Towards Better Control of Clubfoot Correction

+1Cohen, T I; 2Smith, P; 3Altiek, H; 4Harris, G F
+1OREC, Milwaukee, WI, 2Department of Biomedical Engineering, Marquette University, Milwaukee, WI, 3Shriners Hospital for Children, Chicago, IL
tamara.cohen@marquette.edu

ABSTRACT INTRODUCTION:
Clubfoot is a congenital deformity affecting the development of the lower extremity. It is characterized by an equinus varus deformity of the hindfoot, as well as cavus and adduction of the midfoot [1]. Treatments to correct foot positioning in clubfoot are typically performed during the first year of life and include surgical and conservative options. The Ponseti method is a conservative procedure, which involves a series of manipulations and castings followed by brace application, and often a percutaneous Achilles tenotomy.

Although studies have qualitatively examined casts used in the Ponseti method, the appropriate casting material has not been identified based on mechanical properties. Investigations of pressure response on different cast materials concluded that these materials do exhibit a viscoelastic behavior [2]. Results from previous studies have indicated the potential success of the Ponseti method with the use of other cast materials [3]. Material selection could affect not only the comfort level of the patient but also the efficacy of the technique [4].

Three common cast materials utilized in orthopaedics are plaster of Paris, fiberglass, and Softcast (semi-rigid fiberglass). The purpose of this study is to quantitatively compare the three cast materials used in conjunction with the Ponseti method to aid in identifying a more appropriate material for treatment.

METHODS:
Device design and testing

A dynamic device of PVC tubing and a single axis hinge was built to model pediatric clubfoot correction using the Ponseti method (Figure 1). A constant torque (low or high) was applied to the system utilizing a pulley and weight system to simulate the joint stiffness. The torque values, equal to 3.86 and 6.62 inches, were the minimum and maximum values required to supinate and abduct a clubfoot correction training model (MD Orthopaedics; Wayland, IA).

While in static position, the device was weighted and a single layer of padding was wrapped about the entire apparatus according to standard casting practices. The device was casted by a trained investigator with each material based on the Ponseti method [5]. Time was marked at the initiation of casting to monitor the setting time and data acquisition intervals. Four layers of wetted cast material was wrapped and molded to the device using standard casting application and manufacturers’ recommendations. The materials tested include plaster of Paris, BSN Medical; Charlotte, NC), fiberglass (3M™; Parsippany, NJ), and Softcast (3M™; Parsippany, NJ), a semi-rigid fiberglass material.

A triad of 7-mm diameter IRED markers was placed at each end of the model, and the 3D motion was recorded with an Optotrak Certus Measurement System camera (Northern Digital Inc., Ontario, Canada). Five trials were completed per cast material per torque for a total of thirty trials for this study. Restriction of movement was removed from the distal segment at the end of the setting time. Data acquisition began four minutes after the start of cast application, for a period of ten minutes at a sampling frequency of 1 Hz. Two more ten minute intervals were collected beginning at eighteen minutes and sixty minutes into the trial.

Analysis
The motion data from each trial, stored in the NDI Optotrak software package, were analyzed in Matlab 2008a (MathWorks, Natick, MA) to compute Euler angles and translation throughout testing. The Euler angle sequence, Z-Y-X, was used to describe the joint movement of the patient but also the efficacy of the technique [4]. Treatments were completed per cast material per torque for a total of thirty trials for this study. Restriction of movement was removed from the distal segment at the end of the setting time. Data acquisition began four minutes after the start of cast application, for a period of ten minutes at a sampling frequency of 1 Hz. Two more ten minute intervals were collected beginning at eighteen minutes and sixty minutes into the trial.

RESULTS SECTION:
The greatest as change total rotations occurred about the z-axis for plaster of Paris, which was equal to 2.08 degrees (+/- 0.36 degrees) under minimum torque and 1.95 degrees (+/- 0.35 degrees) under maximum torque (Figure 2). The smallest mean total rotations about the z-axis occurred during the fiberglass trials, which equal 0.34 degrees (+/- 0.20 degrees) under minimum torque and 0.54 degrees (+/- 0.19 degrees) under maximum torque. The mean total rotations about the z-axis for Softcast were found to be 0.85 degrees (+/- 0.26 degrees) and 0.84 degrees (+/- 0.28 degrees) under minimum and maximum torques, respectively. Comparing the rotations across cast materials, the values were found to be significantly different (p << 0.05). Across the toes, these values were not found to be significantly different.

The average rotational displacement about the z-axis was calculated per interval. The greatest degree of rotation was found to be during the first ten minute interval of testing (Table 1). These rotations were found to be significantly different between cast materials, as well as from the change is angular rotation of the later intervals (p << 0.05).

DISCUSSION:
The results presented in this study represent the kinematics for the comparison of three common cast materials used in conservative correction of clubfoot. The findings indicate that rigidity of cast material increases in the following order: plaster of Paris, Softcast, fiberglass. This differs slightly from the pressure-volume study conducted by Deshpande, as that study showed the Softcast to be more compliant [2]. Discrepancy could be attributed to a complex combination of motion, padding, and/or multilayering effect. However, material dependency could advocate the use of Softcast in the technique, as does Brewster and Pinner [3, 4].

Another finding from this study is the maximum displacement gradient which occurs in the first interval of time after setting, and accounts for over 65% of the total angular displacement. Relevant outcomes of this work include: 1) the motion dependence on cast material type and 2) independence from the applied torque. This indicates that severity of clubfoot deformity will not alter the inherent cast material creep response.

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REFERENCES: