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Finite element analysis of the three different posterior malleolus fixation strategies in relation to different fracture sizes

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ABSTRACT

Purpose: Appropriate fixation method for the posterior malleolar fractures (PMF) according to the fracture size is still not clear. Aim of this study was to evaluate the outcomes of the different fixation methods used for fixation of PMF by finite element analysis (FEA) and to compare the effect of fixation constructs on the size of the fracture computationally.

Materials and methods: Three dimensional model of the tibia was reconstructed from computed tomography (CT) images. PMF of 30%, 40% and 50% fragment sizes were simulated through computational processing. Two antero-posterior (AP) lag screws, two postero-anterior (PA) lag screws and posterior buttress plate were analysed for three different fracture volumes. The simulated loads of 350 N and 700 N were applied to the proximal tibial end. Models were fixed distally in all degrees of freedom.

Results: In single limb standing condition, the posterior plate group produced the lowest relative displacement (RD) among all the groups (0.01, 0.03 and 0.06 mm). Further nodal analysis of the highest RD fracture group showed a higher mean displacement of 4.77 mm and 4.23 mm in AP and PA lag screws model ($p = 0.000$). The amounts of stress subjected to these implants, 134.36 MPa and 140.75 MPa were also significantly lower ($p = 0.000$). There was a negative correlation ($p = 0.021$) between implant stress and the displacement which signifies a less stable fixation using AP and PA lag screws.

Conclusion: Progressively increasing fracture size demands more stable fixation construct because RD increases significantly. Posterior buttress plate produces superior stability and lowest RD in PMF models irrespective of the fragment size.

Introduction

Posterior malleolar fractures (PMF) are relatively common injuries with an incidence of 7%–44% among rotational ankle fractures [1–3]. It can occur in settings of tri malleolar fractures or in association with pilon fractures as a distinguished posterior column fracture [4]. It can also be presented as an isolated posterior malleolar fracture [5]. Less satisfactory clinical outcomes and a higher risk of degenerative osteoarthritis are reported in the literature with posterior malleolus involvement [6–10]. Biomechanically, the displaced posterior malleolar fragment causes a decrease in the joint contact area and predisposing the ankle to degenerative changes [11,12]. Fixation of the posterior malleolar fractures remains an area of controversy in orthopaedic surgery. Most of the surgeons agree with the recommendation that the posterior fragment involving greater than 25% of the articular surface should internally fix, but this figure has been challenged by recent studies and argued the importance of even smaller posterior malleolar fragment to ankle joint stability, so the indications for surgical fixation have expanded. In clinical practice, posterior malleolar fractures can be fixed either using the anterior approach

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with antero-posterior (AP) lag screws or through a direct posterior approach, in which direct reduction and fixation is achieved by using posterior to anterior (PA) lag screws and/or a posterior buttress plate. Very less work has been done to compare the biomechanical stability of the different fixation methods used in recent clinical practice [13]. In an effort to shed more light on this issue, we undertook a finite element analysis (FEA) to compare the biomechanical strength of the different fixation methods used for posterior malleolar fracture fixation. We further analysed the effect of different fixation strategies for the size of posterior malleolar fragment.

Materials and methods

Three dimensional (3D) models

This research work was approved by the Medical Research Ethics Committee of our hospital and was performed in accordance with the Declaration of Helsinki. CT scan images of the right ankle in the neutral unloaded position were used to reconstruct the geometrically accurate three dimensional (3D) model of the ankle joint. There was no past history of trauma and no anatomical abnormality was observed by X-ray examination. The slice

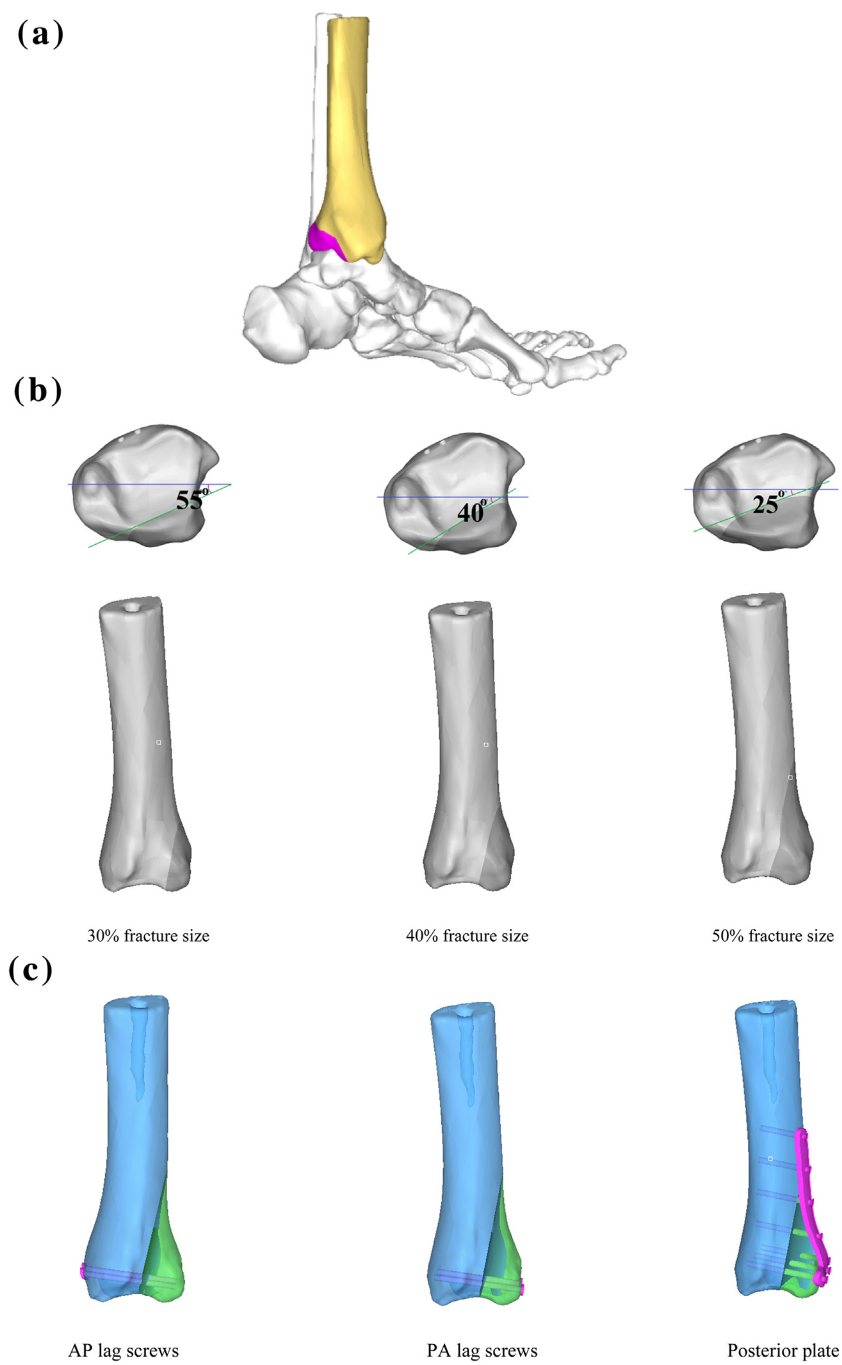

Fig. 1. Different fixation modalities and fracture sizes.
(a) Initial three dimensional (3D) model.
(b) Three different sized fracture patterns with articular surfaces showing the fracture angles.
(c) Implanted models of the distal tibia with the simulated fracture of the posterior malleolus showing AP, Pa lag screws and posterior plating.