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**Effect of foot orthotic on bone alignment:
Foot and lower limb 3D reconstruction from EOS® biplanar radiographic imaging**

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INTRODUCTION

Classification and evaluation of alignment of the feet during weight bearing is of interest to the foot surgery and footwear community. However, traditional weight bearing radiographs are often limited to 2-dimensions (2D). Therefore, direct angle measurements on standard radiographs are potentially inaccurate, due to foot orientation and projection [1,2]. Magnetic resonance imaging (MRI) and computed tomographic (CT) techniques are capable of capturing bone alignment in 3-dimensions (3D), but lack usefulness in most clinical situations because images are captured in a non-weight bearing position and the process is time-consuming [1]. The aim of this study is to present a new method to reconstruct an individual foot and lower limb in 3D from biplanar EOS® X-ray imaging (EOS Imaging, France) combined with MRI. EOS® imaging system is a newly developed system that takes simultaneously taken biplanar low-dose radiography pictures [3].

METHODS

One healthy male subject participated in this pilot study (Age 25 yr, Height 1.82 m, body mass 72 kg). A subject-specific foot orthosis (FO) was made for the subject by an experienced prosthetist using a corrected loaded footprint technique.

Two sets of EOS® bi-planar X-rays were taken of the left leg (from mid-shaft femur and distally): one with the FO in place and one using the shoes standard insole, as control (C). The subject was standing in a relaxed positioning with the right foot resting on a plastic support.

MRI of the lower extremity was obtained in a Signa HDxt 1.5T (GE healthcare, USA) scanner and a detailed foot scan was taken in a Signa HDxt 3.0T scanner (GE healthcare, USA) with a 4-channel foot coil. Bone structures were segmented from the MRI scan and the bone contours on the EOS images were drawn up with a thin line using Mimics 19 (Materialise®, Belgium).

An iterative closest point optimization program was programmed in Matlab® (Mathworks, USA) capable of reconstructing the bone positioning based on the segmented MRI bone STL files, EOS® X-ray and drawn EOS bone contour (Fig 1(A)).

Data were imported to the AnyBody modeling system (AnyBody Technology, Denmark), where coordinate systems for Tibia, calcaneus and the 1st metatarsal bones were created (Fig. 1(B)). The coordinate system for tibia was created based on ISB standards [4], the coordinate systems for calcaneus and 1st metatarsal were based on points selected on the longitudinal axis using MeshLab (CNR, Italy). Rotations of the 1st metatarsal and calcaneus

relative to tibia coordinate system were calculated in AnyBody, rotation order Z, Y and X.

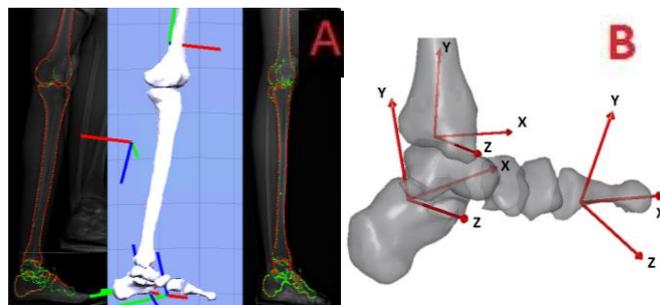


Fig. 1 (A) Reconstructed lower limb based on the EOS® scan. (B) Reconstructed foot in AnyBody modeling system with computed coordinate systems.

RESULTS AND DISCUSSION

The results show that FO seem to cause the calcaneus and 1st metatarsal bones to rotate around their own x axis. This corresponds well with the purpose of the FO, to lift the medial longitudinal ankle arch. FO bone rotation subtracted from C trial, differences are presented in table 1.

Table 1 Difference between each bone rotation between C and FO (FO subtracted from C)

| Rotation axes | Bone | |
|---------------|-----------|----------------------------|
| | Calcaneus | 1 st Metatarsal |
| X | 6.74° | 6.73° |
| Y | 7.07° | 0.24° |
| Z | 0.91° | 0.77° |

Research focusing on foot orthotics and non-surgical interventions and how they affect lower extremity jointalignment have been surprisingly overlooked [5]. This might be due to the difficulty in assessing differences based on medical imaging data. The presented method can/may be used to investigate the 3D effect of orthopedic footwear, at a very low radiation dose exposure to the subject. However further investigation is needed to confirm the above results.

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