Does the calcaneus morphology have an influence on the risk of posterior heel ulcer?

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Introduction

Pressure ulcers (PU) affect almost half of the patients in reanimation or geriatric units. Forty percent of those PU are posterior heel ulcers. The main suspected causes are the excessive pressure intensity (leading to internal strains above 50 % for about 10 minutes) and prolonged compression (leading to internal strains above 20 % for about two hours) [1]. Prevention through daily examination lacks efficiency because of the nature of these deep tissue injuries resulting from internal strains. When visual symptoms appear it is often too late for PU prevention. It is consequently crucial to monitor the internal strains. But is there a difference in terms of strain from a patient to another because of the difference in their calcaneus shape?

Methods

To answer this question, a lower leg Finite Element (FE) model was elaborated based on a previous foot model [2]. This new model represents the soft tissues of the lower leg as four different sub-domains each modelled using a Neo Hookean material with Young moduli and Poisson ratios of 200 kPa and 0.495 for the skin, 30 kPa and 0.49 for the fat, 1 GPa and 0.495 for the Achilles tendon, and 60 kPa and 0.495 for the muscles [3], Fig. 1. Bones are modelled as rigid solids, 18 different shapes of calcanei are simulated. This leg model rests on a FE model of a cushion with three compartments of varying stiffnesses: under the calf, the Achilles tendon, and behind the heel.

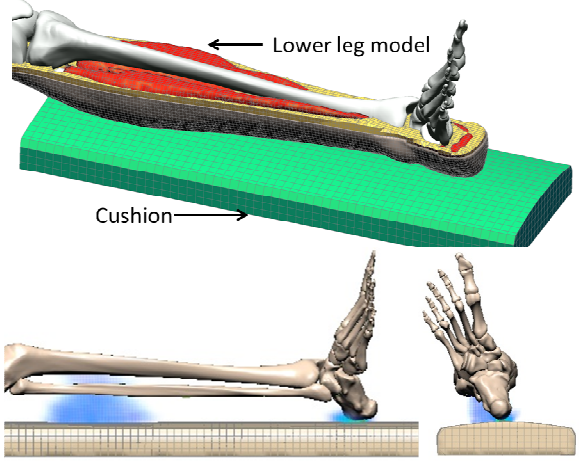

Fig. 1: *Top: the four types of materials defining the lower leg FE model: skin (only one layer of elements around the leg), muscles (in red), fat (in yellow), and Achilles tendon. Bottom: clusters of the nodes with VM strains above 20 % with a stiff cushion below the heel and a soft cushion elsewhere. The maximum VM strain (57 %, in red) is located under the heel, at the interface between fat and calcaneus.*

Results

Table 1 shows the summary of all the FE simulations for the 18 lower legs under gravity. To measure the PU risk, the volumes of the largest clusters with contiguous nodes with VM strains over 20 % or 50 % are observed during simulations.

Table 1: *Average of the volume, in cm^3, of the largest cluster of nodes with a VM strain above 20 % and 50 %, and their deviation in %.*

Cushions' configurations	Stiff calf Soft Achilles Soft heel	Stiff heel Soft Achilles Soft calf	all stiff	Very stiff heel Soft Achilles Soft calf
Mean cluster vol. . over 20 % in cm^3	0.836 [+/- 0.0%]	0.479 [+/- 23.8%]	0.209 [+/- 3.2%]	1.826 [+/- 16.8%]
Mean cluster vol. over 50 % in cm^3	-	-	-	0.020 [+/- 152.0%]

Discussion

The influence of the calcaneus' morphology is clearly demonstrated by the cluster volumes with deviations of 23.8 % and 16.8 % in the simulations with stiffer stiff cushions below the heel of the 18 models. The same morphology was used for those models in the proximal section which explains the low deviation (0 and 3.2 %) below the calf. Additionally, this lower leg FE model could be used to identify the cushions' stiffness minimizing the ulceration risk for each individual over time: a very stiff cushion below the heel leads to a cluster volume of 0.02 cm^3 that could create a PU in less than 10 minutes, while a softer cushion avoids creating any cluster with internal strains over 50 %: in that case, the risk of PU creation is around two hours [1]. Moreover, the largest cluster can be located with the simulations: it is at the interface between the calcaneus and the fat layer when the cushion is stiffer under the heel, Fig. 1, therefore increasing the risk of PU when maintained for a long time.

Clinical relevance

This study quantitatively proves that the calcaneus shape has a strong impact on the risk of PU creation.

Conflict of Interest

Some authors are involved with the TexiSense Company (http://www.texisense.com/home_en).

References

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