The development of finite element models for analysis on biomechanical performance of hallux valgus foot in gait

The human foot is a complicated structure consisting of 28 bones and numerous muscles, ligaments, and other connective tissues. Currently, the evaluation on the functional role of different anatomical components regarding to load bearing merely depends on generalized plantar distribution. The states of internal stress/strain remain insufficiently addressed due to the difficulties and limitations of the conventional experimental approach. Alternatively, finite element (FE) method is capable of modelling structures with irregular geometry and complex material properties, and varying boundary and loading conditions. As the deformities of the complex foot structures increase the challenge in the modelling process, few studies concern FE models of a deformed foot so far.

Hallux valgus (HV) is one of the most common foot deformities with the high prevalence of 23% in adult and 35.7% in elderly population. The increasing HV severity often induces foot discomfort, additionally, more and more elderly people complain instability and risk of falling during walking. The first objective of this project is to enhance the FE method in development of foot models and develop FE models of a normal foot (as control), a mild HV foot and a severe HV foot to take insight into the substantial variations in the biomechanical behaviour of the HV feet in gait. The second objective is to investigate the effects of HV degree on the foot biomechanics in gait.

Three-dimensional finite element (FE) model consisting of 28 bony segments, 103 ligaments, plantar fascia, major muscle groups, and the bulk of encapsulated soft tissue for each foot (normal; mild HV; severe HV) will be developed. The geometries of the bones and the soft tissue will be reconstructed from medical images in MIMICS 17.0. All solid parts including bones, ligaments, cartilages and the plate will be meshed into hexahedral elements. The tibia inclination and loading profiles derived from gait analysis will be applied to each FE model for simulating the stance phase of gait. Gait experiments will be performed using a three-dimensional motion analysis system and a force platform. All FE analysis will be conducted in the FE package ANSYS 17.0. Parameters including internal stress distribution on bones, the angular displacement and contact pressure of transverse tarsal joints and metatarsophalangeal joints, the force transfer between hind-, mid- and fore-foot segments, and the displacement of the first ray will be predicted.

It is of high significance to take insight into the biomechanical behaviour of HV foot which is an increasingly prevalent foot deformity, particularly in the elderly population. Using FE method to develop numerical models of the deformed feet is an important step in the investigation of foot biomechanics during locomotion. This project will establish an enhanced approach to predicting injury risk and evaluating biomechanical function efficiency of HV deformed foot. Also, knowledge of this project could improve the understanding of the underlying mechanisms of structural mechanical problems and abnormal gait pattern of HV feet.