A FINITE ELEMENT MODEL ANALYSIS ON THE MECHANICAL BEHAVIOR OF THE CARPAL BONES UNDER TWO PHYSIOLOGICAL LOADING CONDICTIONS

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Introduction

The wrist is a complex joint that bridges the hand and the forearm. It is one of the most critical joints on the biomechanical point of view due to its collection of multiple bones and joints. Its main function is to position and orient the hand in space, but also to transmit strength between the forearm and the hand. The load transmission often leads to injuries in the carpal bones and their supporting joints and ligaments [Carrigan, 2003].

The aim of this work was to create an anatomically accurate three-dimensional finite element model of the wrist. Therefore, a model, incorporating the bones, cartilages and ligaments tissues of the carpal structure, was developed. The finite element method was used to perform the biomechanical analysis on the carpal bones under two physiological loading conditions.

Methods

The three-dimensional model of the wrist was constructed from images of a computerized tomography (CT) of a volunteer without any evidence of pathology. The CT images provide the true geometry of the bones' structures and the different bone densities, allowing to currently define the mechanical properties.

A set of links were modeled to simulate the cartilage and ligament structure, regarding its insertion in the bones and their stiffness[Carrigan, 2003; Manal, 2002]. The physiological loading condition used were representative of a maximum and minimum gripping action, and the forces were applied on the metacarpal [Gíslason,2010; Schuind, 1995]. The load cases applied were used to access the principal strains in the carpal bones.

Results

The principal strains (maximum and minimum) results for the carpal bones, in the frontal and sagittal aspects, were calculated.

Regarding the minimal and maximal principal strains values, for frontal aspect, the difference observed between the minimum and maximum gripping load cases, were approximately 5000μstrain,

Concerning minimal and maximal principal strains values, for sagittal aspect, the difference observed between the minimum and maximum gripping load cases, were on average an order of magnitude higher.

In both load cases the bones most mechanically requested were the lunate, the hamate and the capitate. The lunate suffered a greater deformation in the proximal zone, the zone in which it articulates with the radius and the ulna. The capitate and hamate suffered a greater deformation in the distal zone. The capitate in the area where it articulates with the metacarpal 3, and the hamate in the area that articulates with metacarpals 4 and 5.

And the bone which was less mechanically requested, was the trapezio.

Discussion

The numerical results show that the carpal bones suffer higher values of deformation in the joints where they interacted with the bones of the hand and forearm (carpometacarpal and radiocarpal joints, respectively), than where they interact with each other (midcarpal joint).

References

Carrigan *et al*, Ann Biomed Eng, 31:718-725, 2003.
Gíslason *et al*, Med Eng Phys, 32:523-531,2010.
Manal *et al*, J Biomech, 35:125-133, 2002.
Schuind *et al*, J Biomech, 28:587-601, 1995.

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