A VIRTUAL TOOL FOR THE CLINICAL PLANNING OF THE ULNAR PALSY TREATMENT

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INTRODUCTION

Mechanical efficiency of the hand can be reduced because of different pathologies. One of these pathologies is ulnar palsy. Ulnar palsy is common in Hansen's disease patients. *Mycobactrium leprae* bacteria attack the ulnar nerve at the elbow level, which reduces the motor capability of the intrinsic muscles of the hand. This paralysis results in the *claw hand* deformity. It occurs because of the loss of the balance between the intrinsic and extrinsic muscles that power the hand [1].

Mathematical models of the finger have been used in the past to study different aspects of hand function. In this work, the use of a 3D model of the index finger for the clinical planning of the ulnar palsy treatment is investigated.

METHODS

A biomechanical model of the finger previously developed by the researchers [2] was used to simulate the ulnar palsy and a tendon transfer for the restoration of the hand function.

The biomechanical model considered the finger as a skeletal open chain of 4 rigid bodies (the bones) connected to the carpus through different joints that characterize the kinematic behavior of the chain. The DIP and PIP joints were modeled as 1 degree of freedom joints capable of flexion-extension movements, while MCP joint is modeled as a 2 degree of freedom joint capable of flexion-extension and abduction-adduction movements with respect to a fixed metacarpal bone. The data for the location and orientation of the rotation axes came from An et al [3] and Brand and Hollister [1]. Muscles, tendons and ligaments control the movement of the chains. A total of 7 muscles (FP, FS, LU, DI, VI, EC and EI) were considered using a Hill's 3 component model that takes into account the muscle activation level and the force-length and force-velocity relationships, as well as the different index of architecture of muscles. Muscles transmit force to the tendons, which finally insert into the bones. To model the effect of tendons crossing the joints, straight lines connecting 2 points were considered, except for the extensors, for which Landsmeer's model I was used. Appropriate force balances were considered in the connecting points of this deformable tendon net, where tendon excursions were calculated by combining the excursions at each joint according to the tendon net configuration. Because tendons were assumed inextensible, tendon excursion defined the change in muscle length. Tendon paths came from the literature [3]. The collateral ligaments of the MCP joint were modeled as non-linear elastic elements.

First, the model was used to simulate the ulnar palsy. The paralysis of the ulnar nerve was modeled by reducing the PCSA of the intrinsic muscles (DI, VI and LU) proportionally to the severity of the palsy. With this model, a search for feasible postures of the finger with ulnar palsy was performed. Moreover, the grasp capabilities of the normal and injured finger were compared for two different grasps (Table 1).

Table 1: Postures defining the grasps that have been analyzed.

Grasps	MCP flex	MCP abd	PIP flex	DIP flex
Wide	60º	0º	60º	45º
Narrow	30º	0º	45º	45º

Second, the model was used to simulate the tendon transfer of the PL muscle to restore hand function. This transfer was modeled by introducing the transferred tendon path in the model, which affected the MCP flexion-extension and abduction-adduction balances. With this model, a new search for feasible postures of the restored finger was performed, as well as the evaluation of grasp capability achieved after the restoration.

RESULTS AND DISCUSSION

From the search for feasible postures performed with the ulnar palsy model, only feasible postures were found for a combination of MCP flexion angles smaller than 20º and PIP flexion angles greater than 90º, i.e. the model predicts that only clawing postures are possible when an ulnar injury occurs. On the other hand, the model predicted a greater reduction of the grasp capability for an 80% injured hand for wide grasp (81%), than for narrow grasp (51%), which agrees with literature [1]. Both results validate the model.

The model for the restored finger predicted feasible non-clawing postures, in contrast with the results of the injured finger model. On the other hand, the restored finger model predicted a 73% improvement of grasp capability for wide grasp and a 38% improvement for narrow grasp.

CONCLUSIONS

Biomechanical models of the hand could be used as virtual tools to investigate the consequences of pathologies such as ulnar palsy and to check the advantages and disadvantages of the different clinical techniques that could be used to restore hand function.

REFERENCES

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