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Obtaining Patient Torso Geometry for the Design of Scoliosis Braces. A Study of the Accuracy and Repeatability of Handheld 3D Scanners

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Abstract

Objective: Obtaining patient geometry is crucial in scoliosis brace design for patients with adolescent idiopathic scoliosis. Advances in 3D scanning technologies provide the opportunity to obtain patient geometries quickly with fewer resources during the design process compared with the plaster-cast method. This study assesses the accuracy and repeatability of such technologies for this application.

Methods: The accuracy and repeatability of three different handheld scanners and phone-photogrammetry was assessed using different mesh generation software. Twenty-four scans of a single subject's torso were analyzed for accuracy and repeatability based on anatomical landmark distances and surface deviation maps.

Results: Mark II and Structure ST01 scanners showed maximum mean surface deviations of 1.74 ± 3.63 mm and 1.64 ± 3.06 mm, respectively. Deviations were lower for the Peel 1 scanner (maximum of −0.35 ± 2.8 mm) but higher with the use of phone-photogrammetry (maximum of −5.1 ± 4.8 mm). The mean absolute errors of anatomical landmark distance measurements from torso meshes obtained with the Peel 1, Mark II, and ST01 scanners were all within 9.3 mm (3.6%), whereas phone-photogrammetry errors were as high as 18 mm (7%).

Conclusions: Low-cost Mark II and ST01 scanners are recommended for obtaining torso geometries because of their accuracy and repeatability. Subject's breathing/movement affects the resultant geometry around the abdominal and anterolateral regions.

Keywords

3D scanner, scan accuracy, torso geometry, scoliosis brace, adolescent idiopathic scoliosis

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Introduction

Adolescent idiopathic scoliosis (AIS) affects approximately 2.5% of the population.[1,2] Conservative treatment is initially recommended with surgery being considered for patients presenting severe deformities.[3,4] Conservative treatments aim either to correct the deformity or to stop curvature progression, thus avoiding surgical intervention, bringing both patient and economic benefits.[5,6] Conservative treatments include bracing, electrostimulation, and physiotherapy.[5,7] A randomized controlled trial conducted by Weinstein et al[8] demonstrated the effectiveness of wearing a brace to reduce AIS progression, confirming this as the treatment of choice for the conservative management of AIS.[9] Although this supports the use of bracing, less is known about the optimal design and geometry for these braces.

Most scoliosis braces are customized for each patient, and therefore, the torso geometry needs to be obtained during the design process. Most commonly, a plaster-cast method is used to replicate the patient's geometry, creating a positive mold that is manually rectified into a geometry that the orthotist believes will prevent deformity progression. The brace material is then molded and trimmed accordingly to create a custom brace. The design process is heavily reliant on the skills and expertise of the orthotist, requiring significant time and resources.

Previous studies have used computer-aided design approaches as an alternative to the plaster-cast method showing benefits regarding in-brace correction and treatment success in patients with AIS.[10,11] This method involves scanning the patient's body surface, a technique that has been assessed for use in clinical applications on hand orthoses,[12] the assessment of the human foot,[13] and prosthetic socket design.[14] Nevertheless, these studies have focused on other body parts, and therefore their accuracy results are not transferable to the torso geometry. Surface topography and 3D scanners have been used in patients for the assessment of torso asymmetry[15,16] and for the analysis of scoliosis progression as alternative noninvasive methods to x-ray examinations.[17] The reliability of torso measurements from 3D scans using surface topography has been previously studied[18]; however, the applied 3D scanning and reconstruction technologies were used to assess the torso shape, and the accuracy of the systems was not reported. The accuracy of different 3D surface scanners for the assessment of spinal deformity was studied by Grant et al,[19] but the analysis involved scanning an object that replicated patient anatomy and spinal curvature (a torso plaster casts) rather than direct scanning of patients. Thus, a greater understanding is needed regarding the accuracy and repeatability of 3D scanners to scan a patient's torso and locate anatomical

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