PATIENT-SPECIFIC MODELLING OF THE TRAPEZIOMETACARPAL JOINT LIGAMENTS

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Introduction

The trapeziometacarpal (TMC) joint is the hand joint most affected by osteoarthritis (OA). Surgical treatments, such as arthroplasty, ligament reconstruction or trapezectomy, are sometimes required to treat pain or functional limitations induced by this pathology. Unfortunately, these surgical approaches sometimes lead to some complications like implant dislocation or thumb deformation [1]. Although multifactorial, these complications are associated to the intensity and nature of mechanical loads applied on the joints. Computational modelling is an alternative to understand these internal loadings and improve the surgical treatments. Nevertheless, current computational models of the TMC joint rarely include patient specificity, especially ligaments' mechanical properties which differs importantly according to the patient [2]. Nonetheless, patient-specific modelling of the TMC joint ligaments is necessary to improve surgery benefits, given that the ligaments' importance in the TMC joint stability. The objective of this study was thus to create patient-specific finite element models of the TMC joint ligaments, based on in vivo experimental data.

Methods

A finite element model of the TMC joint bones and ligaments was developed in FEBio [3]. The bones' model was generated by segmentation from a patient's CT scan. The three-dimensional ligaments' geometry was created based on previous literature on ligaments' length, width and thickness and attachment area measured on cadaveric specimens [4]. The ligaments modeled in this study were the five main ligaments identified on previous cadaveric studies, namely: the dorso radial ligament, the anterior oblique ligament, the posterior oblique ligament, the intermetacarpal ligament and the ulnar collateral ligament. The bones were modeled as rigid bodies and the ligaments were modeled with linear elastic isotropic material property. Ligaments' extremities were tied to their attachment areas. TMC joint of 15 participants were tested with a test bench, to determine the individual force displacement data. Force-displacement of the participants' TMC joint in flexion, extension, abduction and adduction were measured by force sensor and kinematic markers placed on the thumb. Patient-specific ligament Young modulus were calculated by matching computer predictions to force displacement data experimentally measured, by using the FEBio optimization module (Fig.1).

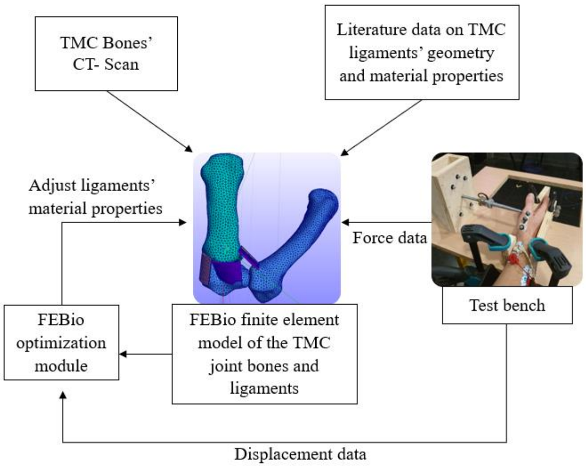

Figure 1: Schematic of the methodology used to personalize the computational model of the TMC joints ligaments.

Results

Our computational model reveals important variations of the TMC joint ligament young modulus according to the patient. Important variations of ligament young modulus between the different tests (flexion, extension, abduction and adduction) were also observed within the same patient (more than 50 %).

Discussion

Our study proposes a new non-invasive method to individualize computational finite element models of the TMC joint ligaments. Even if some limitations could be considered, this study provides a non-invasive methodology to personalize computational models of the TMC joint with the aim of improving the patient treatments.

References

1. Mathias Rouveyrol et al, Hand Surgery and Rehabilitation, 40(4):464-471, September 2021.
2. Priscilla D'Agostino et al, The Journal of Hand Surgery, 39(6):1098-1107, June 2014.
3. Steve Maas et al, Journal of Biomechanical Engineering, 134(1):11005-NaN, January 2012.
4. Mitsuhiko Nanno et al, The Journal of Hand Surgery, 31(7):1160-1170, September 2006.