffic accidents.[3] Low-impact injuries result in nondisplaced or minimally displaced fractures. The fracture is termed as an intra-articular fracture when it involves the posterior facet.[4] Seventy-five percent of calcaneal fractures are intra-articular.[5]

Anterior process fracture, tuberosity (body) fracture, tuberosity avulsion, isolated sustentacular fracture are a few extra-articular fractures. Most of the extra-articular fractures are caused by avulsion force or in twisting injuries. Displaced posterior tuberosity fractures need to be addressed early to avoid soft tissue complications (**Fig. 27.1**). Anterior process fractures may go unnoticed after twisting injuries of ankle and need to be identified while evaluating chronic unresolved ankle pain.

The mechanism of intra-articular calcaneal fractures is quiet complex and controversial. Axial force transmitted from the talus is responsible for developing various fracture lines and fracture patterns of the calcaneum (**Fig. 27.2**). Essex-Lopresti has elaborated the fracture mechanism, according to which, when an axial force is applied with foot placed flat on the ground, primary fracture line is first produced laterally by the lateral edge of the talus and the calcaneus is fractured obliquely in two parts, a medial sustentacular or constant fragment and a large inferolateral fragment[6] (**Fig. 27.3**).

Fig. 27.1 Extra-articular fracture involving posterior calcaneal tuberosity. The mechanism of injury is usually an avulsion force of Achilles tendon on the calcaneal tuberosity.

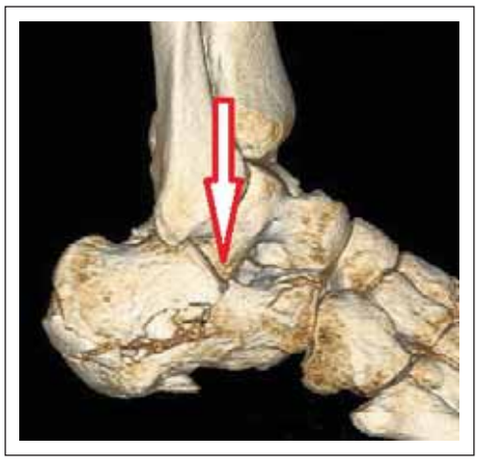

Fig. 27.2 Axial force applied by the talus on calcaneus results in various fracture lines and fracture patterns of the calcaneus.

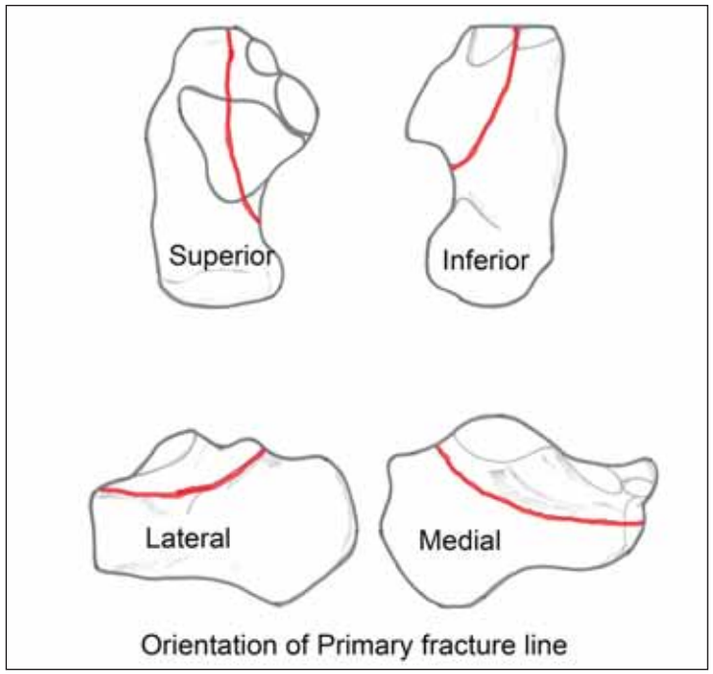

Fig. 27.3 Oblique orientation of the primary fracture line dividing calcaneus in two parts, a medial sustentacular or a constant fragment and a large inferolateral fragment.

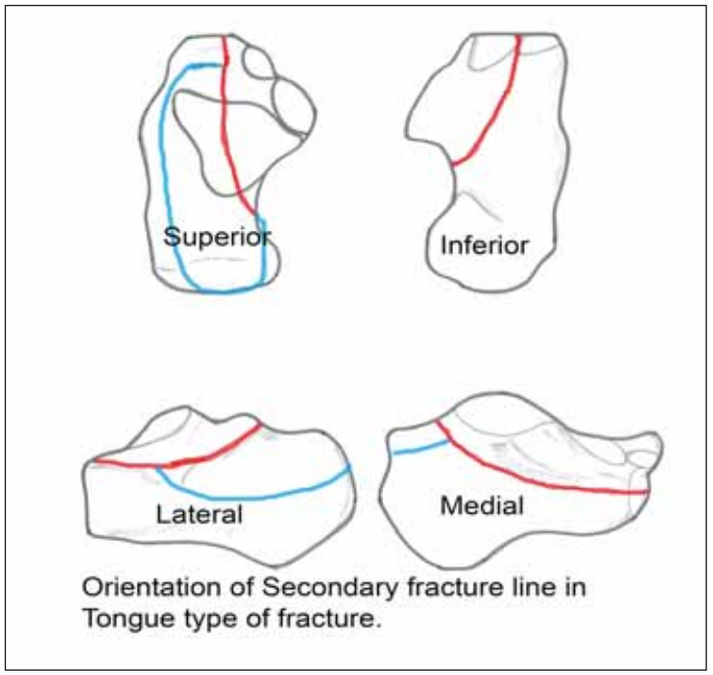

Fig. 27.4 In a tongue type of fracture, secondary fracture line runs beneath the posterior facet and reaches up to the posterior tuberosity.

Anteriorly, the fracture line may exit at the angle of Gissane or may continue further to exit at the calcaneocuboid joint.[1] Posteriorly, the fracture line runs medially.[1] If the force causing the fracture is continued, a secondary fracture line is created, generating a three-part fracture. Three-part fractures are further divided into two groups depending on the position of the secondary line on lateral radiographs: a tongue-type fracture and a joint depression–type fracture.[4] If the force is purely axial, the secondary fracture line appears just beneath the posterior facet and passes along the body of the calcaneus to exit laterally below the tendo-Achilles, creating a tongue-type fracture[6] (**Fig. 27.4**). If the load is slightly more horizontal, the secondary fracture line passes down to the lateral side of the calcaneum just behind the posterior facet, creating a joint depression–type fracture[6] (**Fig. 27.5**). A free lateral piece of posterior facet may be created in such a situation, which is known as superolateral fragment, semilunar fragment, or comet fragment. The calcaneus becomes more deformed and comminuted if the force is continued further.

Classification

More than 40 classification systems have been proposed to evaluate calcaneal fractures. Before the introduction of computed tomography (CT) scan, calcaneal fractures were classified on the basis of plain radiographs. CT scan analysis has completely changed the treatment and prognosis of calcaneal fractures. Classification systems based on CT scan are more reliable, guide surgeons in the treatment planning, and carry

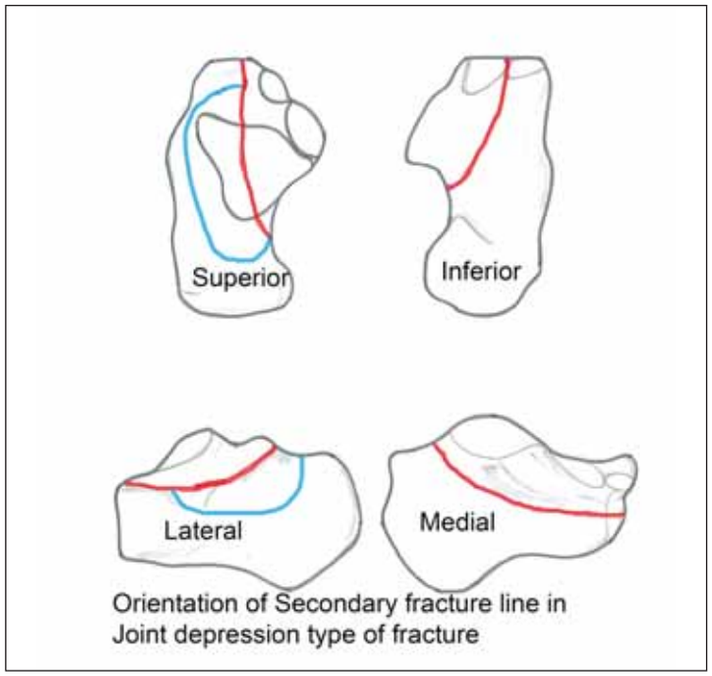

Fig. 27.5 In joint depression type of fracture, secondary fracture line runs beneath the posterior facet and ends just behind the posterior facet.

Fig. 27.6 Lateral radiograph of ankle showing tongue type of fracture due to secondary fracture line involving the posterior calcaneal tuberosity.

prognostic value. A few commonly used classification systems are the Essex-Lopresti, Orthopaedic Trauma Assiciation (OTA), Crosby, Sanders, Zwipp, Regazzoni, and Eastwood.

Classification Based on Standard Plain Radiographs

Based on conventional plain radiographs, in 1948, Palmer[7] described two distinct patterns of fracture of the calcaneus, which were refined by Essex-Lopresti[6] in 1952. The fracture is classified as two-part or three-part fracture. Two-part fracture is produced by a primary fracture line. The primary fracture line runs obliquely, creating a medial sustentacular or constant fragment and a large lateral fragment. Three-part fracture is produced by addition of a secondary line and these fractures are further divided into two groups depending on the position of secondary fracture line:– tongue-type fracture (**Fig. 27.6**) and joint depression–type fracture (**Fig. 27.7**). Variations of Essex-Lopresti classification have been described later by Widen, Arnesen, and others.

In 1975, Soeur and Remy[8] classified calcaneum fractures based on the number of articular bone fragments that were seen on anteroposterior radiographs of the midfoot and the lateral and Harris radiographs of the heel. Nondisplaced shear fractures with only widening of the joint space were termed as first-degree fractures. Second-degree fractures were those with secondary fracture line resulting in minimum three pieces; two of which included articular surface. Highly comminuted fractures were classified as third-degree fractures.

Fig. 27.7 Lateral radiograph of ankle showing joint depression type of fracture. Note the position of secondary fracture line running beneath the posterior facet and ending just behind the posterior facet.

Classification Based on CT Scan

The fracture fragments cannot be defined accurately on plain radiographs. The classification systems based on radiographs were of very less or no prognostic value. CT scan is an accurate method of scanning the complex calcaneal fractures.

In 1990, Crosby and Fitzgibbons[9] suggested a classification system based on CT scan. The fracture is classified into three types depending on the fracture displacement through the posterior facet (**Table 27.1**).

Three-part fractures described by Essex-Lopresti were further classified by Eastwood[1] et al into three subtypes. He reviewed details of 120 calcaneal fractures on plain radiographs and CT coronal images. In 96% cases, he identified three main fragments: sustentaculum, lateral joint fragment, and body fragment. Eastwood classification is mainly based on the composition of the lateral wall of the fractured bone, which is formed by lateral joint fragment and body fragment (**Fig. 27.8**). Subtypes of three-part fractures in Eastwood classification are as follows:

Table 27.1 Crosby and Fitzgibbons classification system

Type of fracture	Fracture pattern
Type I	Slightly displaced (less than 2 mm) or nondisplaced
Type II	More than 2 mm of displacement or depression of the fracture fragments
Type III	Highly comminuted fractures

Type I: The apparent lateral wall of the fractured bone is formed only by the lateral joint fragment.

Type II: The lateral wall is formed by the lateral joint fragment above and body fragment below.

Type III: The lateral wall is formed apparently by the body fragment. The lateral joint fragment is impacted within the body fragment.

The composition of the lateral wall can be anticipated preoperatively from CT scan sections at the level of the lateral malleolus. Formal osteotomy of the lateral wall is always necessary in Eastwood Type III fractures and is often required in Type II fractures. The pathological anatomy and the classification explained by Eastwood were intended to plan surgical management of calcaneal fracture and carry no prognostic significance.

Regazzoni classification[10] is based on the AO classification of M.E. Mueller, which is referred to for classification of long bone fractures. The fractures are classified as follows:

Type A: Peripheric fractures

Subtypes: A1, extra-articular; A2, avulsion fracture of the sustentaculum tali; and A3, isolated anterior process—intra-articular.

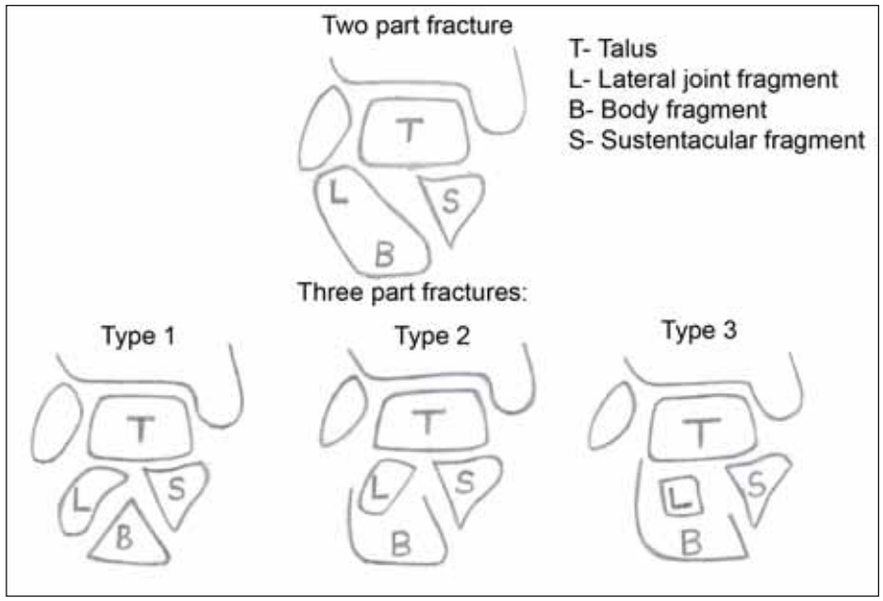

Fig. 27.8 Diagrammatic presentation of Eastwood classification demonstrating the composition of lateral wall of the calcaneum in two- and three-part fractures.

Type B: Fractures of the talocalcaneal joint only.

Subtypes: B1, posterior facet–single; B2, posterior facet—multiple; and B3, tarsal sinus and/or middle and/or anterior facet.

Type C: Fractures that also include the calcaneocuboidal joint.

Subtypes: C1, both joints single; C2, one joint multiple or tarsal sinus; and C3, both joints multiple.

Sanders et al[4] introduced a classification system in 1993. The most important advantage of Sanders classification is that it is easy to use; it establishes treatment guidelines for the surgeon; and it carries a prognostic value. The classification is based on the number and location of articular fracture fragments. The coronal and axial CT scan sections are evaluated and the section with the widest undersurface of the posterior facet of the talus is taken into consideration for classification of the calcaneal fracture (**Fig. 27.9**). The talus in this section is categorized into three equal columns by two lines, A and B. Line A is lateral, while line B is medial. These two lines,

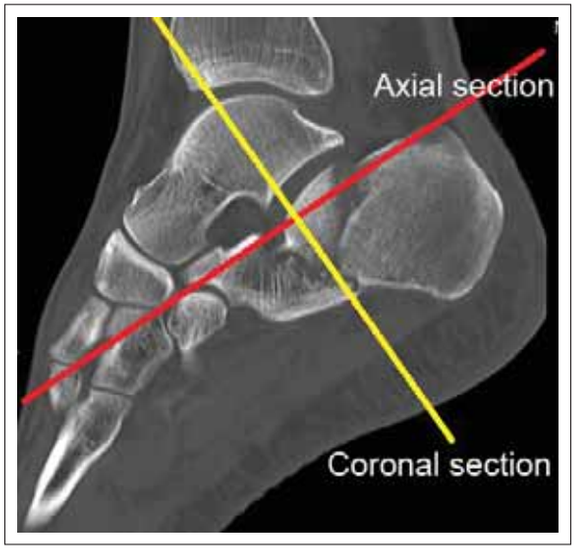

Fig. 27.9 Sanders classification is based on coronal and axial CT scan sections taken at the widest undersurface of the posterior facet of the talus.

when projected on the calcaneus, divide the posterior facet into three potential parts: lateral, central, and medial. A third fracture line C corresponding to the medial edge of posterior facet of the talus separates the posterior facet of the calcaneus from the sustentaculum and creates a fourth potential part. In this way, the calcaneus is divided into four potential parts: lateral, central, medial, and sustentaculum. The fractures are classified by Sanders as shown in (**Fig. 27.10**) and **Table 27.2**. Using this classification, Sanders et al[4] concluded that most common calcaneal fractures are Type II fractures, which are best treated surgically and have a good prognosis. Type III fractures are less frequent and have a worse prognosis, whereas Type IV fractures are rare fractures in which reconstruction of the posterior articular facet is difficult (**Figs. 27.11–27.15**).

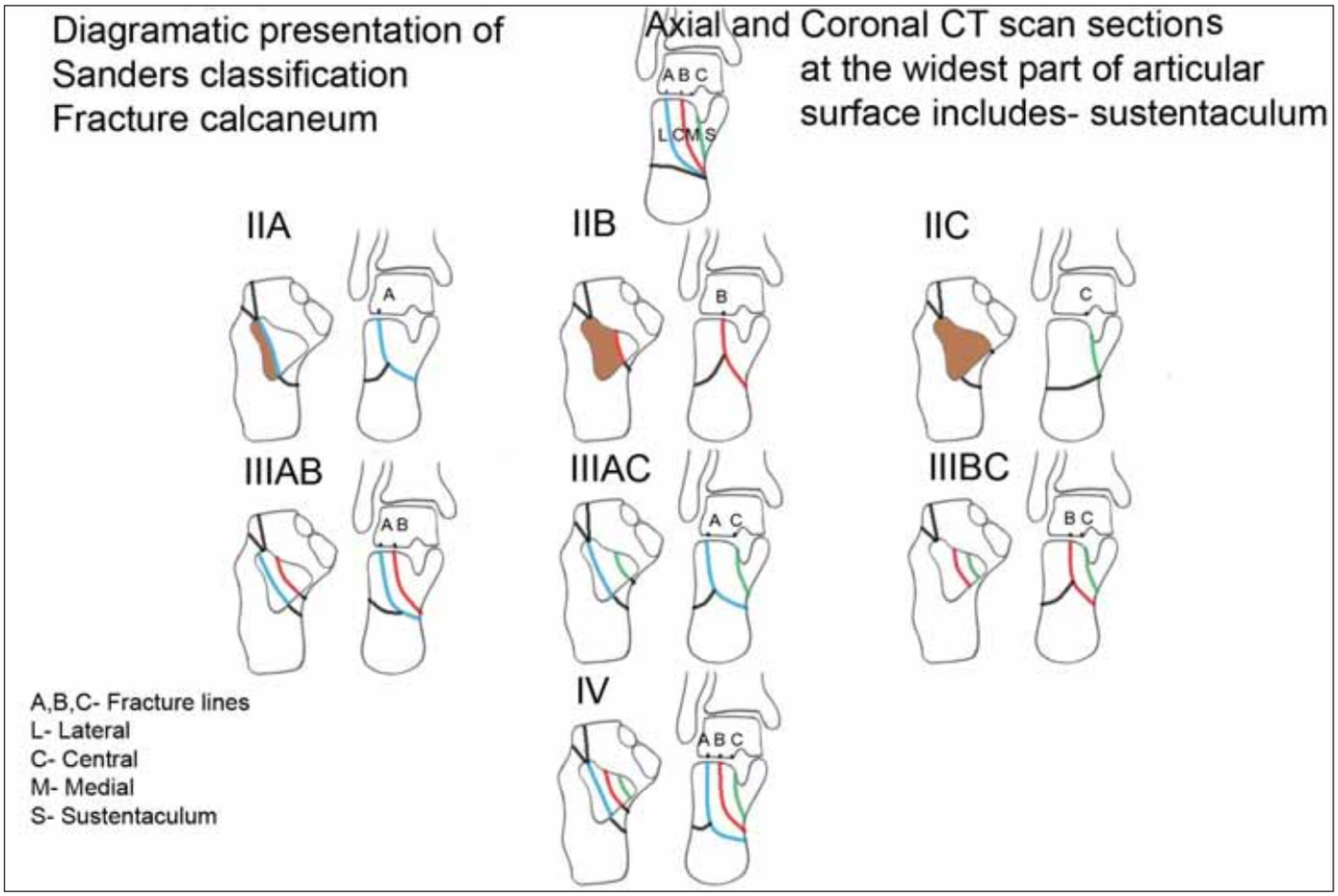

Fig. 27.10 Diagrammatic presentation of Sanders classification. The classification is based on three fracture lines seen in coronal and axial CT scan sections.

Fig. 27.11 Axial and coronal CT scan images of Sanders Type I fracture. The fracture is undisplaced.

Fig. 27.12 Axial and coronal CT scan images of Sanders Type IIA fracture. Only one fracture line A is noted.

Fig. 27.13 Axial and coronal CT scan images of Sanders Type IIB fracture showing fracture line B.

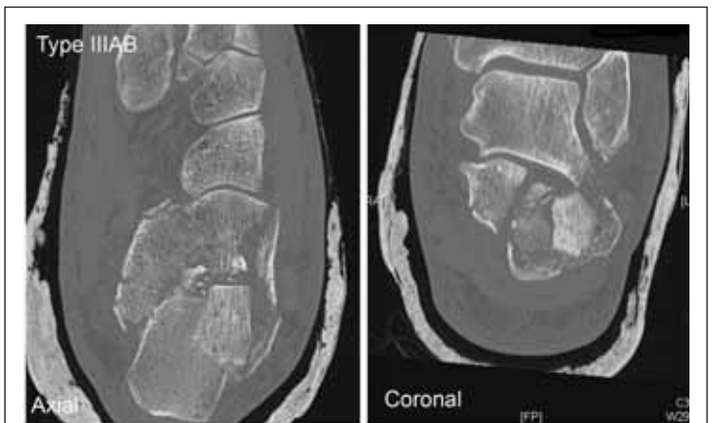

Fig. 27.14 Axial and coronal CT scan images of Sanders Type IIIAB fracture.

Fig. 27.15 Axial and coronal CT scan images of Sanders Type IV fracture with three fracture lines.

Table 27.2 Sanders classification system

Fracture type	Fracture description
Type I	Nondisplaced articular fractures irrespective of fracture lines
Type II	Two-part fracture of the posterior facet
II A	Primary fracture line A
II B	Primary fracture line B
II C	Primary fracture line C
Type III	Three-part fracture that features a centrally depressed fragment
III AB	Fracture lines A and B
III AC	Fracture lines A and C
III BC	Fracture lines B and C
Type IV	Highly communited fractures—four-part or more articular fracture

According to the OTA classification system,[11] calcaneal fractures are classified into three main types: A, B, and C.

Type A: Fractures of anterior process (A1), sustentaculum (A2), and tuberosity (A3).

Type B: Extra-articular fractures, which are further classified as noncomminuted (B1) and comminuted (B2).

Type C: Fractures involving the posterior facet. They are further subclassified as nondisplaced (C1), displaced two-part fractures (C2), displaced three-part fractures (C3), and displaced four-part fractures (C4).

Zwipp[12] has rated calcaneal fractures from one to eight points. Five main potential fracture fragments (sustentaculum, tuberosity, posterior facet, anterior process, and anterior facet) and three calcaneal joints are given one point each. One additional point is given for associated fracture tibia or fibula and up to three points may be given depending on the soft tissue injury.

Raffaele Rubino[10] reported a prognostic value of four classifications of calcaneal fractures. They are Essex-Lopresti, OTA, Swiss Regazzoni, and Sanders classification. He concluded that CT-based classifications, especially Regazzoni and Sanders, exhibit high prognostic value compared with plain radiographic classifications. Regazzoni classification is more accurate as it assesses extra-articular fractures, intra-articular fractures, and calcaneocuboid joint.[10] As the Sanders classification evaluates only the posterior facet of the talocalcaneal joint, a small percentage of fractures cannot be classified with this classification system.

OTA, Regazzoni, Sanders, Crosby, and Essex-Lopresti classification systems show moderate reliability when classified on the basis of two-dimensional (2D) CT scan with multiplanar reconstructions. These systems show no significant improvement in the reliability with addition of three-dimensional (3D) reconstruction. However, as Zwipp classification system is based on the number of potential main fracture fragments, it shows poor interobserver reliability when classified on the basis of 2D CT scan alone. Addition of 3D reconstruction shows significant improvement in the evaluation of this classification system[13]; hence, 3D reconstruction is recommended in conjunction with 2D CT scan when calcaneal fractures are to be classified with Zwipp classification system.

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