Optimizing Cable-Driven Assistive Glove Design to Help Open Post-Stroke Paretic Hand

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Profound weakness of the extensor muscles of the fingers in combination with excessive involuntary coactivation of the extrinsic flexors severely limits hand function in many stroke survivors. Providing extension assistance can improve hand motor control. Cables traversing the back of the hand offer a means for generating assistive extension forces while minimizing the mass and bulk that must be added to the hand (Fischer et al. 2007). The routing of these cables, however, can impact comfort and performance. Yet, these pathways have not been studied in detail. This study compared 5 different cable configurations (Figure 1) to determine which configuration could achieve the desired finger extension while minimizing force needed for finger flexion and the resulting stress on the skin or joint, which may cause discomfort/pain.

A sagittal-plane biomechanical model of a paretic finger actuated by a cable with constant tension was developed. Finger segment lengths, masses and moments of inertia were obtained from the literature. Joint stiffness/damping coefficients for stroke survivors were estimated from published values. The cable configurations compared were the current design and four base shapes in linear, sinusoidal, parabolic and cubic Bezier function. For each of the four base shapes, the optimal trajectory was determined using sequential quadratic programming optimization (Figure 1b-e), subject to the constraint that the resting finger posture be sufficiently extended to perform a cylindrical grasp with joint angles less than or equal to MCP 7.5°, PIP 18°, DIP 22.5°. The objective function was to minimize the sum of: (i) force required to close the finger against the assistive glove as normalized by the grip strength, (ii) pressure on the skin and (iii) joint compressive force.

Among the five shapes, the cubic Bezier trajectory was found to achieve the sufficient finger opening with the least overall extra effort/discomfort/pain (33% less closing effort than in the currently employed cable routing, 52% less skin pressure, while 33% increased joint compression force, compared with the current design). This study demonstrates the ability of biomechanical modeling and optimization to substantially improve mechanical design of assistive devices for better performance and comfort.

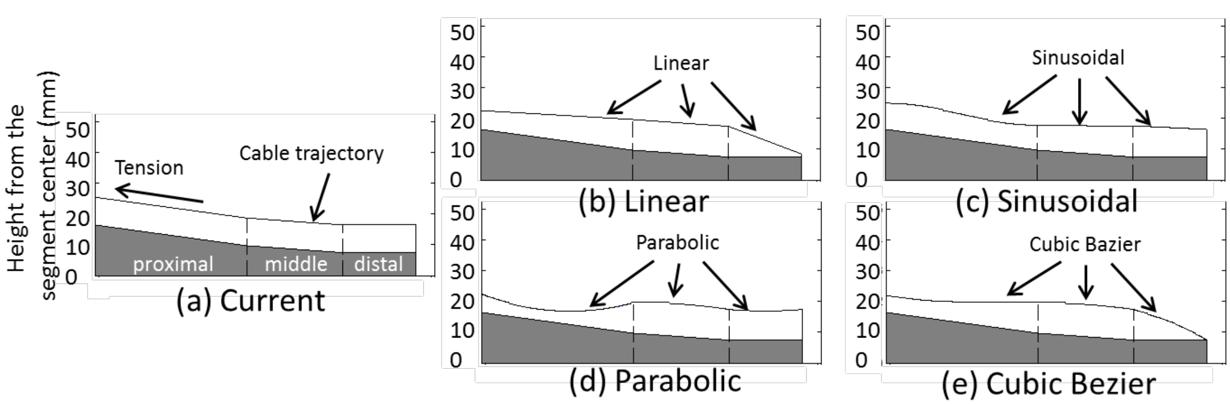

Fig. 1. Illustration of the cable trajectories over each finger segment (in grey) for the current cable-driven assistive glove (a) and the optimal designs found for each base shape function (b-e).

[1] Heidi Fischer, Kathy Stubblefield, Tiffany Kline, Xun Luo, Robert Kenyon, and Derek Kamper, Hand Rehabilitation Following Stroke: A Pilot Study of Assisted Finger Extension Training, Topics in Stroke Rehabilitation, 14(1), p1-12, 2007

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