Fractures of the Calcaneus



Mandeep S Dhillon

Foreword
Mark Myerson

2nd Edition

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CHAPTER

5

Fracture Classification

Richard E Buckley, Sandeep Patel

"A classification is useful only if it considers the severity of the bone lesion and serves as a basis for treatment and evaluation of the results".

–Professor Maurice Müller

INTRODUCTION

Fractures of the calcaneus are relatively rare injuries. They represent only 1.2% of all fractures in adult population.[1] The calcaneus is the most frequently fractured tarsal bone[2] and through the years has received considerable attention from orthopedic surgeons. This is due to the fact that this fracture represents a life-changing injury that mainly affects young active people.[3] The burden to society is significant, with the socioeconomic impact being substantial in terms of days away from work and recreation.[4] Additionally, the management when indirect costs are included appears to be high regardless of operative or nonoperative treatment.[4]

Classification systems in orthopedic trauma surgery serve as tools for identifying fracture patterns, establishing treatment guidelines, and determining the prognosis of an injury. Furthermore, they facilitate data collection and presentation, thus allowing accurate communication among orthopedic surgeons in everyday clinical practice and research.[5] Historically, the first attempts to describe and classify calcaneus fractures were made by Malgaigne in 1843[6] and Hoffa in 1888.[7] Böhler[8] and Palmer[9] followed with their classifications in 1931 and 1948, respectively. Despite the low incidence of calcaneus fractures in the general population, >40 classifications have been described and presented in the orthopedic literature.[10] Most of these classification schemes are not currently in use and are considered to be of historical value. Nevertheless, it should not be forgotten that the historic value of these classifications is priceless. The numerous classification systems can be categorized as being developed before the computed tomography (CT) scans were popular and those after CT scans were commonplace. Nineteen conventional radiographic classifications have been used at least once since 1980, and another 15 are CT based and are considered contemporary.[10] On the contrary, there are 30 systems left unused or only mentioned in the literature after 1980.[10] In addition to clinically developed classifications, there are two systems that were developed based upon cadaveric models.[11,12] The involvement of the posterior facet determines whether the fracture is extra- or intra-articular. Extra-articular fractures include the tuberosity fracture, the sustentaculum fracture, the anterior process fracture, and the anterior avulsion fracture.[13]

The success of each classification system is measured by defining its reliability and validity. The reliability refers to interobserver reliability and reflects the precision, i.e., the agreement between different observers. The validity measures the accuracy of a classification system and is reflected in intraobserver reliability. This means that a good classification system for calcaneus fractures would be one in which multiple surgeons could classify a fracture as a "type A" (interobserver reliability), and the intraoperative findings would confirm that the type of fracture is indeed a "type A" (validity or intraobserver reliability).[5]

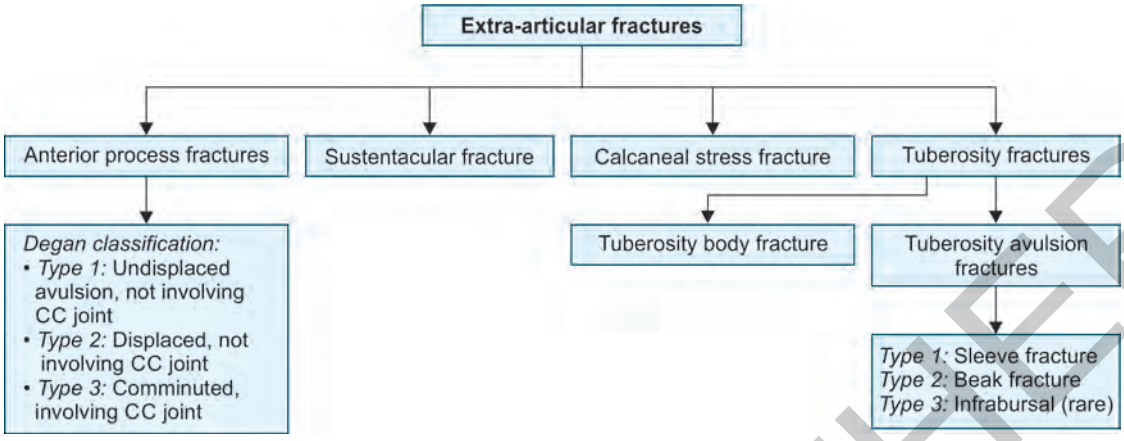
EXTRA-ARTICULAR FRACTURES

The extra-articular fractures represent up to 60% of calcaneal fractures in children, and their incidence has been reported to be 25–40% of adult calcaneal fractures.[3,13-16] According to the mechanism of injury, they can generally be classified as compression or avulsion fractures. Another classification scheme categorizes them according to their location in calcaneus. See **Flowchart 1** for the classification of extra-articular fractures.

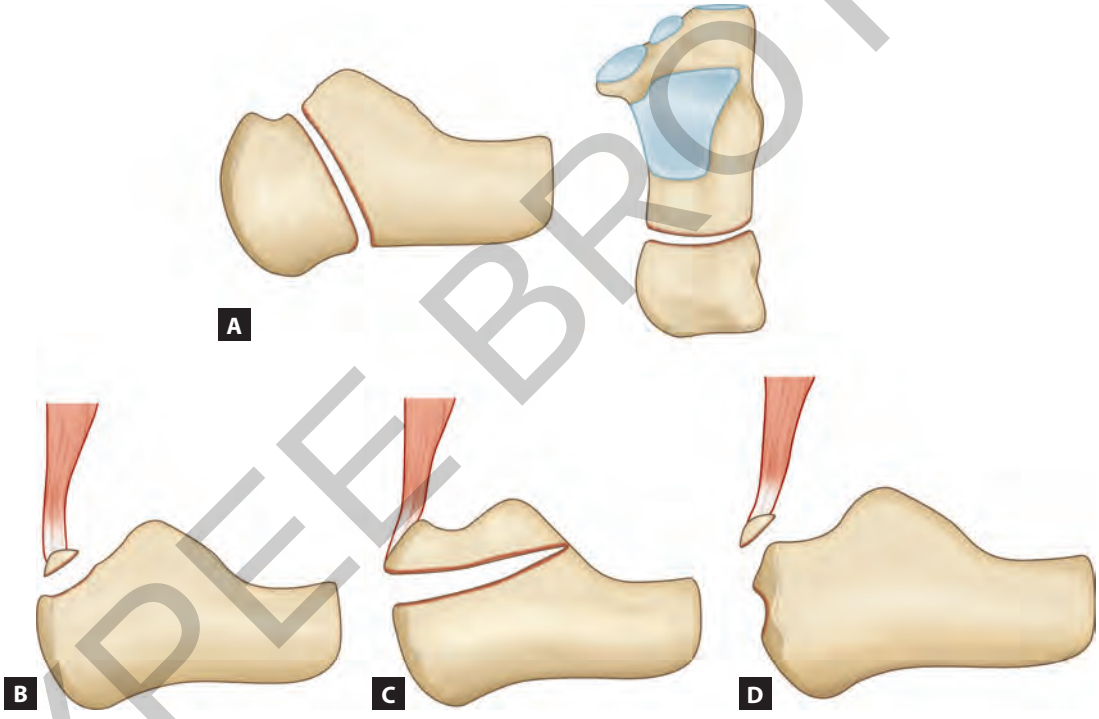
Fitzgibbons et al. have classified extra-articular fractures into anterior process, middle calcaneal (body, sustentaculum, peroneal tubercle, and lateral tubercle),

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Flowchart 1: Classification of extra-articular fractures.



(CC: calcaneocuboidal)



Figs. 1A to D: (A) Tuberosity body fracture; (B to D) Various types of tuberosity avulsion fractures: (B) Type I; (C) Type II; (D) Type III.

and posterior calcaneal (tuberosity and medial tubercle) fractures.[17]

The tuberosity fractures **(Figs. 1A to D)** are usually avulsion fractures and of the following types:

- *Type I:* "Sleeve fracture"—represents a sleeve of posterior tuberosity that has been avulsed from the pull of the gastrocnemius muscle.
- *Type II:* "Beak fracture"—with avulsion of the entire posterosuperior part of the tuberosity. Type II fracture is also referred to as the "extreme tongue-type" fracture[18] **(Fig. 2)**.
- *Type III:* "Infrabursal avulsion fracture"—has been recently described as an infrabursal avulsion fracture of the middle third of the posterior tuberosity.[19]

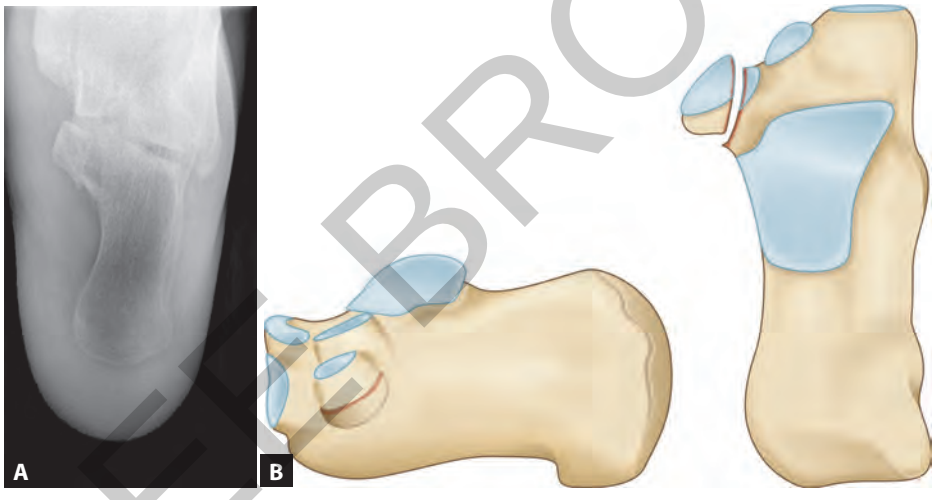
The common denominator of these fractures apart from the mechanism of injury is that they occur in elderly osteopenic patients.[19] Furthermore, an extra-articular avulsion fracture that happens in the neuropathic Charcot foot has been well described in the literature.[13,20,21]

The sustentaculum is considered an extra-articular fracture **(Figs. 3A and B)**, although it includes the middle facet of the subtalar joint.[22] Its incidence is 26% of all calcaneal

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Fig. 2: Lateral radiograph demonstrating the so-called beak fracture. This type of fracture is notorious for skin complications if left untreated.



Figs. 3A and B: (A) Axial radiograph (Harris view) image shows an isolated sustentaculum fracture; (B) Line diagram depicting the fracture.

fractures, and it seems to be higher than previously thought.[3] Rowe included fractures of sustentaculum, anterior process, and tuberosity in one category.[23] It probably represents a high-energy injury that occurs with other varus loaded hindfoot and ankle trauma, and usually a talus fracture.[22,23]

Calcaneus stress fractures **(Fig. 4)** are also extra-articular fractures, and a detailed discussion of stress fractures is provided in Chapter 26.

The anterior process can fail either in compression or in avulsion and its fracture is accompanied by other foot injuries or preexisting deformities (calcaneonavicular coalition).[13] The Degan classification **(Figs. 5A to C)** describes three types according to the percentage of area

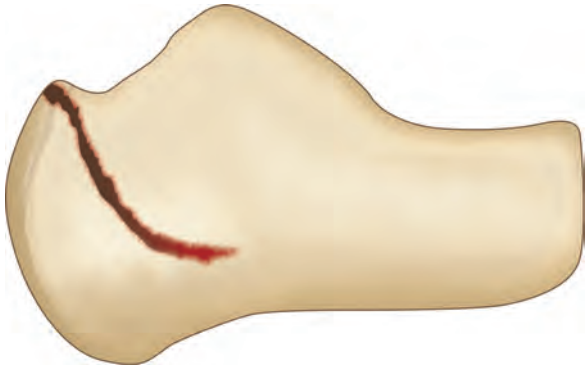
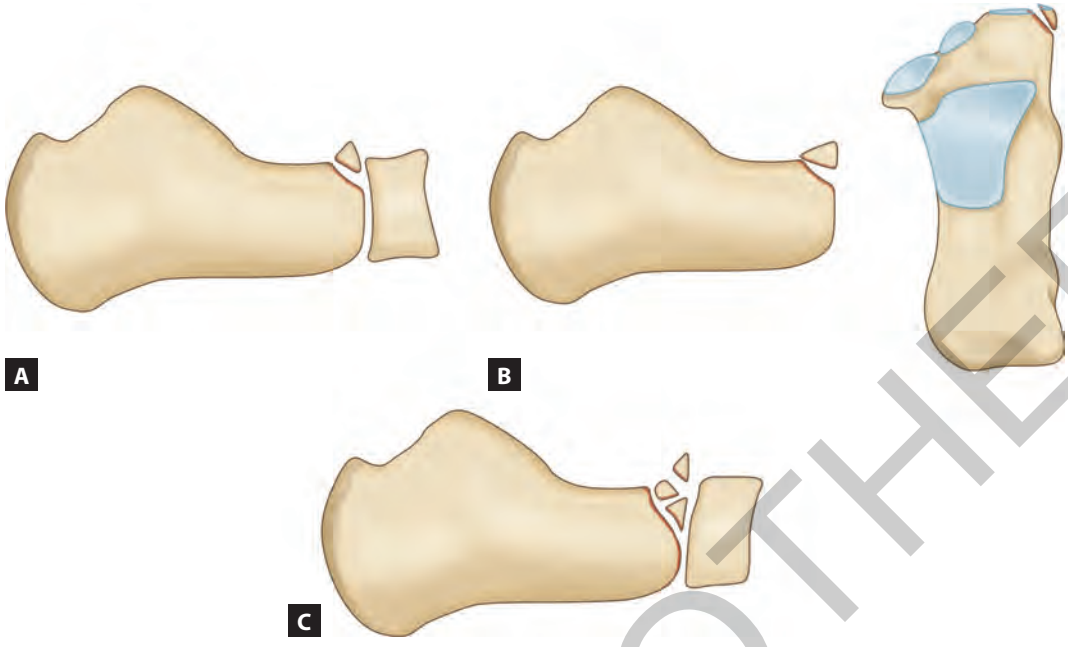


Fig. 4: Stress fracture of calcaneus, which is usually limited to the tuberosity and is often not seen on initial X-rays.

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Figs. 5A to C: Degan classification showing the types of anterior process fractures: (A) Degan type I; (B) Degan type II; (C) Degan type III.

and displacement of the fractured anterior process and involvement of the calcaneocuboid joint.[24] A distinct type of injury that is not an anterior process fracture is the anterior avulsion fracture, which represents an avulsion of digitorum brevis muscle from the dorsolateral surface of the calcaneus and is commonly misdiagnosed as an ankle sprain.

BÖHLER CLASSIFICATION

In 1931, Dr Lorenz Böhler from Austria described the mechanism and the pathoanatomy of calcaneus fractures.[8] He did not describe the pattern of primary and secondary fracture lines that we currently appreciate as the typical pattern of fracture configuration, but he reported two fracture lines that split the bone in the longitudinal axis, leaving the sustentaculum in its place. He also recognized the lateral wall blowout and the consequent direction of major displacement. He was then able to describe the primary clinical deformity seen after these fractures, which is loss of height and broadening of the os calcis as well as the fragmentation and proximal displacement of the tuberosity that is usually seen. One of the major contributions of Dr Böhler's work in calcaneal fractures is the description of the so-called "tuber-joint angle", which is now known as the "Böhler's angle". In addition, he appreciated the fact that in these fractures, this angle can be measured as smaller, flat, or even reversed, a fact that is currently known to be an indirect measurement of the energy absorbed from the bone at the time of injury, a predictor of the outcome in displaced intra-articular calcaneal fractures, and also a tool for selecting patients for operative treatment.[25,26] The amount of depression of Böhler's angle is currently used to classify the displaced intra-articular calcaneal fractures as those with an angle of <0° and those with an angle of >15°. Angles that are closer to normal (25–40°) have a more favorable outcome.[27]

ESSEX-LOPRESTI CLASSIFICATION

The work of Mr Essex-Lopresti, which was published in 1952,[16] greatly contributed to our understanding of the pathoanatomy and the mechanism of calcaneus fracture and offered a classification that is still a valuable tool for orthopedic trauma surgeons. Essex-Lopresti acknowledged the data available from previous works, mainly from Palmer[9] and Böhler,[8] and created a new classification scheme that discriminates extra-articular (not involving the "subtaloid" joint) from intra-articular fractures.

For intra-articular fractures, he proposed a mechanism that explains the displacement of major fragments and he classified the subsequent deformity. The momentum of force during a fall from a height is transmitted from the tibia to talus and consequently to calcaneus through two "routes". The "outer route" creates the primary fracture line through the crucial angle of Gissane. According to Essex-Lopresti, the remaining force is transmitted through the "inner route" and creates a constant sustentaculum fracture that is usually connected to a great part of the subtalar joint (posterior facet). Depending upon the amount of the energy absorbed and the position of the foot, a second fracture line or lines are created. Two distinct types of displacement can then

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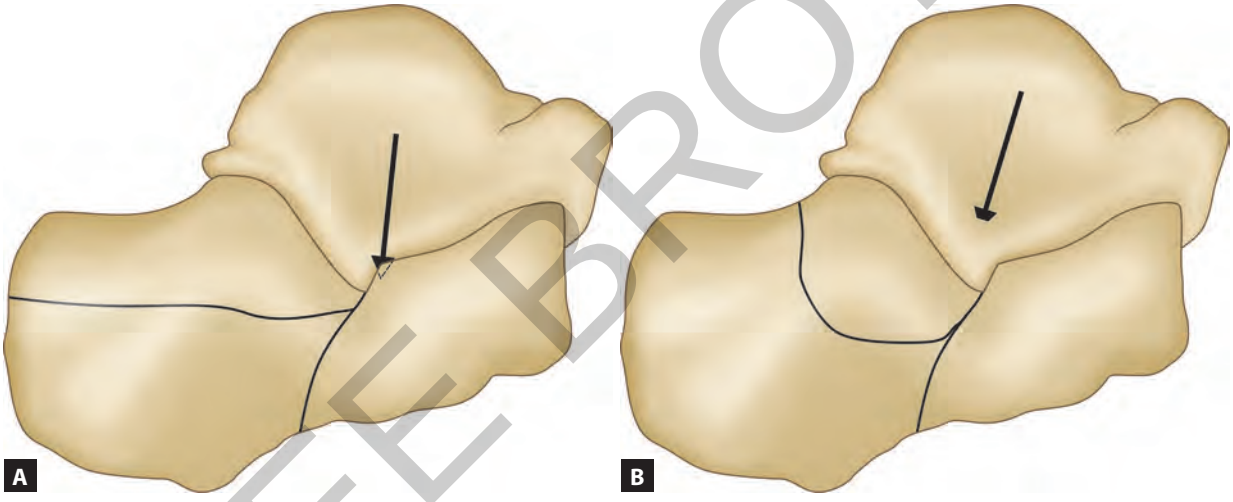
occur according to the secondary fracture line configuration. In the so-called tongue-type fracture, the secondary line runs from the crucial angle of Gissane to the posterior surface of the tuberosity, and subsequently, a part of the posterior facet is attached to the posterior tuberosity. The talus, which is then driven into the calcaneus through the anterior part of the tongue, separates the sustentaculum from the rest of calcaneus through the primary fracture line. In the more common "joint depression-type" fracture, the secondary fracture line exits just behind the posterior facet **(Figs. 6 and 7)**. Based upon this classification scheme, Essex-Lopresti was able to make suggestions for treatment, prognosis, and outcome.

Original Essex-Lopresti classification:

- *Type I:* Subtalar joint intact
  - *Type I.A:* Calcaneal tuberosity fracture
    - *Type I.A1:* Beak type (Boyer)
    - *Type I.A2:* Medial border avulsion fracture
    - *Type I.A3:* Vertical fracture
    - *Type I.A4:* Horizontal fracture
  - *Type I.B:* Calcaneocuboid joint involved
    - *Type I.B1:* Parrot nose type
    - *Type I.B2:* Various other types
- *Type II:* Fractures involving the subtalar joint
  - *Type II.A:* Tongue-type fracture
  - *Type II.B:* Joint depression-type fracture

ZWIPP CLASSIFICATION

The Zwipp classification **(Fig. 8)** was developed in 1989[28] and is one of the first CT-based classifications. It differentiates calcaneal fractures into two to five fracture fragments (sustentaculum, tuberosity, subtalar joint, anterior process,



Figs. 6A and B: Essex-Lopresti classification. (A) Tongue-type fracture; (B) Joint depression-type fracture. *Source*: Reprinted with permission.



Figs. 7A to C: (A) Lateral radiograph; (B) Sagittal computed tomography (CT) image demonstrating a tongue-type intra-articular calcaneus fracture; (C) Sagittal CT image showing a joint depression-type intra-articular calcaneus fracture.

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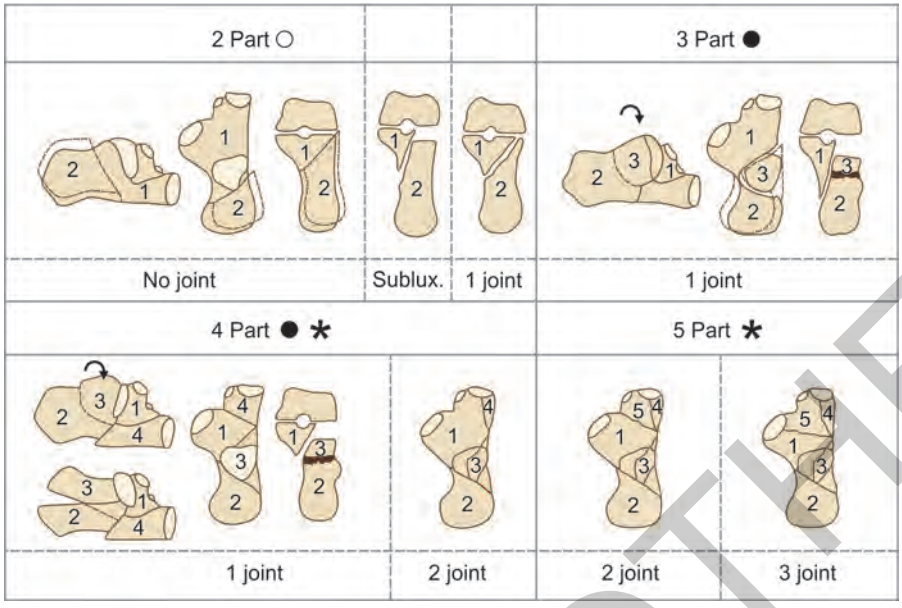


Fig. 8: Zwipp classification.
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and anterior subtalar joint fragment) and into the number of joints involved (posterior subtalar, calcaneocuboid, and anterior subtalar joint). A score is given to each fracture by adding the number of fracture fragments to the number of joints involved. Additional points are given for open fractures and the involvement of other tarsal bones. The maximum score that can be achieved with this classification is 12. The most severe "blowout" fracture is characterized as a five-fragment/three-joint fracture.[29]

CROSBY–FITZGIBBONS CLASSIFICATION

The Crosby and Fitzgibbons classification was developed in 1990.[30] It is a CT-based system that classifies the intra-articular fractures into three types:

1. *Type I:* Slightly or undisplaced posterior facet fractures
2. *Type II:* Displaced posterior facet fractures
3. *Type III:* Comminuted posterior facet fracture

SANDERS CLASSIFICATION

The Sanders classification **(Fig. 9)**[31] belongs to the CT-based classifications, and according to one recent review article, it is the most commonly cited classification of calcaneus fractures in the current orthopedic literature.[10]

This classification refers to intra-articular fractures and was developed in 1993 after following 120 patients for a minimum of 1 year. It utilizes the axial and coronal hindfoot CT cuts. The planes of reconstruction are the semicoronal (perpendicular to posterior facet) and the axial (parallel to the sole of the foot). The cut showing the widest part of the undersurface of the posterior facet of the talus is taken into consideration, and this is divided into three equal columns by two lines (A and B). Another line (C) that is drawn from the medial edge of the posterior facet of the talus divides the corresponding calcaneus from the sustentaculum. Thus, the entire calcaneus is divided in four segments: Lateral,

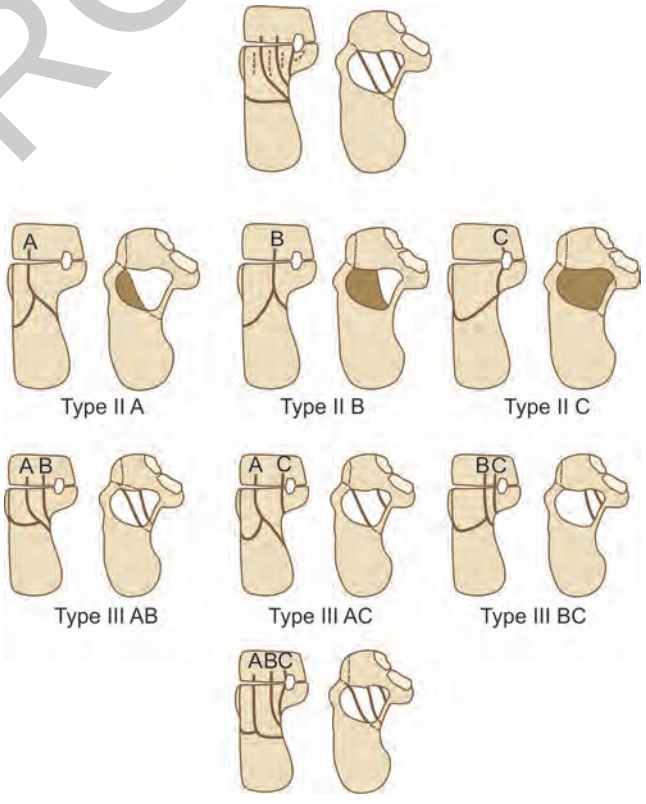
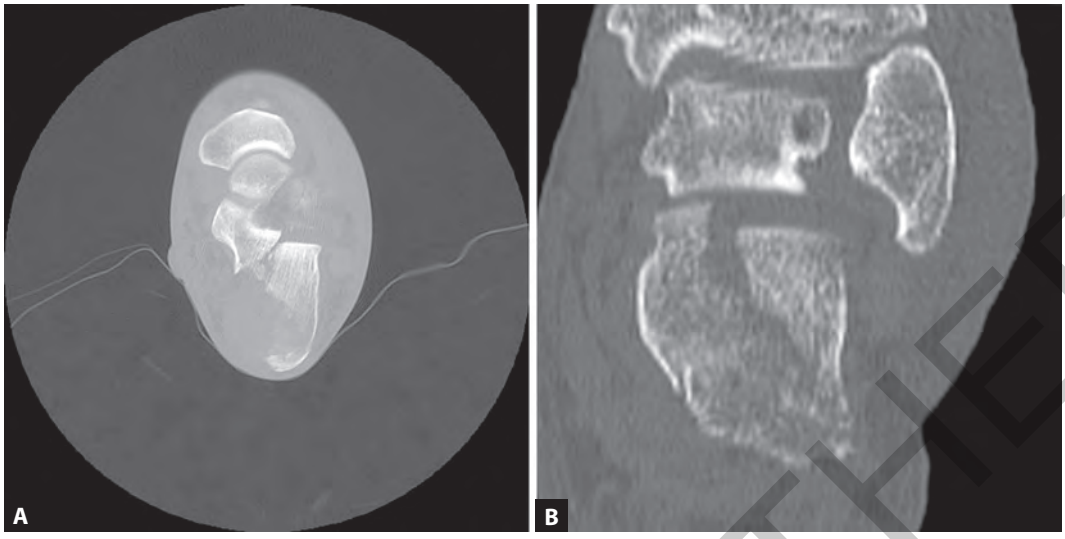
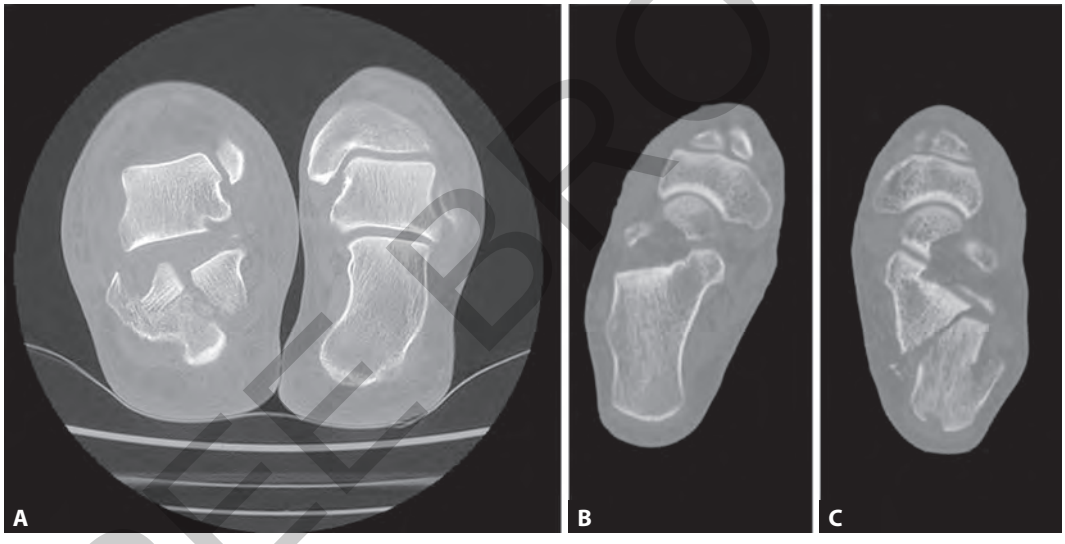


Fig. 9: Sanders classification system.
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Figs. 10A and B: (A) Axial and (B) coronal computed tomography (CT) images of a Sanders type II calcaneus fracture.



Figs. 11A to C: (A) Coronal computed tomography (CT) image showing a Sanders type IIIAB fracture; (B) Axial and (C) coronal CT images of a different patient.

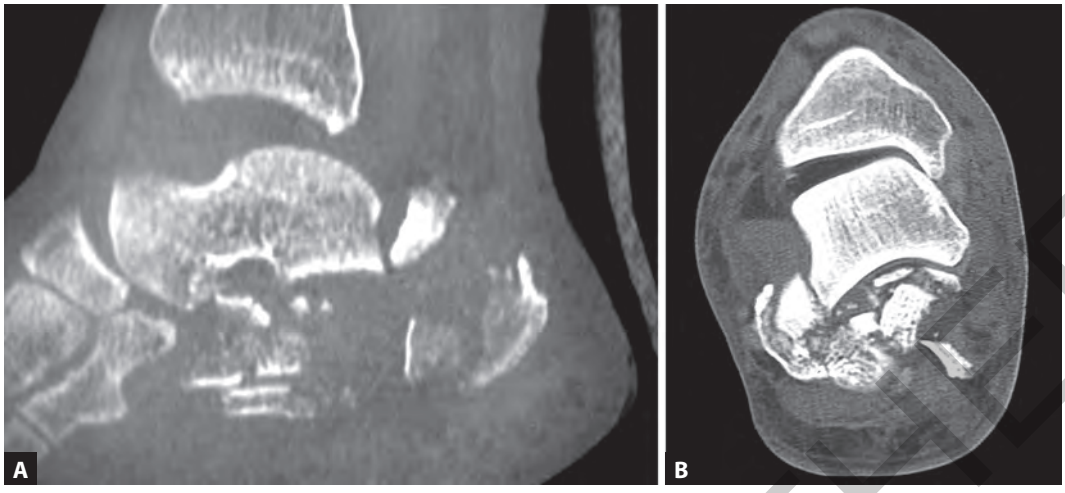
central, medial, and sustentaculum segments. Four types of fractures are then described according to the number and the location of the fracture fragments. Type I fractures are truly nondisplaced intra-articular fractures. Type II fractures represent two-part fractures that can be subcategorized into IIA, IIB, and IIC subtypes **(Figs. 10A and B)**. Type III fractures **(Figs. 11A to C)**, which are subcategorized as IIIAB, IIIAC, and IIIBC, usually have a depressed articular segment. Type IV fracture represents a four-part or very comminuted fracture **(Figs. 12A and B)**:

1. *Type I:* All nondisplaced fractures regardless of the number of fracture lines
2. *Type II:* Two-part fractures of the posterior facet, displacement ≥2 mm
   - *Type IIA:* Fracture line lateral
   - *Type IIB:* Fracture line medial
   - *Type IIC:* Fracture line sustentaculum tali
3. *Type III:* Three-part fractures with a centrally depressed fragment; subtypes IIIAB, IIIAC, and IIIBC
4. *Type IV:* Four-part articular fractures; highly comminuted.

AO/OTA CLASSIFICATION

The comprehensive classification system that was developed by Maurice Müller and the AO Group[32] is a classification system for long bone fractures. It was later revised to include the fractures of the acetabulum, pelvis, and spine. The foot area was not included in this original scheme. Zwipp et al.[33] developed the integral classification for injuries (ICI) that is applicable to foot.

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Figs. 12A and B: (A) Sagittal and (B) coronal computed tomography (CT) images showing a comminuted Sanders type IV calcaneus fracture.

The fracture and dislocations compendium of the Orthopedic Trauma Association (OTA) in 2007 revised the codes for some body areas, including the foot.[34] A new alphanumeric code was applied to every body area and is now in agreement with the AO classification (AO/OTA). The foot region is now given the number 8 and calcaneus is given the number 2. Avulsion fractures are type A, nonarticular body fractures are type B, and articular fractures involving the posterior facet are type C **(Fig. 13)**. This is the most common system used for documentation for publishing purposes.

- *Type A:* Avulsion or anterior process or tuberosity fractures
  - *Type A1:* Anterior process
    - *Type A1.1:* Noncomminuted fractures
    - *Type A1.2:* Comminuted fractures
  - *Type A2:* Medial, sustentaculum tali
    - *Type A2.1:* Noncomminuted fractures
    - *Type A2.2:* Comminuted fractures
  - *Type A3:* Tuberosity
    - *Type A3.1:* Noncomminuted fractures
    - *Type A3.2:* Comminuted fractures
- *Type B:* Nonarticular body fractures
  - *Type B1:* Noncomminuted fractures
  - *Type B2:* Comminuted fractures
- *Type C:* Articular fracture involving posterior facet
  - *Type C1:* Nondisplaced fractures
  - *Type C2:* Two-part fractures
  - *Type C3:* Three-part fractures
  - *Type C4:* Four or more parts fractures

(*Note: 82 has to be added before A, B, C; 8 = foot, 2 = calcaneus*)

DISCUSSION

Radiography versus CT-based classifications: The reality that CT-based classifications have gained acceptance over plain radiography-based classifications can be explained due to the complex anatomical structure of the calcaneus, with four articular surfaces and three articulations.[35] This makes CT an invaluable tool in assessing the complex distorted anatomy in the fracture setting and also aids significantly in preoperative planning. Despite this, a recent study[36] demonstrated that coronal CT scans might not accurately depict the amount of displacement. The authors argue that depression and rotation of the posterior facet fragment is commonly underestimated on coronal CT. They suggest coronal reconstruction images for better estimating the depression of fragment, and whenever this is not available, they recommend lateral radiographs for displacement evaluation.

Reliability and validity: The four most commonly used calcaneal fracture systems are the Essex-Lopresti, the Zwipp, the Crosby, and the Sanders classifications.[10] Reliability and validity are the two characteristics that make a classification system successful.[5] The variables that define the interobserver reliability are not clearly defined in the literature.[37] Nevertheless, there are several studies that have tested the interobserver reliability of calcaneus classification systems. Schepers et al. demonstrated moderate reliability and agreement among observers (orthopedic surgeons and radiologists) for the Crosby and Sanders classifications.[10] The Essex-Lopresti classification had higher reliability among orthopedic surgeons. Higher agreement was also observed among orthopedic surgeons compared

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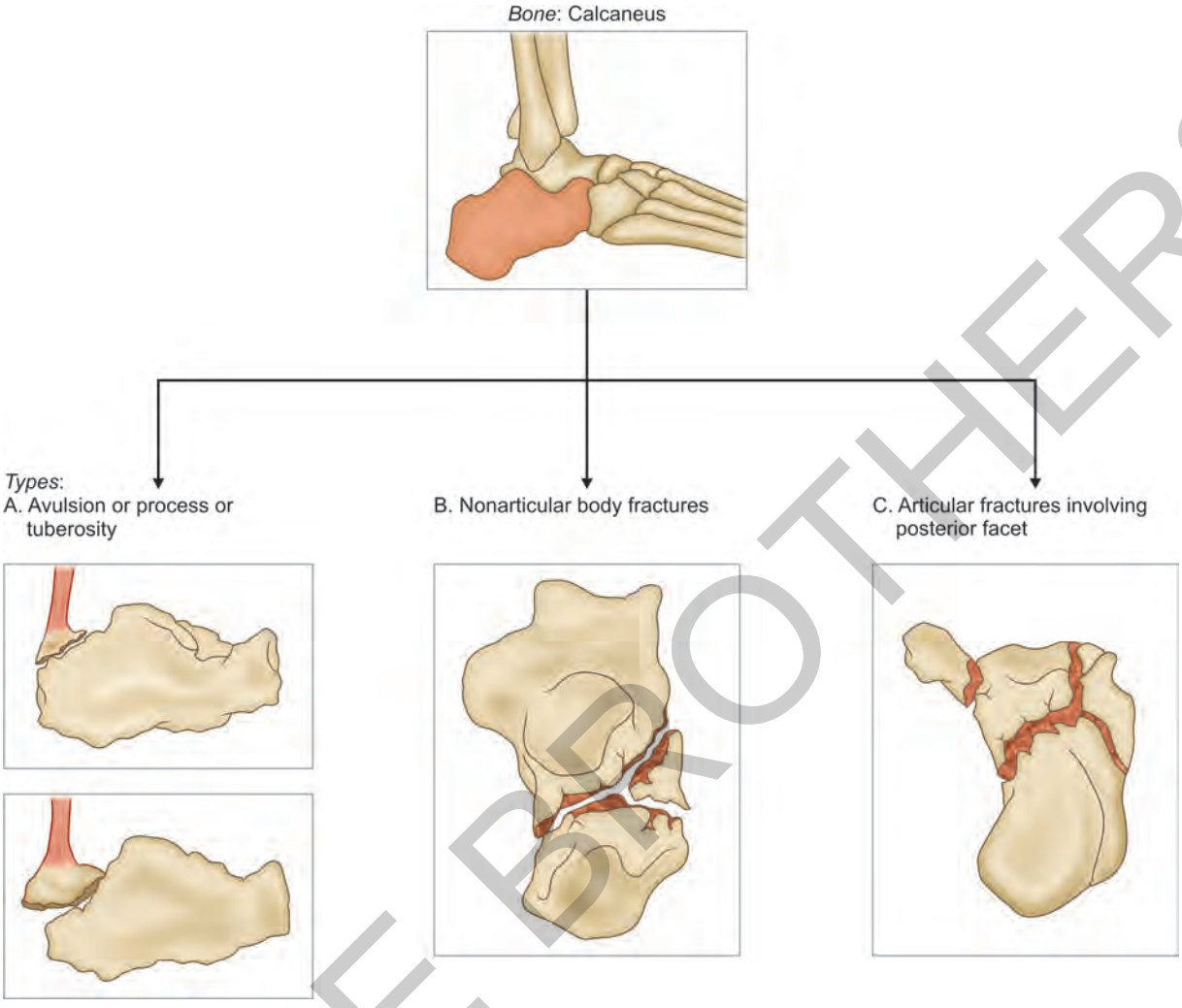


Fig. 13: AO/OTA classification.
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to radiologists when an acetabulum fracture classification, which is a complex three-dimensional (3D) structure such as the calcaneus, was tested in an animal model.[38] The authors attributed this to the operative experience of surgeons that allows them to acquire a 3D understanding of fracture patterns. Humphrey et al.[37] also tested the interobserver reliability of the Sanders classification. CT scan images as well as diagrammatic representations of the Sanders classification were given to experienced orthopedic trauma surgeons. Only moderate interobserver reliability was documented, leading the authors to suggest appreciation of every possible available piece of information (patient-related factors, injury factors, and full imaging studies) for treatment guidance and prognosis. Lauder et al.[39] after testing the Crosby–Fitzgibbons and Sanders classifications showed moderate interobserver reliability for both systems. The intraobserver reliability (validity) of the latter classification was substantial. Additionally, Bhattacharya et al.[40] argued that both interobserver and intraobserver reliability of the Sanders system is only fair to moderate, thus suggesting caution in its usage and its interpretation. On the other hand, Furey et al.[41] concluded that with this classification system there was moderate agreement among the users, suggesting the system's consistency and uniformity.

Classification scheme guidance and prognostic value: Bhattacharya et al.[40] argued that a precise classification is not an absolute prerequisite in the management of calcaneal fractures. However, Sanders states that a detailed classification is needed for good management of these injuries.[42] In terms of treatment guidance and prognostic value of the most commonly used classification systems (i.e., construct validity),[43] Böhler's angle has been suggested to predict the long-term outcome of calcaneal fracture patients.[25] It has also been shown that patients with a flat

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angle have better outcomes after operative treatment than with nonoperative care.[26] The Essex-Lopresti system has been suggested to be of a prognostic value.[26] Andermahr et al.[44] compared the Zwipp and Sanders classifications and found that both systems are good prognostic tools, although the Zwipp system is more accurate and the Sanders classification is easier to use in everyday clinical practice. Furthermore, the Sanders classification has been shown to be predictive of outcome in various studies.[26,45] On the contrary, Lauder et al.[39] argued that neither the Crosby nor the Sanders classification system can be considered ideal for treatment suggestions and prognosis. Finally, Rubino et al.,[46] in a recent study aiming to identify the most predictive fracture classification and clinical outcome tool, compared the Essex-Lopresti, AO/OTA, and Sanders classifications. They concluded that CT-based classifications had higher predictive value than the conventional radiography-based classifications.

SUMMARY

None of the available classifications fulfills all the fundamental criteria for a perfect calcaneus fracture classification system. For the existing systems, reliability is usually moderate, and there is no direct association with treatment. On the other hand, it seems that there is sufficient correlation with the outcome.[10] The Crosby and Sanders classifications appear to fulfill most of the required criteria for good classification systems. The concept of testing the reliability and validity of fracture classifications is a new one, especially for the calcaneus as very little has been published to date. It is worth mentioning that in a study published in 2004 that evaluated the methodologies that were used up to that time for testing the reliability of various fracture classifications, no papers concerning foot injuries met the inclusion criteria.[43] Finally, there are very few studies that have tested the validity of foot and calcaneus classification systems. A 3D phase concept of development and validation of classification systems for calcaneal fractures has been proposed by Audige et al.[47] and is probably the best way to approach the problem. The development of a new or the revision of existing classification systems by clinical experts should be followed with a multicenter agreement study in clinical practice. The third step of a prospective clinical observational study should be the assessment of the prognostic value of such a new classification scheme.

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Fractures of the Calcaneus

The 2nd edition of the book, *Fractures of the Calcaneus*, is an evolved book, focused on orthopedic surgeons who deal with cases of foot trauma. The calcaneus is one of the most common bone fractures seen, and the treatment practices in most of the countries are still evolving, with many surgeons being unaware of the newer techniques of management, the modern diagnostic modalities and the complications that can ensue. In one comprehensive text, the book comprises all available methods of fracture and complication management, with the best minds in the field giving insights about what is state-of-the-art today.

This book offers an overview of all types of calcaneal fracture, with clearly defined diagnostic methods and modern management options; this edition has many new chapters keeping in mind the knowledge updates after the 1st quarter of the 21st century comes to an end. The principles are outlined, emergency and complication management methods are clearly defined, and the illustrations range from highly informative drawings, tables, algorithms, photographs, radiographs, and even some videos that are linked online. The format is simple and self-explanatory, and focuses on the needs of both the average orthopedic surgeon and the specialist foot consultant. Experts in the field discuss the best way to diagnose and initially stabilize calcaneal fractures, the recommended imaging studies, a variety of operative and nonoperative management protocols and present evidence-based treatment guidelines.

The contributors to this book hail from all over the world and represent the current thinking of surgeons, thus offering the reader the best of the world scenarios. Specialized techniques have been clearly described, and complication management is well- explained, along with rehabilitation aspects as well as outcome evaluation methodology.

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Printed in India

Available at all medical bookstores
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ISBN 978-93-5465-665-1