ABSTRACT
BIOMECHANICAL MODELING OF CLUBFOOT

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Congenital talipes equinovarus, or clubfoot, affects approximately 200,000 newborns worldwide each year and presents with equinovarus of the hindfoot, as well as cavus and adduction of the midfoot. In addition to bone malformation and displacement, soft tissue contractures encapsulate the medial and posterior aspects of the affected foot. The Ponseti method is a conservative treatment that progressively repositions the clubfoot through weekly casting, followed by bracing. Concerns exist regarding the variability in outcomes, resistance to treatment, and risk of relapse, which occur in approximately 10% of the population. Potential factors contributing to variability and resistant clubfoot include cast material performance, as well as biomechanics of medial soft tissue of the clubfoot. There are no clinical guidelines for clubfoot correction based upon mechanical response of commonly used casting materials, nor the mechanics of the medial fibrotic clubfoot tissue. Untreated or under-corrected clubfoot can result in abnormal gait, pain, and further foot deformity.

The purpose of this research was to investigate the biomechanics of conservative clubfoot correction through: i) a kinematic assessment of the creep behavior of three common cast materials used during conservative correction, ii) development and validation of a benchtop system for the mechanical evaluation of miniature soft tissue specimens, and iii) performing a mechanical analysis to model the behavior of medial fibrotic mass tissue (MFMT) from children with clubfoot.

Utilizing a model to simulate clubfoot correction, rotational creep was found to be minimal, though dependent on cast material. Reducing cast creep may result in a more efficient correction. Utilizing nylon monofilament, the benchtop system was validated against a commercial system (MTS). Versatility was demonstrated with quasistatic and viscoelastic protocols performed on PTFE tape and rabbit ligament, respectively. Clubfoot MFMT underwent a quasistatic and viscoelastic protocol, including cyclic loading and stress relaxation. Major findings include a decrease in hysteresis area during cyclic loading and viscoelastic models describing the stress relaxation behavior of 16 specimens. Results from this research provide mechanical insight into the correction process that may lead to individualized, evidence-based clubfoot care. Future directions include in vivo analysis of tissue properties and mechanical-genetic correlation.