Deformable Finger Model for Post Procedural Analysis of Finger Flexion Device

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INTRODUCTION

The project intends to create a virtual finger capable of producing realistic deformations when forces are excerted upon it by the a virtual representation of an external flexion fixator device (FFD). The device is based upon designs for a new external fixator device developed to aid patients with untraumatic finger flexion disorders [1].

Pins attached to the device are inserted into the patient's bone, then screws of the device are turned by small increments to force the finger from a flexed position to a more natural, erect one over several months. The effectiveness of this treatment can depend on the intial placement of the pins, as incorrect pin locations can cause hazardous force distribution and even damage to the finger. A virtual model will help identify appropriate locations for pin insertion by predicting the surgical outcome for pin locations set by the user.

METHODS

Biomechanical information has been gathered on various tissue structures in the finger central to the flexion action. Tissue such as skin, nerves and subcutaneous fats will not be modeled as they do not contribute to flexion motion and as such are not the primary focus of the forces from the FFD.

The virtual model will consist of the following elements:
Bones – Metacarpal (fixed point) and proximal, medial and distal phalanges
Ligaments – Ligament Bands holding tendons in place and Collateral ligaments connecting finger bones together, particularly the Volar Plate
Tendons – Extensor and Flexor Tendon Networks
Muscles – Intrinsic and Interossei to be at least partially modeled alongside the Metacarpal bones and attached to Tendon Networks

These structures will be modeled in a visually simplistic form to save on computation power as producing an anatomic model is not the goal of this project. However, their mechanical properties must be as close as possible to living tissues in order for the model to have any bearing on a realistic pre/post procedural representation of a treated finger.

Some structure material types are harder to find than others and in these cases alternative figures are considered. There are many more works on leg tendons biological properties than finger tendons, and since the structure of these materials are the same work can be carried out to find a way of scaling results from leg tendons so they are suitable for use in the finger model.

DISCUSSION

A major difficulty in a project such as this is the variance found not only between different patients but even the same patients at different times of the day [2]. Factors such as hydration levels and recent physical activity bear some effect on the mechanical properties of tendons and muscles. As such, a generalised set of mechanical properties will be produced for the biological materials in this project. The tissues will initially be modeled as having uniform mechanical properties for each internal tissue structure, although this is different to the reality.

Another difficulty has arisen in finding the correct details for the connective points between two types of biological tissue [3]. The model will need accurate connective properties at sites where tissue such as bone and tendon connect as these will be the focus of major strains exerted by the FFD. Only invitro datasets from cadavers exist for such areas, and these studies do not focus on fingers.

The proposed model's adaptability is questionable and work should also be undertaken on a suitable graphical user interface so that the program can be easily initialised without large adjustments to the base level program structure. This will make the model accessible to a wider range of potential users as less special training would be required.

CONCLUSIONS

The task presented is ambitious and is likely to come across problems as it develops. The planned model is trying to be as general as possible, but at the same time it will be inherently complex due to the subject matter's nature.

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