Artificial Network Implants for Tendon-Transfer Surgeries

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OPENSIM SIMULATION
OpenSim, a freely available musculoskeletal modeling software, was used to examine the effects of changing implant stiffness on differential action and applied fingertip force on a single triangle from the proposed network.

SOLIDWORKS SIMULATION
SolidWorks simulation was used to model device mechanical behavior using FDA approved materials in the rod model to aid in the optimization.

• Modeled with three different materials: PVDF, 80A Polyurethane, and 60A Polyurethane at four (4) different applied forces.

HISTORY OF TENDON TRANSFER
Sutures have been standard for connecting tissues in surgery for thousands of years. But in orthopedic surgery, the suture cannot scale or distribute a muscle’s forces and movement across one or more tendons.

A NEW APPROACH
A novel design is being developed by Dr. Ravi Balasubramanian’s MIME lab involving a network of artificial triangles that allow for differential action and increased range of movement of the fingers.

GOALS
• Develop simulation methods to test various materials for design construction
• Develop and optimize mechanical designs for use in the tendon transfer network

Fig. 1: Traditional solution for High median ulnar nerve palsy patients, where tendons are transferred from the flexor digitorum profundus (FDP) to the extensor carpi radialis longus (ECRL) muscle.

Fig. 2: Left: Original proposed design solution for tendon transfer surgeries. Right: Differential action in the tendon network system provided by a triangle

Fig. 3: Two models were used in OpenSim. Left: A stiff element lever separating the tendons. Right: An anchor attached to the bone below the tendons.

Fig. 4: An increase in implant stiffness results in an increased amount of applied fingertip force and a decreased range of differential action.

Fig. 5: Rod model with curved ends to better hold routed tendons in place. A hole in the middle allows for sutures to be threaded through the rod allowing more secure attachment of tendons to the network.

Fig. 6: Displacement of rod ends as a function of increasing forces for fixed dimensions.

Fig. 7: Evolution of tendon network system Network Design. Far left: Original design consisting of three triangle network intended to have biological tendon sutured to artificial network. Middle: Secondary design using “free” triangle that biological tendons are routed around. Far Right: Third generation design with rods between tendons, intended to serve same purpose as triangles, with less material surface area.

Fig. 8: Differential action in the tendon network system provided by rod design

FUTURE WORK
• Optimization of device size for greatest fingertip force and movement differential
• Development of commercialization strategy including customer metrics

KEY RESULTS
• PVDF shows the least deformation for the widest range of forces
• Increasing implant stiffness results in increased available fingertip force and decreased differential action

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REFERENCES