**Journal of Orthopaedic Trauma Publish Ahead of Print**
**DOI: 10.1097/BOT.0000000000002098**

# Defining the ideal 'nail exit path' of a tibial intramedullary nail – a computed tomography analysis of 860 tibiae

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Conflict of Interest StatementL: A. Trompeter, M. Kelly and P. Bates have an Education consultancy and / or R+D contract with Stryker. A. Petersik is an employee of Stryker. However, no payment or work is related to this project in anyway and there are no other conflicts of interest that could inappropriately influence this work.

**Objectives**

To identify the ideal distal nail position in the distal tibia, using computed tomography (CT) analysis.

**Methods**

3D models of 860 left tibiae were analysed using the Stryker Orthopaedic Modelling and Analytics software (SOMA, Stryker, Kiel, Germany). The nail axis was defined by seven centre points at the middle of the inner cortical boundary. Where this line fell relative to the centre of the tibial plafond in both the anteroposterior and mediolateral planes was calculated.

**Results**

The mean mediolateral offset of the tibial nail exit path was 4.4 ± 0.2mm (95% confidence interval) lateral to the centre of the tibial plafond. The mean anteroposterior offset of the tibial nail exit path was 0.6 ± 0.1mm anterior to the centre of the tibial plafond.

**Conclusions**

We have presented an anatomic study analysing the ideal nail exit path using CT scans of 860 tibiae. We have defined the ideal nail exit path of a tibial nail is lateral with respect to the centre of the tibial plafond. This is supported by previous clinical studies and has significant implications for preventing malalignment when treating distal tibial fractures with intramedullary nailing

**Level of Evidence -** Level IV. See Instructions for Authors for a complete description of levels of evidence.

**Keywords**

nail exit path; distal nail target; tibia; fracture; alignment; intramedullary nail



## Introduction

An accurate nail entry point is key to the success of any tibial nailing, particularly when treating proximal tibial fractures (1). It has been shown that the ideal location of the entry point for tibial nailing is just medial to the lateral tibial spine on the anteroposterior radiograph and immediately anterior to the articular margin on the lateral radiograph (2). This entry point is constant and remains the same for all nailing procedures regardless of approach, instrumentation or fracture location. Furthermore, in addition to the location of the entry point, it is the trajectory through that point that is equally important in ensuring adequate reduction. Conversely, managing distal tibial fractures with intramedullary nails presents unique challenges, which include achieving accurate reduction and alignment, maintaining this alignment, avoiding mal and non-union and preventing long term ankle pain (3). Recent literature has recognised the importance of the position of the nail in the distal metaphyseal block and its extrapolation through the plafond. Brinkmann et al. used the phrase “distal nail target” to describe the distal nail position and this can significantly affect alignment of distal tibia fractures following intramedullary nail fixation (4) (5). In this paper we have referred to this as the “nail exit path”. A path can be both in and out of the tibia and a path has both trajectory and position, which are key considerations in distal nail placement. In addition, we have used the term “exit” because it counters the term “entry point.”

A nail tip situated lateral to the ideal nail exit path can lead to varus malalignment of the distal tibia and if situated medial to the ideal nail exit path, can lead to valgus malalignment (figure 1). Malalignment can in turn lead to ankle pain, subtalar joint stiffness (6) and possibly osteoarthritis (7). Although several techniques to improve distal tibial alignment have been reviewed, including blocking screws, fibula plating and suprapatellar technique for tibial nailing (8) (9) (10), there is little evidence of where the ideal nail exit path actually is located. Indeed, it is commonly accepted that the ideal nail exit path is the midpoint of the tibial plafond on the anteroposterior and lateral radiographs (11). Recent studies suggest the ideal nail exit path is lateral to the midpoint on the anteroposterior radiograph (4) (5). The aim of this study is to identify the ideal nail position in the distal tibia - the so called ‘nail exit path for the nail, using computed tomography (CT) analysis of 860 tibiae.

**Methods**

The Stryker Orthopaedic Modelling and Analytics software (SOMA, Stryker, Kiel, Germany) is a collection of tools which utilises a database of CT scans and associated three-dimensional (3D) bone models, allowing the user to assess population differences in bone morphology (12). 3D models of 860 left tibiae were analysed using the SOMA software. This anatomic cohort included 801 patients aged between 18 and 98 years old and the average age was 62 years old (59 patients were of unknown age due to anonymised data). There were 445 females (51.7%) in the cohort. Ethnicity of the cohort consisted of 492 (57.2%) Caucasian, 346 (40.2%) Asian, 14 (1.6%) African and eight (0.9%) Middle Eastern. The data was collected from 17 hospitals across seven countries. Less the 3% of the data was acquired from cadaveric specimens. The data was taken from the existing SOMA database repository and no data was specifically acquired for this study. The constructed nail axis along the tibia was defined by seven centre points measured at the midpoint of the inner cortical boundary. These seven points included the first centre located at the middle of the isthmus, three centre points above and three centre points below the first. The midpoint in the inner cortical diameter was determined using the Stryker Anatomy Analysis Tool (SAAT 5.4, database version 5.1) software. A best fit line was calculated through the seven points and this line defines the constructed nail axis. It was extended distally to demonstrate the nail exit path in the tibial metaphysis and where this line fell relative to the centre of the tibial plafond in both the anteroposterior and mediolateral planes was calculated (figure 2). The tibial plafond was defined by eight points placed along the edges of the tibial plafond. The SOMA software then calculated the centre point of these eight points to define the centre point of the tibial plafond.

Two techniques were used to define the three centre points above and below the isthmus: an absolute technique using points 10 millimetres (mm), 20mm and 40mm above and below the isthmus; and a relative technique using points 2.9%, 5.7% and 11.5% of the tibial length above and below the isthmus. The relative technique points were calculated based upon the average tibial length of the cohort, which was 349mm (for example, 10mm / 349mm = 2.9%). This was done to ensure the constructed axis was not affected by tibiae of different lengths. All scans were obtained as per local legal and regulatory requirements which included ethics board approval and patient informed consent, where appropriate.

**Results**

The mean mediolateral offset of the tibial nail exit path was 4.4 ± 0.2mm (95% confidence interval, standard deviation 2.8) lateral to the centre of the tibial plafond using the absolute technique and 4.4 ± 0.2mm (standard deviation 2.7) using the relative technique. The mean anteroposterior offset of the tibial nail exit path was 0.6 ± 0.1mm (standard deviation 2.2) anterior to the centre of the tibial plafond for both relative and absolute techniques. Figure 3 illustrates the mediolateral and anteroposterior offset of the nail exit path for each constructed nail axis. The coordinate origin is the centre of the tibial plafond and the majority of nail exit paths lie lateral to the midpoint on the mediolateral axis and are clustered around the midpoint on the anteroposterior axis. The grey square indicates the mean mediolateral and anteroposterior offset of the nail exit path and its size represents respective 95% confidence intervals. The large dotted rectangle indicates two standard deviations from the mean mediolateral and anteroposterior offsets (approximately 95% of the values lie within this box). Figure 4 shows an an axial slice at the level of the tibial plafond, through the SOMA software constructed 3D model, demonstrating the centre of the tibial plafond (grey circle) and the location of the mean nail exit path (black circle) as determined by the relative and absolute constructed nail axis.

## Discussion

The position of the nail in the distal metaphyseal block – the 'nail exit path' – can significantly affect reduction and alignment of distal tibia fractures (4) (5). We present an anatomic study analysing the ideal nail position using CT scans of 860 tibiae. We have defined the ideal 'nail exit path' of a tibial nail is 4.4mm lateral with respect to the centre of the tibial plafond on the coronal plane and centred on the tibial plafond in the sagittal plane.

Fractures of the tibial shaft are routinely managed with intramedullary nailing (13), the origins of which, lie with Gerhard Küntscher's marrow nailing technique (14). The techniques and designs have evolved (15), with more recent studies showing the benefits of intramedullary nailing for distal tibial fractures, that included improved wound healing (16) (17), minimal surgical dissection, early mobilisation (2) and improved ankle range of movement (18). A recent large randomised clinical trial suggested that distal tibial fractures treated with intramedullary nailing, resulted in a statistically significant better mean Olerud-Molander Ankle Score (OMAS), with no significant difference in complications (19).

Giacomo et al. looked at 122 distal tibial fractures treated with intramedullary nail insertion without fibula fixation (11). They highlighted the difficulty achieving accurate alignment due to the loose endosteal fit of the nail within the hourglass shape of the metaphyseal canal and advised on the importance of the nail centred in the proximal and distal fragments. Our paper demonstrates that whilst the location of the nail in the sagittal plane should be centred on the distal fragment, in the coronal plane, the surgeon should aim the distal tip of the nail to just lateral of the centre point.

Triantafillou et al. also highlight the lack of consensus on the proper distal nail placement in treating distal tibial fractures with intramedullary nailing (4). In the coronal plane, they evaluated 85 distal tibial fractures and 65 distal tibial fractures in the sagittal plane both treated with intramedullary nailing. There was 27.5% fracture malalignment in the sagittal plane when the nail was placed medial to the centre of the joint versus only 2.9% when the nail was placed lateral to the centre of the joint (within 25% of the centre of the joint). Acceptable coronal alignment was less than five degrees and acceptable sagittal alignment was defined as within five degrees of 83 degrees dorsal tilt on lateral imaging.

Brinkman et al. evaluated 130 distal tibial fractures treated with intramedullary nailing over a ten year period (5). They concluded that malalignment (greater than five degrees), was less common for nail exit paths central or slightly posterolateral. Again, they have calculated the ideal nail exit path indirectly by comparing which nail exit path minimises malalignment. As with Triantafillou et al., they have demonstrated the importance of the nail exit path clinically with respect to malalignment and this anatomic study adds further data to define that point more precisely.

Following review of several current manufacturer surgical technique guides for intramedullary tibial nailing, we found there is agreement on a defined entry point as per Tornetta III et al. (20). However, when these manufacturer surgical technique guides discuss the distal nail exit path of the nail, the guidance is considerably less clear and not in accordance with our findings (21) (22). We propose firstly, that in the surgical technique guides, there should be more emphasis placed on accurate placement of the nail exit path and secondly, the ideal nail exit path definition should be defined. The guides advise on proximal to distal placement of the nail tip, but either do not give any advice on the nail exit path or advise the guidewire should be central in the metaphysis and diaphysis on anteroposterior and lateral radiographs.

Defining the ideal nail exit path in the sagittal plane requires further attention. All the manufacturer's tibial nails that we have reviewed, were straight in the coronal plane and therefore our best fit line is a good representation of the nail axis in the coronal plane. However, in the sagittal plane most tibial nails have a bend proximally and many, but not all have a bend in the nail distally as well (21) (22). As in the coronal view, we have defined the ideal nail exit path in the sagittal plane as an extrapolation of the straight isthmic portion of the nail. Any anterior bend of the nail distally needs to be taken into account by the operating surgeon. For the purposes of this study, a straight nail is assumed in the lateral view.

The main limitation to this study is in how we have defined the nail axis in the tibia. This is approximated by best fit lines only. In vivo, there are other factors that could influence the nail position in the tibia, including variable entry point, geometric constraints in the intramedullary canal and bending of the nail. However, if an appropriate size nail with a tight diaphyseal fit after reaming is inserted, this would limit any variation from the nail axis that we have defined in our study. There are also deforming muscular forces to overcome when reducing fractures, and it is not just the nail position itself that needs to be considered. However, this study has emphasised the importance of accurate implant positioning in achieving optimal clinical results. A further limitation of this study is how to translate these CT findings to what is available to the surgeon intraoperatively. Radiographic phantoms made from the CT data employed to determine the nail exit path would be useful for comparison to what a surgeon could control intraoperatively. Unfortunately, radiographic phantoms from the CT data, were not available, but would be a useful further study.

Tornetta III et al. described the now widely accepted ideal proximal entry point located slightly medial to the lateral tibial spine as visualised on the anteroposterior radiograph in 20 cadaveric knees. In their study, a Kirschner wire was placed in the centre of the anatomic safe zone and in line with the tibial shaft. Anteroposterior and lateral radiographs were then taken to assess the distance from the Kirschner wire to the lateral tibial spine (20). This anatomic study has defined the ideal nail exit path with regards to the tibial plafond, which is 4.4mm lateral to the centre of the tibial plafond in the coronal plane and centred on the tibial plafond in the sagittal plane. In practice, achieving distal nail placement just lateral to the centre of the tibial plafond will minimise malalignment and the complications associated with this. Other authors have previously demonstrated this finding in clinical outcomes with regards to location of the nail exit point and malalignment post operatively (4) (5).

## Conclusions

We have presented an anatomical study analysing the ideal nail exit path using CT scans of 860 tibiae. We have defined anatomically the ideal nail exit path of a tibial nail is just lateral with respect to the centre of the tibial plafond and this supports the previous clinical studies (5) (4). This has significant implications for treating distal tibial fractures using intramedullary nailing and preventing malalignment and complications associated with malalignment. We expect these findings to further influence how trauma surgeons consider intramedullary nailing of distal tibia fractures.

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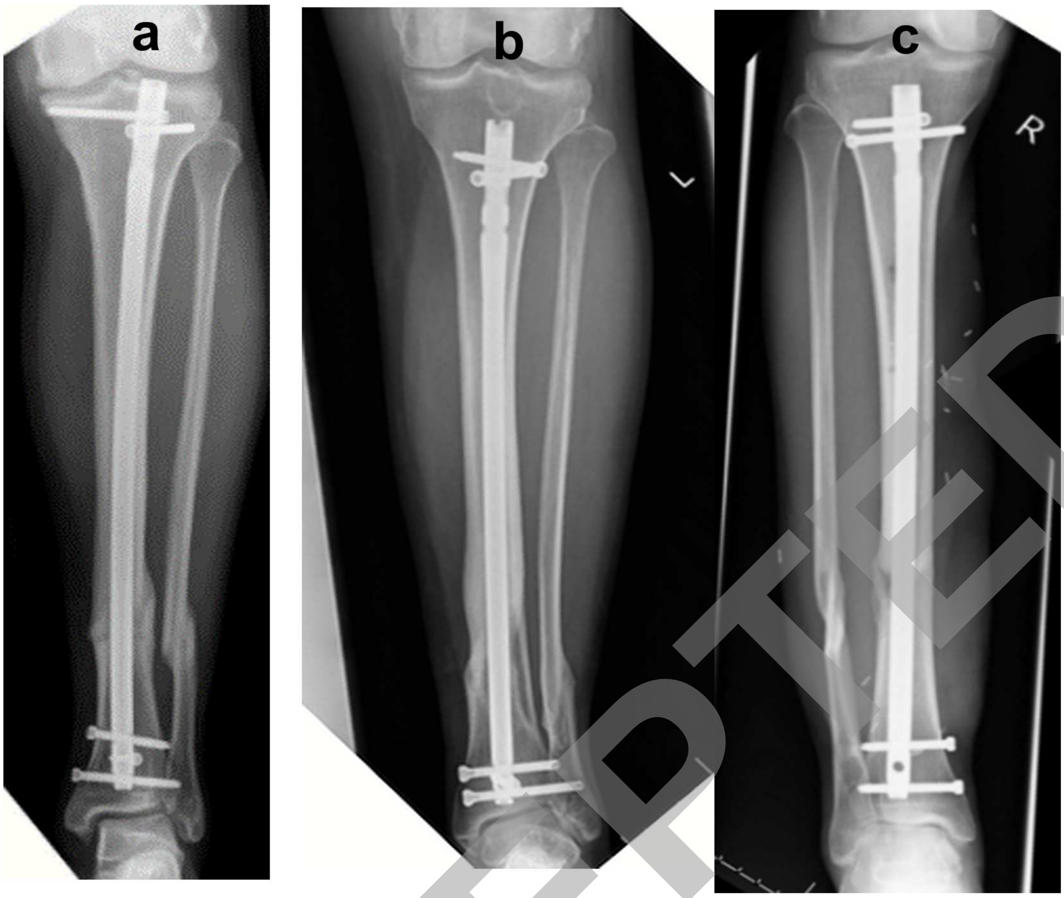
Figure 1. Three radiographs demonstrating a. a subtle valgus malalignment of a distal tibia fracture post intramedullary nail, b. a more extreme valgus malalignment and c. ideal alignment. In radiograph a and b, the nail exit path is situated at, or medial to the midpoint of the tibial plafond and in radiograph c, the nail exit path is situated lateral to the midpoint.

Figure 2. Calculation of best fit line through seven points to represent the nail axis and calculation of the nail exit path.

Figure 3. Visualisation of the mediolateral and anteroposterior offset of the nail exit path for each constructed nail axis (absolute constructed axis represented by crosses and relative by circles). The coordinate origin is the centre of the tibial plafond. The grey square indicates the mean mediolateral and anteroposterior offset of the nail exit path and its size represents respective 95% confidence intervals. The large dotted rectangle indicates two standard deviations from the mean mediolateral and anteroposterior offsets (approximately 95% of the values lie within this box).

Figure 4. An axial slice at the level of the tibial plafond, through the SOMA software constructed 3D model, demonstrating the centre of the tibial plafond (grey circle) and the location of mean the nail exit path (black circle) as determined by the relative and absolute constructed nail axis


a
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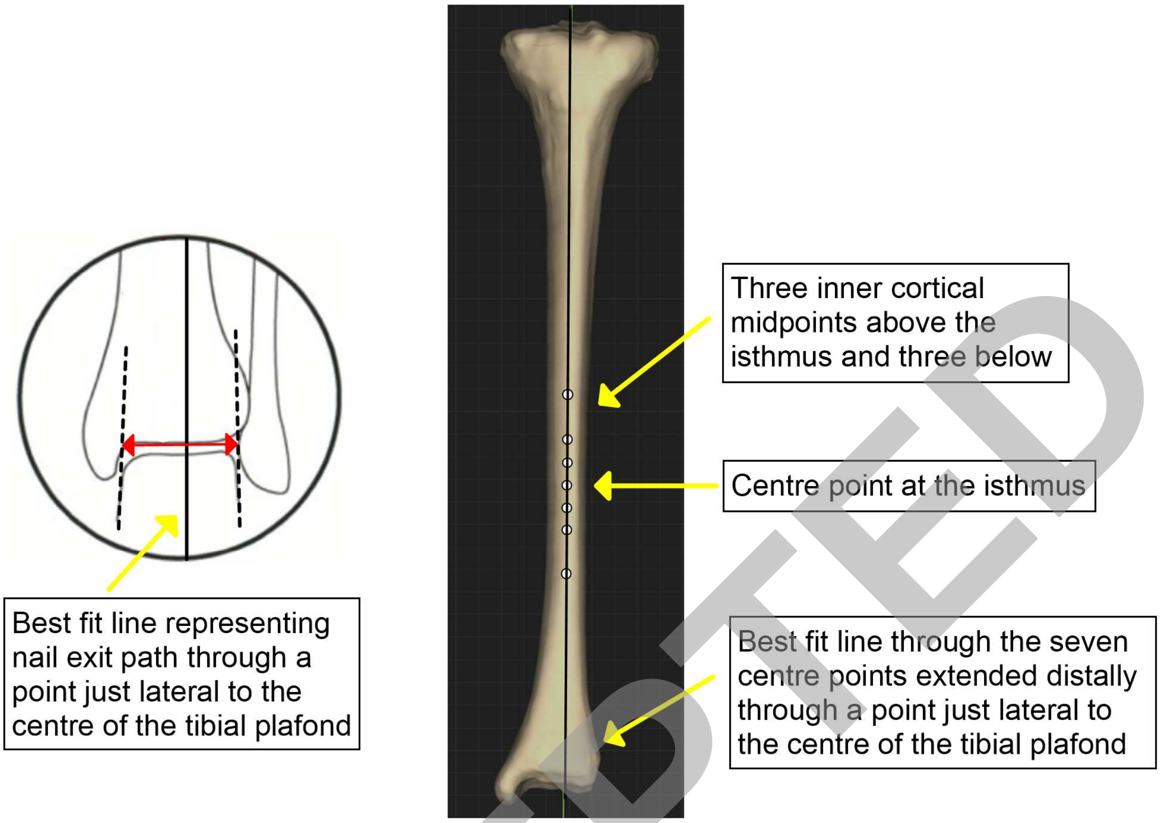
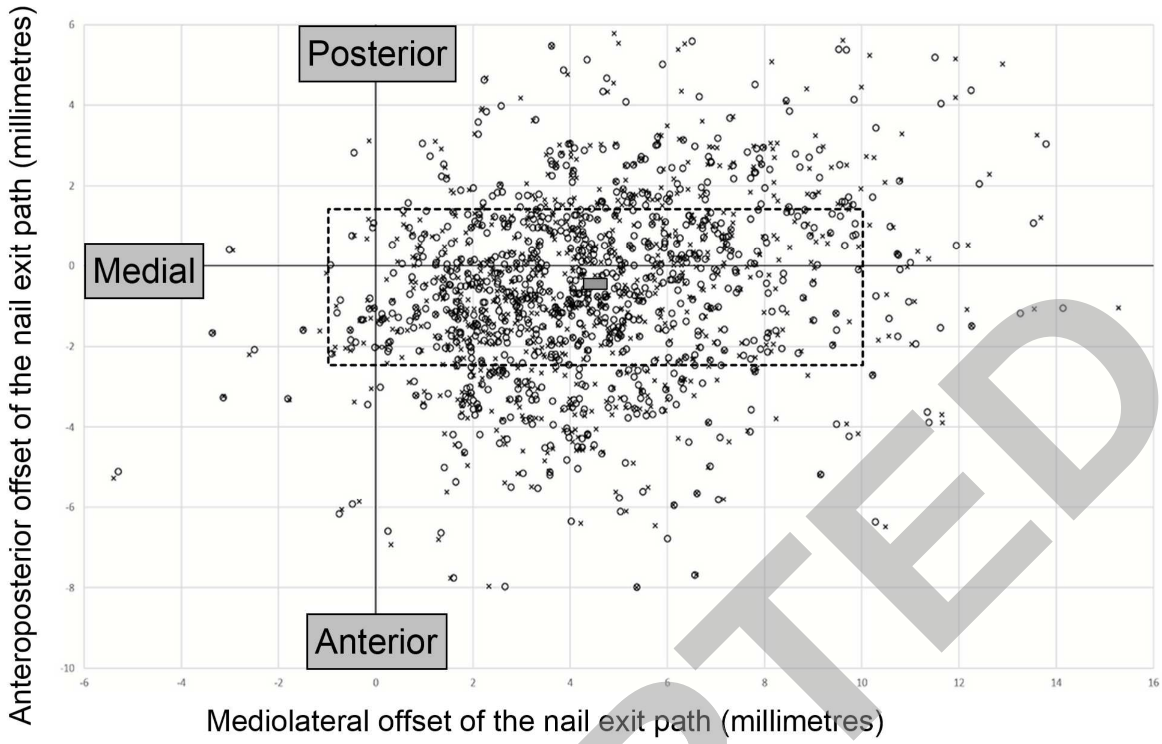
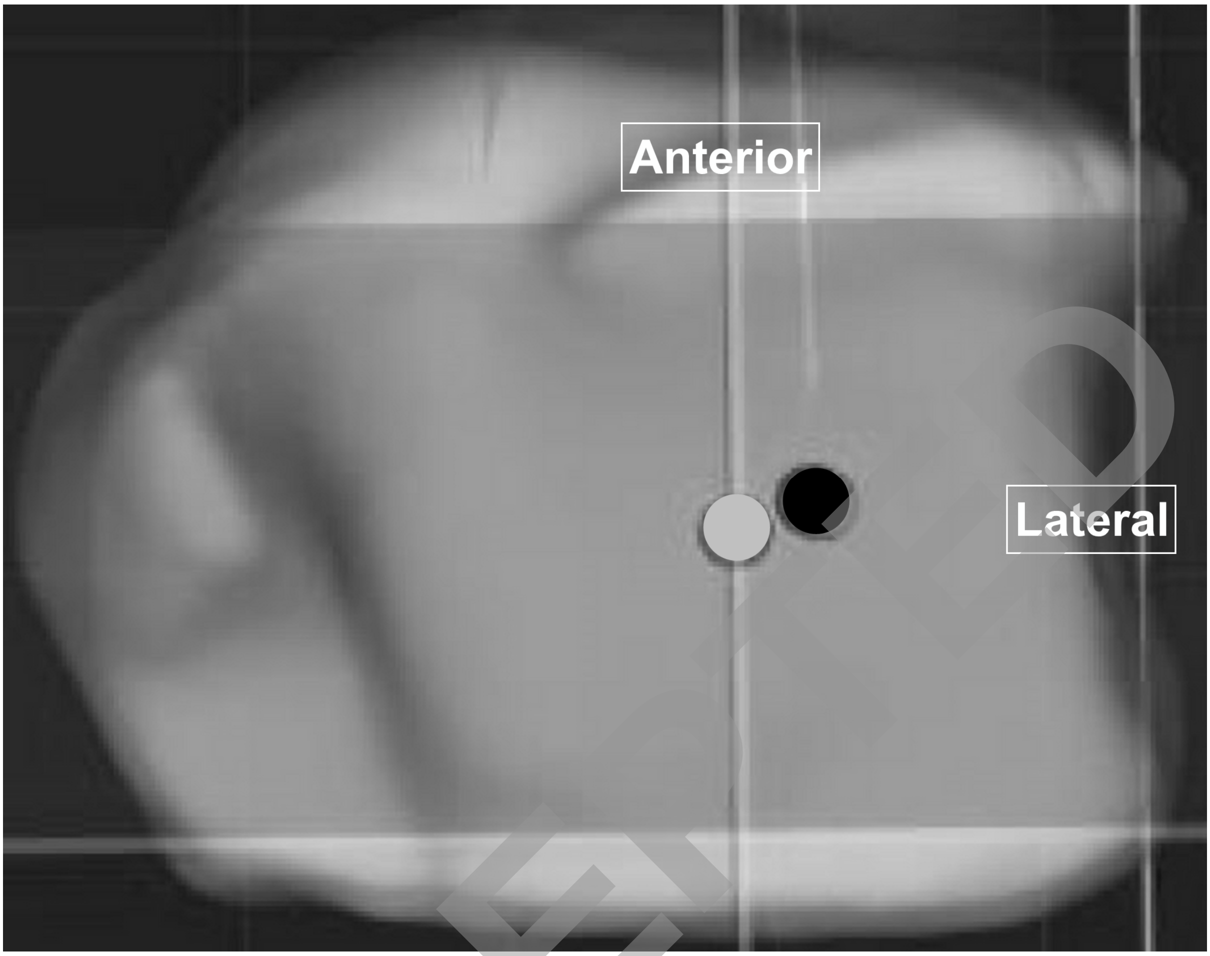

Three inner cortical midpoints above the isthmus and three below
Centre point at the isthmus
Best fit line through the seven centre points extended distally through a point just lateral to the centre of the tibial plafond
Best fit line representing nail exit path through a point just lateral to the centre of the tibial plafond


Posterior
Medial
Anterior
Anteroposterior offset of the nail exit path (millimetres)
Mediolateral offset of the nail exit path (millimetres)


Anterior
Lateral