

A GEOMETRY SENSITIVITY IN FINITE ELEMENT MODELS OF LONG BONES IN OSTEOGENESIS IMPERFECTA

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ABSTRACT

Osteogenesis imperfecta (OI) is a genetic disorder characterized by increased bone fragility and decreased bone mass, leading to high long bone fracture rates. Researchers are developing finite element (FE) models and analysis tools for quantitative assessment of long bone fracture risk in OI. FE techniques discretize OI long bones into small elements for assessment of the structural responses to applied loads. FE models can be applied to assess patient-specific fracture risk during various activities. This approach may help clinicians prescribe or modify activities and may assist in surgical planning to reduce spontaneous fracture risk. FE models of the femur and tibia in children with OI either fully or partially rely on shape-matching and geometrical alterations of a standard three-dimensional (3D) model of a normal bone. Geometry modification and matching to planar images provides good results in mild to moderate OI, but the lack of patient-specific 3D geometry for more severe OI types has not been assessed. The goal of this study was to evaluate the effects of patient-specific geometry (CT) and shape-matched geometry from x-rays of femoral diaphysis FE models for a patient with severe OI. Maximum principal stress magnitude and locus were compared between the two models. The maximum principal stress in the patient-specific geometry model was 30% higher than the shape-matched geometry model and locations differed between models. Thus, shape-matched geometries likely underestimate stress responses in severe OI long bones. Future work will examine the use of magnetic resonance imaging (MRI) to obtain patient-specific long bone geometry for FE models of children with severe OI.

Keywords: finite element, bone, fracture, fracture risk, osteogenesis imperfecta

INTRODUCTION

Osteogenesis imperfecta (OI) is a genetic disorder characterized by increased bone fragility and decreased bone mass, which leads to high rates of long bone fractures. About 90% of persons with OI have a mutation in the genes that code for collagen type I – the major protein of bone [1]. It is estimated that OI affects between 20,000 and 50,000 people in the United States [2]. At least 15 types of OI have been documented to date, with type I being the mildest form, type IV being a moderate form and type III being the most severe form that is compatible with life [3]. Severe OI (type III) is orthopaedically characterized by osteopenia, frequent fracture, progressive deformity, loss of mobility and chronic bone pain. Persons with severe OI often experience fractures during activities of daily living throughout their lifetime. The majority of long bone fractures in OI occur in the diaphyseal region of the bone [4]. This is likely due in part to the reduced cross-sectional area from the thin cortices that are characteristic of long bones in OI.

Understanding the biomechanics of bones in persons with OI is a key component to advancing knowledge about the disease, optimizing treatment and quality of life, and reducing/preventing injury. However, it is often not feasible to study bone biomechanics *in vivo*. Thus, modeling has the potential to play a key role in understanding how OI bones respond to loading experienced during various activities, especially ambulation. Biomechanical modeling can provide insight into bone fracture risks, such as type