POSTERIOR MALLEOLUS LOAD-BEARING CHARACTERISTICS AS A FUNCTION OF ANKLE POSITION AND FRACTURE PATTERN

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INTRODUCTION:

In ankle fractures involving the posterior malleolus, it remains uncertain whether early weight-bearing after operation is suitable. The aim of this study was to theoretically analyze the three-dimensional contact mechanics of the ankle joint in varying degrees of flexion with special reference to the force transmission properties of the posterior malleolus. We developed a model and adopted the discrete element analysis (DEA) technique to calculate the loading of the anatomical structures.

METHODS:

Joint articular contact and ligament loading were explored using the DEA technique by establishing a region of elastic elements between rigid bodies representing the bone. Articular cartilage was represented by compressive springs and ligamentous tissue was modeled using tensile springs. Three dimensional bone models of the talus, calcaneus, tibia, and fibula based on the Visible Human Dataset (National Library of Medicine) were scaled to match CT data recorded principally for this study of a cadaver in various flexion angles including neutral, 20° of dorsiflexion, and 20° of plantar flexion. Regions of potential bony contact were identified by the contour lines of the subchondral bone on each slice of the orthogonal CT sections and were then stacked to create a contact surface. The contact surfaces were subdivided into thousands of triangular elements to create a mesh of compressive springs (Fig. 1). Rows of tensile springs for ligaments were inserted at anatomical positions as identified from dissection data of the same specimen. The stiffness of the springs was determined from previously published data. External static loads were applied to the system in the axial direction to simulate standing in a walking cast. Reaction forces were calculated by the deflection of the spring element system once an equilibrium state was achieved. Posterior malleolar fractures with increasing fragment-size were simulated based on actual fracture patterns of both the oblique type and the transverse medial-extension type (Fig. 2).

RESULTS:

As the flexion angle of the joint was changed from dorsiflexion to plantar flexion, the pressure value of the posterior aspect of the contact mesh increased, hence the most force transmission of the posterior fragment occurred in the plantar-flexed ankle (Fig. 3). Force was transmitted through the posterior fragment in all ankle position scenarios (Fig. 4 and 5). In the most severe case, more than 40% of the total reaction force was transmitted through the fracture region.

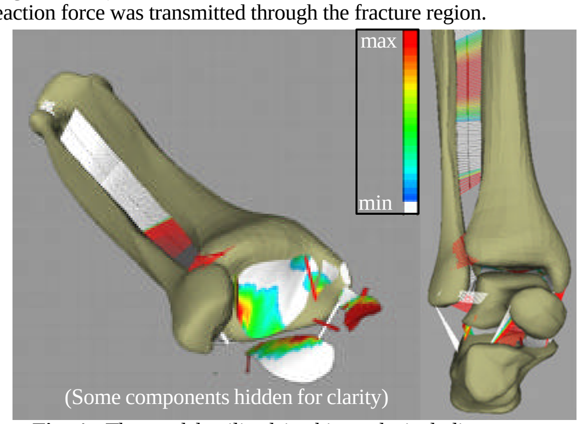

Fig. 1: The model utilized in this study including contact surfaces and ligaments.

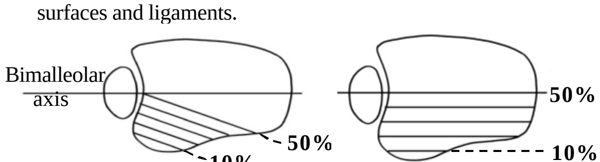

Fig. 2: Fracture pattern of the posterior malleolus utilized in this study: oblique type (left) and transverse type (right).

DISCUSSION:

Several authors of recent studies investigated operative treatment of ankle fracture (including trimalleolar fracture) with early postoperative weight-bearing and concluded that early weight-bearing was safe without redisplacement [1-6]. The findings of our study, however, suggest that early weight-bearing may not be preferable in patients with a surgically repaired or closed-treated posterior malleolar fractures because the force transmission through the fragment could lead to fragment displacement. For patients who must bear weight out of necessity, such as the elderly, partial weight-bearing with the ankle slightly dorsiflexed is suggested.

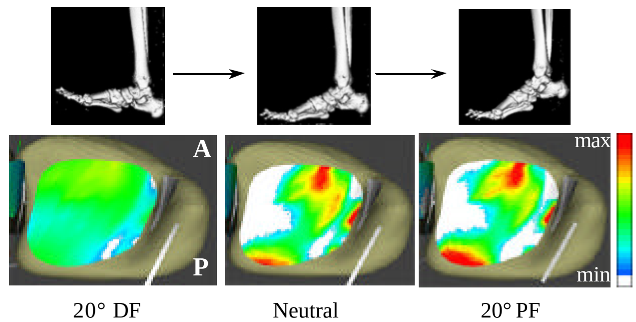

Fig. 3: Effect of ankle position on tibial plafond contact mechanics under similar loading. Maximum pressure = 6 MPa.

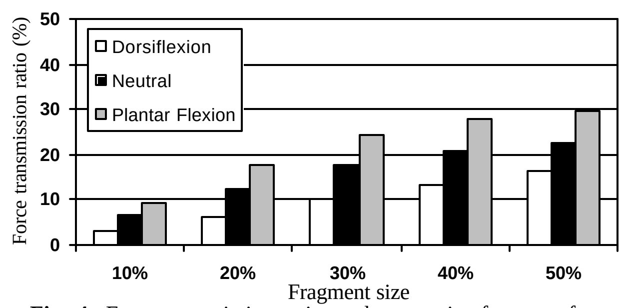

Fig. 4: Force transmission ratio to the posterior fragment for an oblique fracture as a function of fragment size and ankle position.

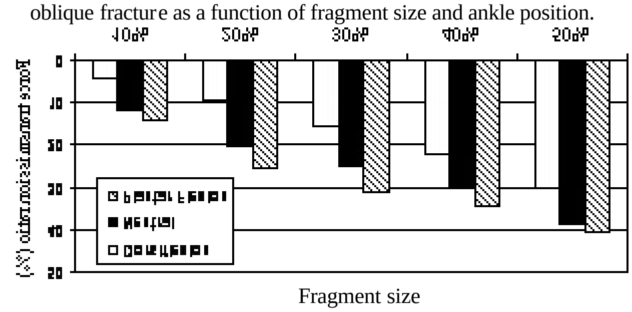

Fig. 5: Force transmission ratio to the posterior fragment for a transverse fracture as a function of fragment size and ankle position.

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