A 3D SIMULATION TOOL TO INVESTIGATE THE EFFECTS OF ANKLE FOOT ORTHOSIS JOINT MISALIGNMENTS

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INTRODUCTION
Accurate alignment of anatomical and mechanical joint axes is one of the major biomechanical principles pertaining to articulated orthoses, yet knowledge of the potential effects of axis misalignment is limited. Congruency between axes is considered important as misalignment results in undesirable forces (both shear and compressive) and moments, generated as the joints move through their range. Such undesired forces and moments may compromise skin integrity; lead to binding, which increases resistance to joint motion and the energy required to function with the device; and increase intra-articular compressive forces and/or tension in the ankle joint ligaments.

Joint axis misalignment consists of two components: linear (anterior-posterior and proximal-distal) and angular (transverse and coronal plane) misalignments. While the consequences of linear misalignments (i.e., 2D) at the ankle joint of an ankle foot orthosis (AFO) were previously modeled,¹ there has been more limited consideration for combined angular and linear misalignments at the ankle (i.e., 3D).

Since there is natural torsion of the tibia, rotational alignment of the ankle joints and the consequences of ankle axis misalignment in 3D needs to be considered. Therefore, our objectives for this project were to develop a 3D model to explore the effects of ankle axis misalignment that can be (1) used to systematically analyze various combinations of ankle axis misalignments and their effect on motion of the device relative to the limb; and (2) compiled into a web-based executable program to be used as an educational, interactive tool.

METHOD
Using a digital model of the lower leg, a set of commonly used AFO trim lines were identified. AFO shells were created with the same internal digitized point locations as the leg and foot. Software was written to virtually relocate the AFO's mechanical axis in 3D space (i.e., to create misalignments). A graphical user interface (GUI) was developed wherein the displacements can be shown in either of two modes: (1) as physical movements of the shells with respect to the leg, and (2) as color coded displacements on the leg (e.g., warm colors indicating displacements that would compress the leg, and cool colors indicating displacements that would create gapping between the leg and orthosis).

The model is based on a number of assumptions: (1) The ideal AFO joint angle is the angle that minimizes the total potential energy of the system. (2) The AFO is rigid. (3) The AFO foot shell remains fixed relative to the foot. (4) Ankle rotations take place about a single axis through lateral and medial malleoli. (5) The AFO ankle joint is a single axis that rotates freely. (6) There is no slippage between the AFO and leg. (7) The AFO does not alter the leg’s kinematics. A linear spring model was used to represent the leg and AFO (Figure 1).

RESULTS
The completed program has been compiled into an executable file that can be uploaded to the Web for dissemination. Validation against the previous 2D model¹ was reasonable given the different modelling approaches used.

CLINICAL APPLICATIONS
Simulations can be used to develop a better understanding of real world phenomena, helping to improve clinical practice.

REFERENCES

American Academy of Orthotists & Prosthetists
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