PARAMETRISATION OF THE CALCANEUS AND MEDIAL CUNEIFORM

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Introduction

Flatfoot is a condition commonly seen in children and sometimes adults, associated with foot arch flattening or lack of development of the foot arch and extreme foot malalignment. Surgical corrective surgery is one option for extreme cases; however, outcomes can be variable and the multiple factors that affect surgical outcomes are still not clearly understood [1]. Due to a general disagreement on the clinical or radiographic criteria to define this condition, it is still considered by most to be a poorly understood topic and consequently all associated definitions are still somewhat superficial [2]. This explains why it is important to determine the key parameters which define the condition.

This research aims to develop a parametric model to improve understanding of adolescent flatfoot surgery to recognise what influential factors are contributing to surgical outcomes. Differences between two specific bones - the calcaneus and the medial cuneiform, which will be altered in shape by Evans' surgery – can then be compared between the pre- and post-operative shapes of these bones. The present paper outlines the methodology to achieve these goals within the context of this study.

Methods

The methodology applied here is based on the paper written by Pascoletti et al. (2021) [3] and applied using the MATLAB (v.17, The MathWorks, Inc., Natick, MA, USA) script written by Pascoletti. This method was used to analyse the morphological differences in two bones, the calcaneus and medial cuneiform, using five CT scans of feet acquired from cadavers.

In iso-topological meshes all nodes in the surface mesh are treated as landmarks. They are created implementing some transformations and the RBF (Radial Basis Function) method, where the information of each individual shape in the database related to location, scale and rotation are eliminated to make the shapes comparable. GPA (Generalised Procrustes Analysis) and PCA (Principal Component Analysis) are applied on the database to find the variability model ($\boldsymbol{P} \cdot \boldsymbol{b}$) that describes the dataset.

$$x = \bar{x} + \boldsymbol{P} \cdot \boldsymbol{b} \qquad (1)$$

Results

It was found that three Principal Components (PCs) were needed to explain 98% of the total variance of the dataset for the calcaneus and one PC for the medial cuneiform. A qualitative analysis using images was made comparing an average shape with the relevant PCs. A quantitative analysis was also made comparing the landmarks coordinates of the singular shapes with the average shape.

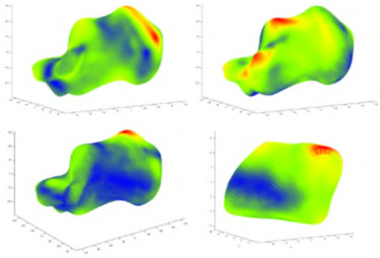

Figure 1: PCs showing the variability of the dataset, highlighting what those PCs are describing (in red)

Discussion

This methodology has the potential to be effective regarding the shape analysis of the calcaneus and medial cuneiform, once applied on the actual pre- and post-operative shapes, being able to tell what these bones have in common and being able to highlight what change has been made to the post-operative bone. More importantly it will make it possible at a later stage to relate the pre- to post-surgery shapes to parametric shape changes and relate these to the surgical outcomes. This study establishes the PCA methodology for the clinical study that will accompany the flatfoot surgery. The implications are immediately obvious and very important, successful surgical outcomes can be related to certain shape changes and these through parametrisation are expressed in numerical form. The final objective then is, evidently, to start foot reconstruction for those predicted and optimum parametrised shape changes, which would lead to better surgical outcomes.

References

1. M. Myerson, Correction of Flatfoot Deformity in the Child, 2019.
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3. G. Pascoletti et al, Appl Sci, 11:1-14, 2021.

Acknowledgements

This work was supported by grant EP/R513027/1 from the EPSRC DTP 2018-2019.