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Characterizing the Rectification Process for Designing Scoliosis Braces: Towards Digital Brace Design

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Abstract : The use of orthotic braces for adolescent idiopathic scoliosis (AIS) patients is the most common non-surgical treatment to prevent deformity progression. The traditional method to create an orthotic brace involves casting the patient's torso to obtain a representative geometry, which is then rectified by an orthotist to the desired geometry of the brace. Recent improvements in 3D scanning technologies, rectification software, CNC, and additive manufacturing processes have given the possibility to compliment, or in some cases, replace manual methods with digital approaches. However, the rectification process remains dependent on the orthotist's skills. Therefore, the rectification process needs to be carefully characterized to ensure that braces designed through a digital workflow are as efficient as those created using a manual process. The aim of this study is to compare 3D scans of patients with AIS against 3D scans of both pre- and post-rectified casts that have been manually shaped by an orthotist. Six AIS patients were recruited from the Ragama Rehabilitation Clinic, Colombo, Sri Lanka. All patients were between 10 and 15 years old, were skeletally immature (Risser grade 0-3), and had Cobb angles between 20-45°. Seven spherical markers were placed at key anatomical locations on each patient's torso and on the pre- and post-rectified molds so that distances could be reliably measured. 3D scans were obtained of 1) the patient's torso and pelvis, 2) the patient's pre-rectification plaster mold, and 3) the patient's post-rectification plaster mold using a Structure Sensor Mark II 3D scanner (Occipital Inc., USA). 3D stick body models were created for each scan to represent the distances between anatomical landmarks. The 3D stick models were used to analyze the changes in position and orientation of the anatomical landmarks between scans using Blender open-source software. 3D Surface deviation maps represented volume differences between the scans using CloudCompare open-source software. The 3D stick body models showed changes in the position and orientation of thorax anatomical landmarks between the patient and the post-rectification scans for all patients. Anatomical landmark position and volume differences were seen between 3D scans of the patient's torsos and the pre-rectified molds. Between the pre- and post-rectified molds, material removal was consistently seen on the anterior side of the thorax and the lateral areas below the ribcage. Volume differences were seen in areas where the orthotist planned to place pressure pads (usually at the trochanter on the side to which the lumbar curve was tilted (trochanter pad), at the lumbar apical vertebra (lumbar pad), on the rib connected to the apical vertebrae at the mid-axillary line (thoracic pad), and on the ribs corresponding to the upper thoracic vertebra (axillary extension pad)). The rectification process requires the skill and experience of an orthotist; however, this study demonstrates that the brace shape, location, and volume of material removed from the pre-rectification mold can be characterized and quantified. Results from this study can be fed into software that can accelerate the brace design process and make steps towards the automated digital rectification process.

Keywords : additive manufacturing, orthotics, scoliosis brace design, sculpting software, spinal deformity
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