International Journal of Research in Orthopaedics
Samria K et al. Int J Res Orthop. 2025 Sep;11(5):1084-1088
http://www.ijoro.org

Original Research Article

DOI: https://dx.doi.org/10.18203/issn.2455-4510.IntJResOrthop20252639

Diagnostic accuracy of digital imaging and computed tomography in calcaneal fracture evaluation

Kartik Samria*, Sunil Kumar Rawat, Krati Bhardwaj, Parakh Dhingra, Ravi Khurana

Department of Orthopedics, SMS Medical College, Jaipur, Rajasthan, India

Received: 26 May 2025
Revised: 07 July 2025
Accepted: 22 July 2025

***Correspondence:**
Dr. Kartik Samria,
E-mail: samria18@gmail.com

ABSTRACT

Background: Initially, suspected calcaneal fractures are typically evaluated using conventional radiography. However, contemporary classification systems for calcaneal fractures rely heavily on computed tomography (CT) due to its ability to provide three-dimensional imaging, which offers a more comprehensive assessment than traditional two-dimensional plain radiography. This study aimed to investigate and compare the diagnostic efficacy of digital X-ray imaging versus computed tomography in evaluating calcaneal fractures.
Methods: This study was conducted S.M.S Medical College Jaipur on 40 patients with isolated calcaneal trauma and was diagnosed radiologically by plain X-ray and CT to have calcaneal fractures. lateral view images was obtained to measure the Böhler's angle, the angle of Gissane, the inclination angle and the facet height. Each angle was measured by two different interpreters (a senior radiologist and a resident) in order to verify accuracy.
Results: A statistically significant difference was observed between Digital X-ray and CT image findings in both intra-articular fractures and total fractures. Specifically, significant differences were noted in the measurements of Bohler's angle, the angle of Gissane and facet height, whereas no significant difference was found in the inclination angle. These findings highlight the superior diagnostic accuracy of CT imaging in assessing calcaneal fractures.
Conclusions: Computed Tomography (CT) scanning has emerged as a indispensable, non-invasive diagnostic tool, widely adopted for its exceptional utility in accurately identifying, classifying and informing treatment strategies for both extra-articular and intra-articular calcaneal fractures, thereby revolutionizing the management of these complex injuries.

Keywords: Computed tomography, Calcaneal fractures, Digital X-ray

INTRODUCTION

The calcaneus, also known as the heel bone, is the largest of the tarsal bones and the one most commonly fractured. Although calcaneal fractures account for only about 2% of all bone fractures, they represent approximately 60% of all tarsal bone injuries.[1] The calcaneus is the primary weight-bearing bone in the foot and plays a key role in the tri-tarsal joint complex. Fractures involving the body of the calcaneus often affect the subtalar joint. These injuries are typically severe and complex, posing significant challenges in diagnosis and treatment and can lead to substantial functional limitations and economic impact.[2] Most Calcaneal fractures are commonly seen in male laborers, highlighting their significant economic impact. Surgery is generally advised when the fracture involves displaced intra-articular fragments, compression of the peroneal tendons or entrapment within the medial compartment.[3] The most common mode of injury in intra-articular fracture axial load shedding due to vertical fall whereas in extraarticular fracture it is twisting forces and direct blows (Figure 1). Intra-articular fractures comprise of 75% of total calcaneal fractures.[4] Standard X-rays are typically used as the first step in assessing calcaneal injuries, though they are limited by their two-dimensional nature.[5] Advanced CT imaging enables precise evaluation

of calcaneal fractures, offering enhanced visualization of fracture fragments and displacement patterns.[6] Calcaneal fractures are categorized into intra-articular and extra-articular types based on subtalar joint involvement, as seen on CT scans. Understanding the fracture classification, anatomy and potential complications is crucial for effective surgical planning and treatment evaluation.[7]

Historically, treatment approaches for calcaneal fractures evolved significantly. Initially, subtalar fusion was a prevalent method due to its relative simplicity. However, recent decades have seen substantial advancements in medical technology and techniques, including anesthesia, antibiotics, CT scans and fluoroscopy. These developments have enabled surgeons to achieve better outcomes in fracture treatment, including calcaneal fractures. As a result, operative treatment has become a widely accepted standard, with many surgeons reporting favorable results after critically evaluating their methods.[8] Although operative treatment has advanced, challenges persist. This study aims to investigate whether recent advancements in fracture care, including improved understanding of fracture patterns, optimized perioperative care, enhanced fixation techniques and early mobilization, positively impact outcomes for calcaneal fracture surgery.

METHODS

This was a cross sectional observational study. This study included 40 patients with isolated calcaneal trauma and was diagnosed radiologically to have calcaneal fractures, who were admitted to S.M.S Medical College and hospitals Jaipur. Sample size was 40 patients selected using purposive sampling technique. Individuals with isolated calcaneal fractures who visited the outpatient department, wards or emergency unit and met the study's eligibility criteria were enrolled from September 2022 to February 2024, after obtaining approval from the institutional ethics committee. Inclusions criteria were patients with direct isolated calcaneal trauma with agreement to give written consent of both sex and Age 18–50-year-old exclusion includes criteria patients with multiple injuries of the lower limb were excluded from the study, patient with pathological calcaneal fractures, patient with other comorbidities probating surgery, calcaneum fractures associated with large open wounds and massive prolonged edema. All patients were subjected to complete history taking and radiological assessment calcaneal lateral and axial digital X-rays and conventional CT of the injured foot, Digital X-ray lateral view images were obtained to measure the Böhler's angle, the angle of Gissane, the inclination angle and the facet height. Each angle was measured by two different interpreters (a senior radiologist and a resident) in order to verify accuracy.

Statistical design

The collected data was tabulated and analyzed by suitable statistical methods using the statistical package for social science (SPSS). Categorial data are expressed as number and percentage. Continuous are expressed as mean and standard deviation (SD). Suitable tests of significance were used. The accepted level of significance in this work is 0.05.

RESULTS

There means age of patients was 32 years and 33 patients (82.5%) were males and 7 patients (17.5%) were female (Table 1). In patient population, the two main injury mechanisms were falling from a height (85%) and road traffic accident 15%. According to associated injuries in the present study's sample, 14 patients (35%) had soft tissue edema, 20 patients (52.50%) had muscle injuries and 6 patients (15%) had tendon injuries (Table 2).

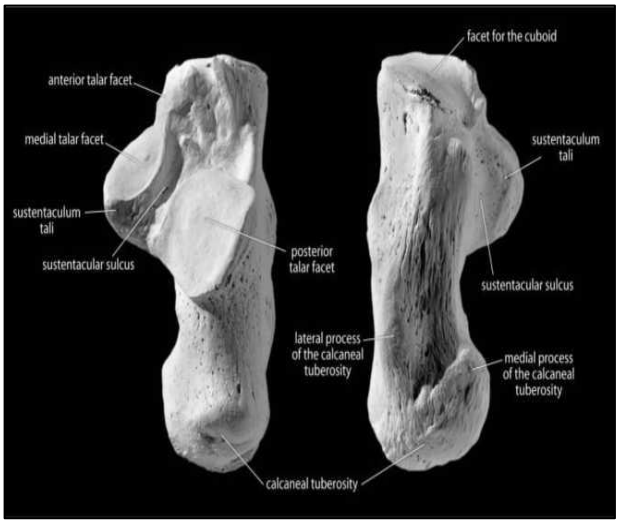

Figure 1: Anatomy of calcalean bone.

Table 1: General characteristics the mean age of patients was 32 years and 33 patients (82.5%) were male and 7 patients (17.5%) were female.

Gender	N (%)
Male	33 (82.5)
Female	7 (17.5)

In the term of comparison between digital X-ray and CT images finding according to sensitivity of diagnosis of fractures, there was a statistically significant difference between digital X-ray and CT images finding in intraarticular fractures and total fractures (Table 3) and in the term of comparison between extraarticular and intraarticular fractures measurements by CT, there was a statistically significant difference in (The Bohler's angle, The angle of Gissane and the facet height, the angle of Gissane) and no statistically significant difference in (The inclination angle) (Table 4). The average follow up is of one year with minimum of six months and maximum of one and half years.

Table 2: There were associated injuries involving fracture, soft tissue edema 14 (4%), muscle injuries 20 (52%), tendon injuries 6 (15%).

Associated injuries	N (%)
Soft tissue edema	14 (35.00)
Muscle injuries	20 (52.50)
Tendon injuries	6 (15.00)
Total	40

Table 3: Comparison between digital X-ray and CT according to type of fracture.

Type of fractures	Type of radiological method	True positive	False negative	P value
Extra articular fractures	CT	8	0	0.450
	Digital X-ray	6	2	
Intra articular fractures	CT	32	0	<0.001
	Digital X-ray	8	24	
Total	CT	40	0	<0.001
	Digital X-ray	14	26	

Table 4: Comparison between extraarticular and intraarticular fractures measurements by CT.

	Extraarticular fractures	Intraarticular fractures	P value
The Bohler's angle	19.07±9.11	15.23±7.89	0.047
The angle of Gissane	124.57±11.91	111.03±8.16	<0.005
The facet height (mm)	38.1±6.30	43±5.09	<0.05
The inclination angle	20.85±5.14	19.74±3.38	0.255

DISCUSSION

The calcaneum is the most frequently fractured bone among the tarsal bones. Ankle injuries are common, accounting for 2% of all fractures, with a significant proportion (60-75%) being displaced and intra-articular. Fractures of the calcaneum can lead to various complications, including loss of height, varus deformity, heel widening and subtalar joint incongruity. The prognosis for extra-articular fractures is generally favorable, whereas the outcomes for intra-articular fractures are more variable. Management of intra-articular fractures is a topic of ongoing debate. Several classification systems exist for intra-articular calcaneal fractures, but there is no consensus on the most practical approach. This study investigates the comparative effectiveness of digital X-ray imaging and computed tomography (CT) in evaluating calcaneal fractures. Our analysis revealed a peak age incidence between 18-40 years, with a mean age of 32 years.

A study by Parmer et al found that the average age of individuals with calcaneal fractures was 50.9 years.[10] In contrast, Buckley's research indicated that the highest incidence of these fractures occurred in individuals between 30-39 years old.[11] In this study 33 patients were males (82 %) and 7 patients were female (17 %), showing male preponderance. Studies have reported varying male-to-female ratios for calcaneal fractures. For example, one study found a ratio of 2.3:1, while others reported ratios of 10:1 and 6:1, all indicating a higher incidence of these fractures among males, particularly those resulting from falls from height.[10,12,13] In this study 25 patients (85%) gave history of fall from height and 15 patients (15%) were involved in road traffic accident. According to Stoller et al, the increased axial load caused by falling from a height and landing on the feet is a major contributor to calcaneal fractures.[14] Furthermore, motor car accidents, where a seated passenger's feet are pressed hard against the floor of the car, are also a common cause of these fractures, although they occur less frequently than falls from height.

Berberian et al, also noted that falls from height were the typical cause of calcaneal fractures.[15] However, this observation contradicts a retrospective study by Worsham et al, who assessed the relationship between calcaneal fractures and lesions in 62 patients. Their findings indicated that motor vehicle accidents (56.4%) and falls from height (24.1%) were the most common causes, with additional causes including motorcycle collisions, crush injuries and pedestrian-vehicle accidents.

In our study, associated injuries involving fracture showed soft tissue edema 14 (4%), muscle injuries 20 (52%), tendon injuries 6 (15%). In the present study, 6 patients (20%) had multiple fractures. Of which 4 patients (66.7%) had ankle and calcaneal fractures, two patients (33.3%) had calcaneal and talar fractures. In the present study, a comparison between digital X-ray and CT images revealed a statistically significant difference in the sensitivity of fracture diagnosis, specifically for intra-articular fractures and total fractures, due to the fact that fractures were not clearly visible on digital X-ray images. There was no statistically significant difference between Digital X-ray

and CT images finding in extra articular fractures and total fractures as it can be viewed on X-ray easily. In terms of comparative measurements between extra-articular and intra-articular fractures using CT in this study, statistically significant differences were observed in Bohler's angle, the angle of Gissane and facet height. Conversely, no statistically significant difference was found in the inclination angle.

A comparable investigation was undertaken by Makki et al, in 2010, wherein they conducted a retrospective analysis of 47 intra-articular calcaneal fractures treated via open reduction and internal fixation in 45 patients by a single surgeon.[9] Their findings indicated that successful restoration of Bohler's angle correlated with improved outcomes, leading them to advocate for prompt osteosynthesis in intra-articular calcaneal fractures to restore the hindfoot's anatomical shape and Bohler's angle.

In 2016, Biz et al observed that patients undergoing open reduction internal fixation (ORIF) exhibited a superior restoration of Bohler's angle (79%) compared to those treated with percutaneous techniques (34%).[16] Notably, both Bohler's angle and Gissane's angle demonstrated a strong correlation with post-operative AOFAS and Gait scores, as confirmed by Wilcoxon Signed Rank Tests. Specifically, the correlation coefficients were 0.624 ($p=0.001$) for Bohler's angle and 0.778 ($p=0.001$) for Gissane's angle, indicating a statistically highly significant correlation. This finding contrasts with the results reported by Sander et al, who failed to identify a significant correlation.

Veltman et al determined that incorporating 3D CT imaging does not enhance inter and intra-observer reliability for classifying calcaneal fractures, suggesting that it should not be a standard component of the diagnostic workup for displaced intra-articular calcaneal fractures.[17] Choplin et al proposed that 3D imaging facilitates the diagnosis of various foot deformities by providing a more comprehensive understanding of the underlying anatomical structures.[18] In agreement, Pretorius et al and Cotten et al advocated for the utilization of 3D CT imaging, particularly in cases involving complex fractures.[19,20]

Allon et al and Mears et al conducted a comparative study evaluating the efficacy of plain radiography, 2D CT and 3D CT in assessing 30 calcaneal fractures, ultimately concluding that 3D CT enhances preoperative planning and facilitates the selection of an optimal surgical approach.[21] Similarly, Pate et al, assessed 202 patients with musculoskeletal issues and determined that 3D CT is particularly beneficial for analyzing fractures involving bones with intricate anatomical structures.[22] Prasartritha et al, evaluated the diagnostic efficacy of 3D CT imaging in 51 cases of fractured calcanei, observing that 3D CT images provided superior visualization of the number and configuration of displaced posterior facet fragments, the fracture lines demarcating the anterior process and middle facet and the extension of fracture lines into the calcaneocuboid joint.[23] The assessment via CT is crucial for ruling out articular surface involvement and ascertaining the extent of the fracture. Generally, patients diagnosed with calcaneal body fractures tend to have a more favorable prognosis compared to those with intra-articular fractures and typically, management involves conservative treatment.[24]

Computed tomography (CT) is the only imaging modality that provides a comprehensive understanding of the fragment size and the number of intra-articular fracture lines. Furthermore, CT accurately delineates the location and orientation of the variable fracture lines that separate the anterolateral fragment, thereby guiding the surgeon in the necessary dissection to visualize and treat the fracture effectively. Moreover, CT offers a more precise visualization of the lateral wall, particularly in relation to the lateral malleolus and peroneal tendons, compared to axial radiographs, thereby facilitating a more accurate assessment.[25]

This study is subject to several limitations. Firstly, the relatively small sample size of 40 patients may limit the generalizability of the findings to broader populations. Additionally, the cross-sectional design restricts the ability to assess long-term outcomes or the progression of fracture healing. The study relied on measurements by two observers, which, despite efforts to ensure accuracy, may still introduce interobserver variability. Furthermore, the exclusion of patients with multiple injuries, open fractures or comorbidities may have resulted in selection bias, potentially affecting the applicability of the results to more complex clinical scenarios. Lastly, the study was conducted at a single tertiary care center, which may limit external validity.

CONCLUSION

This study highlights the crucial role of CT scanning in the diagnosis, classification and treatment planning of calcaneal fractures, demonstrating its superiority over traditional X-ray imaging in providing detailed cross-sectional images and 3D reconstructions. By showcasing the precision and effectiveness of CT scans in evaluating complex calcaneal anatomy and fracture patterns, this research advances knowledge in orthopedic trauma care, ultimately contributing to improved patient outcomes through more accurate and informed treatment strategies. The findings underscore the importance of integrating CT scanning into standard practice for managing calcaneal fractures, particularly for intra-articular fractures where precise imaging is critical for surgical planning and preventing post-injury complications.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

REFERENCES

1. Ratliff AH, Dixon JH, Magnussen PA, Young SK. Selected References in Orthopaedic Trauma. Springer Science Business Media. 2012.
2. McReynolds IS. Trauma to the os calcis and heel cord. Disorders Foot Ankle. 1982;2:1497-542.
3. Sanders R. Current concepts review-displaced intra-articular fractures of the calcaneus. JBJS. 2000;82(2):225-50.
4. Heckman J. Fractures and dislocations of the Foot, chapter 32. Rockwood Green's Fract Adults. 1996;2:2325-54.
5. Janzen DL, Connell DG, Munk PL, Buckley RE, Meek RN, Schechter MT. Intraarticular fractures of the calcaneus: value of CT findings in determin- ing prognosis. AJR Am J Roentgenol. 1992;158(6):1271–4.
6. Schechter MT. Intraarticular fractures of the calcaneus: value of CT findings in determining prognosis. AJR Am J Roentgenol. 1992;158(6):1271–4.
7. Rubino R, Valderrabano V, Sutter PM, Regazzoni P. Prognostic value of four classifications of calcaneal fractures. Foot Ankle Int. 2009;30(3):229–3.
8. Koval K, Sanders R. the radiologic evaluation of calcaneal fractures. Clin Orthop. 1993;290:41-58.
9. Makki D, Alnajjar HM, Walkay S. Osteosynthesis of displaced intra- articular. J Bone Joint Surg. 2010;92:693-700.
10. Parmer HV, Triffitt PD, Gregg PJ. Intra–articular fractures of calcaneus treated operatively or conservatively: a prospective study. J Bone Joint Surg. 1993;75:932-43.
11. Buckley R, Tough S, McCormack R, Pate G, Leighton R, Petrie D, et al. Operative compared with non-operative treatment of dispalced intra-articular calcaneal fractures: a prospective, randomised, controlled multicentric trial. JBJS. 2002;84:1733-44.
12. Nambiar MR, Umesh SN, Kamath KR. Percutaneous pin fixation of calcaneal fractures. J Orthop Assoc South India. 2004;1:64-7.
13. Paley D, Fischgrund J. Open reduction and circular external fixation of intra–articular calcaneal fractures. Clin Orthop. 1993;290:125–40.
14. Stoller DW, Tirman PF, Bredella M. Ankle and foot, osseous fractures, calcaneal fractures. Diagnostic imaging: orthopaedics. Salt Lake City, Utah: Amirsys. 2004;40:70-4.
15. Berberian W, Sood A, Karanfilian B, Najarian R, Lin S, Liporace F. CT classification and results of operative treatment. Foot Ankle Clin. 2013;55(211):43-51.
16. Biz C, Barison E, Ruggieri P, Iacobellis C. Radiographic and functional outcomes after displaced intra-articular calcaneal fractures: a comparative cohort study among the traditional open technique (ORIF) and percutaneous surgical procedures (PS). J Orthop Surg Res. 2016;11(1):92.
17. Veltman ES, van den Bekerom MP, Doornberg JN. Three-dimensional computed tomography is not indicated for the classification and characterization of calcaneal fractures. Injury. 2014;45(7):1117-20.
18. Choplin RH, Farber JM, Buckwalter KA, Swan S. Three- dimensional volume rendering of the tendons of the ankle and foot. Semin Musculoskelet Radiol. 2004;8(2):175-83.
19. Pretorius ES, Fishman EK. Volume-rendered three-dimen- sional spiral CT: musculoskeletal applications. Radiographics. 1999;19(5):1143-60.
20. Cotten AIS, Moise AB. Musculoskeletal System. Berlin, Heidelberg: Springer; 2002.
21. Allon SM, Mears DC. Three dimensional analysis of calca- neal fractures. Foot Ankle. 1991;11(5):254-63.
22. Pate D, Resnick D, Andre M, Sartoris DJ. Perspective: three-dimensional imaging of the musculoskeletal system. AJR Am J Röntgenol. 1986;147(3):545-51.
23. Prasartritha T, Sethavanitch C. Three-dimensional and two- dimensional computerized tomographic demonstration of cal- caneus fractures. Foot Ankle Int. 2004;25(4):262-73.
24. Griffin D, Parsons N, Shaw E, Kulikov Y, Hutchinson C, Thorogood M, et al. Operative versus non-operative treatment for closed, displaced, intra-articular fractures of the calcaneus: randomised controlled trial. BMJ. 2014;349:6779.
25. Daftary A, Haims AH, Baumgaertner MR. Fractures of the calcaneus: a review with emphasis on CT. Radiographics. 2005;25(5):1215-26.

Cite this article as: Samria K, Rawat SK, Bhardwaj K, Dhingra P, Khurana R. Diagnostic accuracy of digital imaging and computed tomography in calcaneal fracture evaluation. Int J Res Orthop 2025;11:1084-8.