

## Do 3D Printed Calcaneus Models Change Fracture Classification and Surgical Planning?

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**Introduction/Purpose:** Roy Sanders clearly described the classification and management of calcaneus fractures over two decades ago. Despite this clear explanation, later authors have questioned inter-observer reliability of the Sanders classification scheme. In part, this may be due to the complex geometry of the calcaneus and its known fracture patterns. Recently, 3D printed models have been used to better understand complex distal radius fractures. We hypothesize that patient-specific 3D printed models of calcaneus fractures should give surgeons a better understanding of the fracture pattern which would result in more reliable fracture classification and treatment plans between different surgeons. The purpose of this work is to evaluate the superiority of 3D printed models vs standard CT scans with respect to reliability of fracture classification and surgical plan.

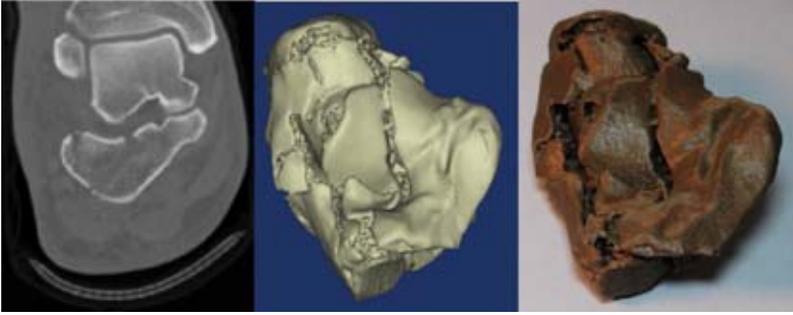
**Methods:** Following IRB approval, the surgical billing database at a level one trauma center was queried for calcaneus fracture as the primary diagnosis. Patients were included if they were found to have isolated calcaneus fractures with adequate imaging and a unilateral closed calcaneus fracture. Exclusion criteria included patients with polytrauma, open fracture, tobacco history, diabetes, or peripheral vascular disease. Roughly equal numbers of type 2, 3, and 4 calcaneal fractures were selected by a medical student and orthopaedic resident. Mimix software was used to segment each fracture and create a printable surface file. Cura software was used to generate printer path instructions and an Ultimaker 2 extended 3d printer using PLA filament was used to print the fractures. Each fracture was classified and surgery planned based on evaluation of either the CT scan, virtual model, or printed model. The Kappa Statistic was then used to evaluate the inter-rater reliability for each modality.

**Results:** 30 calcaneus fractures were evaluated by 4 Orthopaedic Surgeons. Inter-observer kappa values for CT, virtual model, and printed model groups were 0.336, 0.393, and 0.302 for the Sanders classification, 0.224, 0.390, and 0.609 for the Essex-Lopresti classification, and 0.253, 0.246, and 0.110 for treatment plans.

Intra-observer comparisons between CT and printed model groups were consistent between modalities 50% of the time for Sanders classification, 83% of the time for Essex-Lopresti classification, and 66% of the time for plans (kappa 0.564, 0.604 and 0.438).

Of the patients with different intra-observer Sanders classifications, 50% also had different treatments selected whereas those with differences in Essex-Lopresti classification had a different plan 70% of the time. These correlations had a kappa value of 0.317 and 0.303 respectively.

**Conclusion:** Sanders classification based on printed models alone did not yield improved inter-observer reliability compared to CT scans. Conversely, Essex-Lopresti classification with printed models had the best reliability between surgeons. Physical models may clarify borderline Essex-Lopresti classifications potentially impacting further treatment. However, treatment plans based on physical models alone yielded the worst reliability. This may be due to, in part, to increased artifact with increased data processing and model creation. Care should be taken not to rely on 3D models for clinical decisions until questions concerning the reasons for poor inter-observer reliability are understood.



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