Research Square

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Radiological Posterior Medial Danger Zone of the Ankle. Protecting the Posterior Tibial Tendon During Ankle or Pilon Fracture Fixation

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Abstract

Background: The surgical treatment of pilon and posterior malleolar fractures can risk damage to the posterior tibial tendon. The lateral safe zone has been confirmed previously to prevent syndesmosis incisura encroachment during hardware placement, however the risks to the tibialis posterior tendon medially has not been investigated.

Our aim in this study was to identify the fluoroscopic safe zone medially, to prevent inadvertent injury to the tibialis posterior tendon during both direct and indirect fixation techniques.

Methods: A cadaveric study was performed using 21 fresh frozen cadaveric specimens. A medial posteromedial approach was performed on each specimen to expose the tibialis posterior sheath. A flexible wire was placed down the lateral aspect of the tibialis posterior sheath as a radio opaque marker. Fluoroscopic imaging was performed in the anteroposterior and lateral position to identify the medial danger zone.

Results: In all specimens, the wire was located medial to a vertical line corresponding to the articular surface (the medial danger zone line) of the medial malleolus on anteroposterior imaging. On lateral imaging, the radiopaque marker followed the medial malleolus obliquity and continued to correspond to approximately 30% of the posterior plafond.

Conclusion: This study demonstrated that a medial danger zone fluoroscopic landmark is unambiguous in localizing the tibialis posterior sheath and that any metal work medial to this line is likely to be at risk of damaging the tibialis posterior tendon. The lateral radiograph showed that any anteroposterior screw could involve the tibialis posterior sheath even if the penetration is only 70% across the tibial width.

Clinical relevance: This article describes a radiographic and clinical danger zone for fixation and hardware placement during open reduction internal fixation of ankle and pilon fractures This information will assist surgeons in avoiding posterior tibial hardware placement.

Introduction

Ankle fractures are common place with a reported incidence of 132 fractures per 100,000 men a year and 112 fractures per 100,000 women a year.[3] Of these, trimalleolar fractures have been reported in up to 40%.[10] Tibial pilon fractures are considerably less common with an annual incidence of 4 fractures per 100,000 population.[17] The surgical treatment of trimalleolar and pilon fractures (PIL) is routine in most trauma units. Trimalleolar fractures have historically resulted in poor functional results, however more recent studies are noting improvements with fragment specific fixation.[12,14] Pilon fractures encompass a wide range of complexity, although a systematic review reported that the anterior approach had the lowest rate of complications.[11]

Currently, there are a variety of approaches to fixation for both the posterior malleolar fracture (PMF) of a trimalleolar fracture and PIL.[6,9,15] Both direct approaches to the posterior tibia and indirect reduction and anteroposterior fixation have been advocated in the treatment of both PMF and PIL.[7,12,18] Additionally there has been an increase in interest in the injury to the tibialis posterior tendon (TPT) recently with PMF and PIL injuries, with an approximate 40% of TPT entrapped if the fracture line enters the tendon sheath.[1,19] Although previous articles have indicated the risk to the TPT with medial malleolar fixation, there has been an absence of literature on risk to the TPT during tibial fixation, when the metalwork has been placed from either anterior or posterior. [4,5]

The primary aim of this study was to identify the fluoroscopic danger zone medially, to prevent inadvertent injury to the TPT during both direct and indirect fixation techniques to the tibia.

Methods

This study was undertaken at Keele University under the auspices of the Human Tissue Authority license held by the Keele Anatomy and Surgical Training Centre at the University of Keele Medical School. Cadaveric images were strictly used with permission. The study was considered and given permission by the Keele Anatomy Research Group. We examined 21 fresh frozen cadaveric lower limbs that had been amputated at the level of the mid tibia. No specimen had any signs of premortem surgical intervention or scars about the ankle and were morphologically normal.

The specimens were positioned prone. The medial posteromedial (MPM) approach was performed, using a consistent repeatable incision of 10cm extended proximal from a line drawn from the palpable distal extent of the medial and lateral malleoli as detailed by Philpott et al.[15] The MPM was marked out along the posteromedial edge of the tibia. The investing fascia was opened longitudinally exposing the TPT sheath. The TPT sheath was opened longitudinally, but maintaining the distal aspect of the sheath to keep the TPT in place.

A flexible steel wire (0.9mm thickness) was fed down the sheath, lateral to the TPT, therefore achieving a radiological marker for the tendons most lateral extent. Fluoroscopic imaging was then performed, capturing anteroposterior and lateral views of the ankles to assess the wire position on routine imaging (Fig. 1). The images were then analysed to predict the medial ‘danger zone’ where the TPT was at risk from metalwork encroachment.

Results

Using radiographic imaging on our 21 fresh-frozen specimens we were able to define a medial danger-zone to potentially avoid TPT entrapment or screw penetration. By layering the radiographs with the wire in place a composition image was created (Fig. 2). On Anterior-posterior imaging, by placing the wire within the lateral aspect of the TPT sheath all 21 specimens we found that this was parallel to a vertical line corresponding to the articular surface of the medial malleolus. On lateral imaging we were able to

identify, all wires followed the obliquity of the medial malleolus and resided within the posterior 30% of the posterior tibial plafond.

Discussion

The primary aim of this study was to identify the fluoroscopic danger zone medially, to prevent inadvertent injury to the TPT during both direct and indirect fixation techniques to the tibia. This study has described an anatomical medial danger zone with the assistance of radiographic evidence for the fixation of ankle, specifically, to avoid TPT entrapment or injury. The nul hypothesis can therefore be rejected. This is the first study that we are aware of that describes a medial danger zone during fixation of the tibia in PMF and PIL injuries.

Previous literature has concentrated on 'safe zones' in PMFs in respect to the lateral aspect of the tibia. Williams et al demonstrated in a cadaveric study that there was a posterior incisura fluoroscopic landmark which localised the posterior syndesmotic border and that screws lateral to this line likely violated the syndesmosis.[22] Clarke et al provided evidence with cadaveric specimens for posterior-to-anterior percutaneous fixation of the ankle, concluding that a safe zone approximately 1cm above the level of the tip of the medial malleolus and immediate lateral to the Achilles tendon.[2] Yu et al, added found that in adding a medial approach, showed a significantly reduced malreduction rate and risk to post-traumatic arthritis by improving the reduction and screw placement. [23] None of these papers looked at the risk to TPT regarding entrapment, even though Yu et al found a significantly improved outcome when the medial approach was added, or the additional complexity of the posteromedial fracture. [13,20,23]

The risk of TPT injury in medial malleolar fracture fixation has been investigated. Fermino et al, in a cadaveric study, categorized the medial malleolus into 3 zones, zone 1 (anterior colliculus), zone 2 (intercollicular groove) and zone 3 (posterior colliculus). Screws placed into zone 3 resulted in TPT abutment and in zone 2 were on average 2mm away from the TPT.[16] DeMill et al reported similar findings in a clinical study, noting an increased probability that hardware in zones 2 and 3 could compromise PTT.[4] The zone 3 corresponds to the distal aspect of the 'danger zone' in this study, but the previous studies did not indicate the proximal extent where the TPT is at risk.

The TPT risk of injury is likely under reported. As illustrated in Figs. 3 and 4, injury or entrapment of TPT is possible with metalwork placed either from posterior or anterior. Some reports of TPT injury have also been reported with 4 cortices syndesmosis screws placed posteriorly and tendon entrapment in fractures. [1,8,19] Kaiser et al in their cadaveric paper on medial anatomical structures at risk in quadricortical syndesmosis fixation showed the TPT was at risk if metal work pierced the medial tibia in the posterior third on the true lateral. This is in keeping with our study where the TPT sheath was located in the posterior third of the tibia on the lateral radiograph. This also explains how fractures of the posteromedial aspect of the tibia are often difficult, and underappreciated, on the lateral radiograph. [21]

Combined with the lateral safe zone, this paper gives us a topographical image of the posterior tibia, and its areas of concern regarding metal work position (Fig. 5).

Limitations

This study has several limitations. The sample size of 21 specimens, while sufficient for this exploratory study, limits the generalizability of our findings. Another limitation is the static nature of cadaveric positioning during the study. The prone position, although standardized for consistency, does not account for the potential effects of different patient positions or dynamic loading on the relationships of the TPT and surrounding structures.

Conclusion

This study demonstrated that a medial danger zone fluoroscopic landmark is unambiguous in localizing the tibialis posterior sheath and that any metal work medial to this line is likely to be at risk of damaging the tibialis posterior tendon. The lateral radiograph showed that any anteroposterior screw could involve the tibialis posterior sheath even if the penetration is only 70% across the tibial width.

Declarations

Ethical approval statement

This study was conducted in accordance with the principles of the Declaration of Helsinki and complied with the Human Tissue Act 2004. Ethical approval was granted by Keele University Research Ethics Committee.

Consent to Participate declaration.

Not Applicable.

Financial interests:

Prof Lyndon Mason is an implant designer and receives royalties from Orthosolutions. The other authors declare no financial interests.

Author Contribution

BJ -Data Collection , Wrote Manuscript JA - Wrote Manuscript CO - Data Collection LM - Research Lead , Wrote ManuscriptAll authors reviewed Manuscript.

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Data availability declaration:

The data supporting the findings of this study are restricted due patient privacy and ethical regulations. Access to the X-ray images is available from the corresponding author upon reasonable request and with institutional review board approval.

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Figures

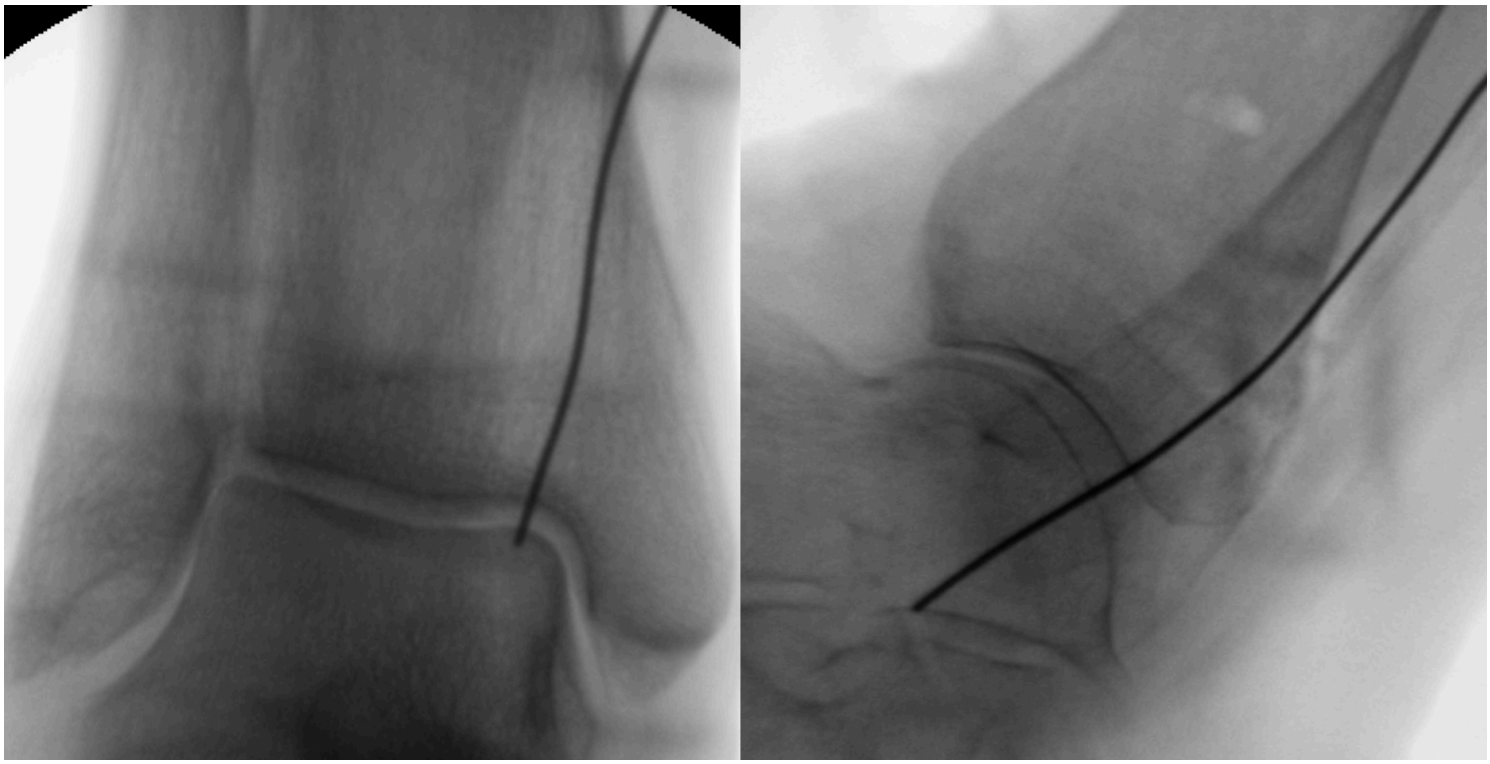


Figure 1

Anteroposterior and lateral fluoroscopic imaging of cadaveric specimens with metal wire placed down tibialis posterior tendon sheath.



Figure 2

Anteroposterior and lateral radiograph with superimposed schematic representation of the wires representing the lateral extent of the tibialis posterior sheath.

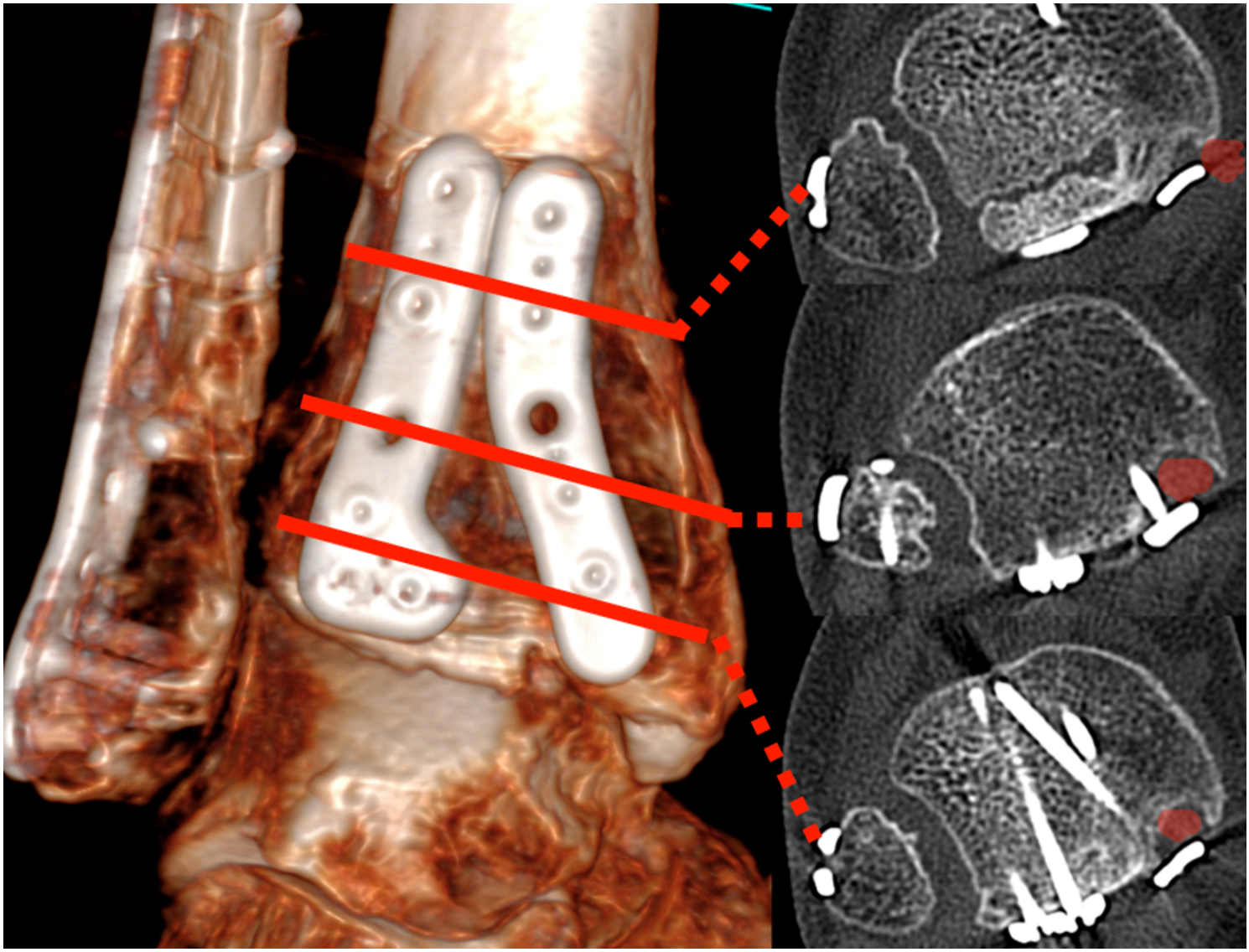


Figure 3

A Mason and Molloy 2B PMF treated with fragment specific fixation postoperative CT showing tibialis posterior entrapment (red) under the posteromedial plate.

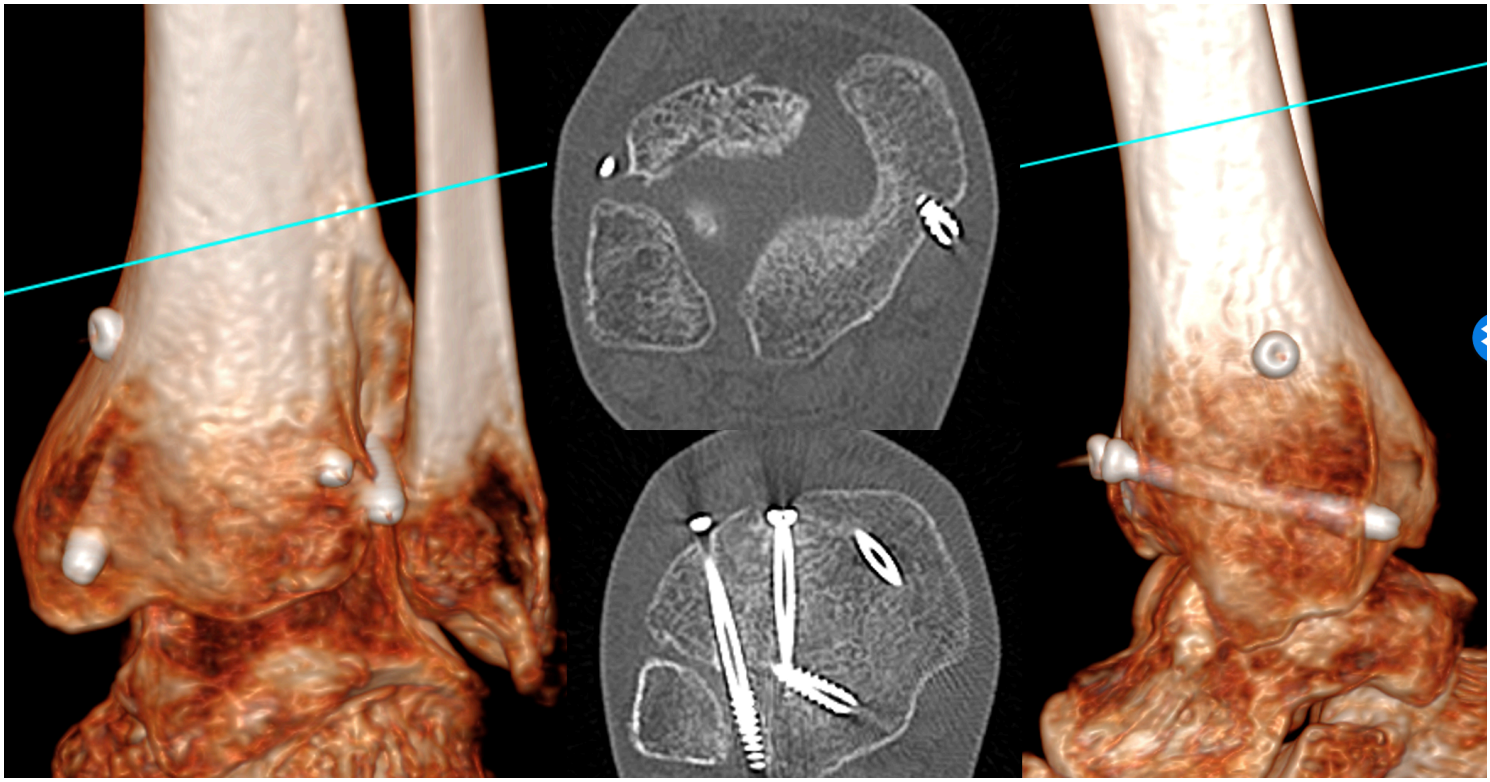


Figure 4

An anterior PIL fracture postoperative CT with anteroposterior screw fixation, showing penetration into both the lateral and medial danger zones with incisura and tibialis posterior penetration.

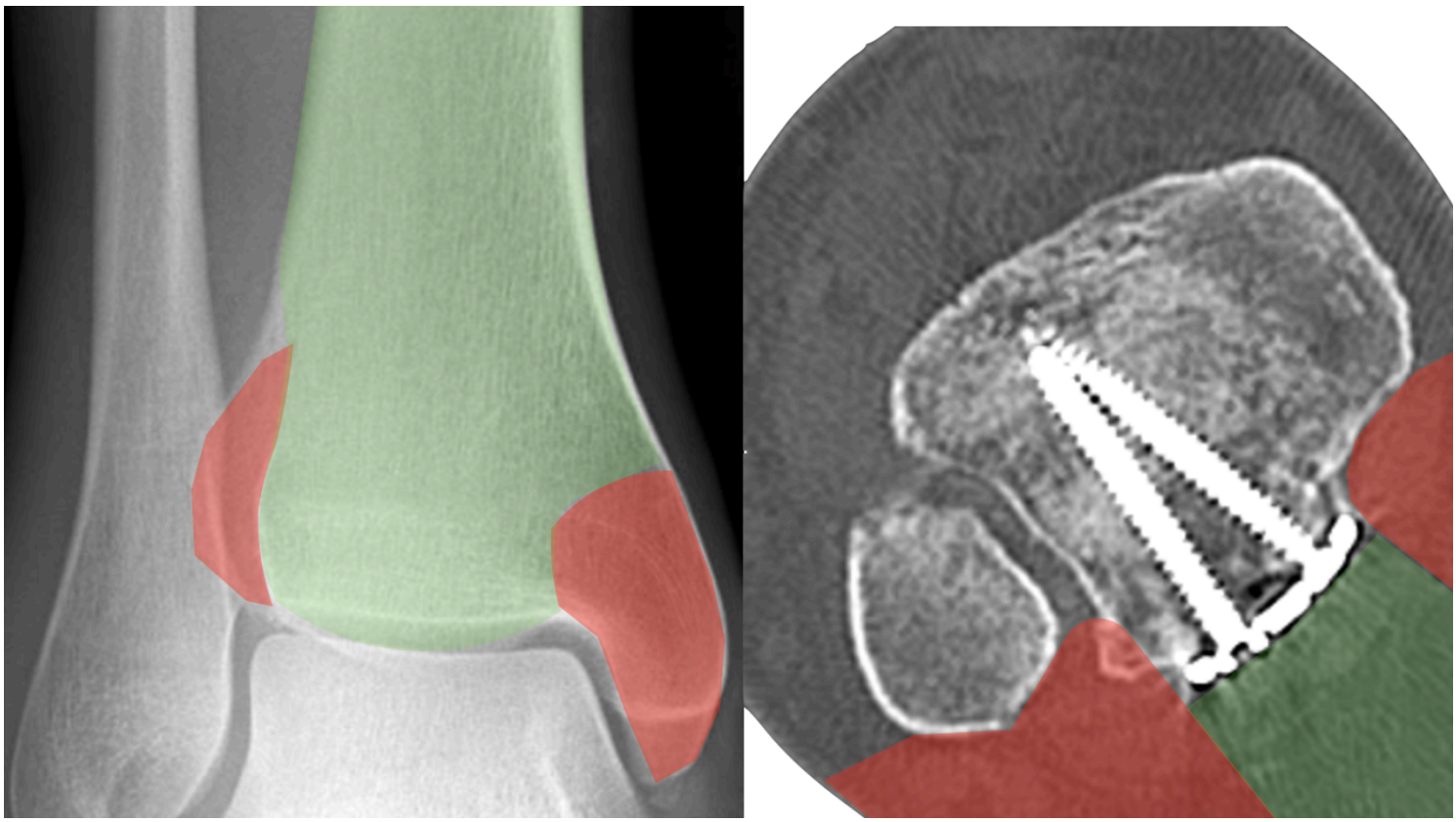


Figure 5

Schematic representation showing both the medial and lateral danger zones (red) and safe area (green) with axial CT showing the safe corridor for metal work insertion.