OPTIMIZING CABLE-DRIVEN ASSISTIVE GLOVE DESIGN TO HELP OPEN POST-STROKE PARETIC HAND

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MOTIVATION

- Hemiparetic stroke survivors have difficulty in performing daily tasks such as picking up and releasing objects due to severe impairment in finger extension [1,2].
- Many stroke survivors can close the fingers, but cannot voluntarily extend the fingers.
- A cable-driven assistive glove intends to help extend stroke survivors' fingers [3]. However, the current glove applies suboptimal moments and compressive forces across the finger joints, causing unnatural finger opening trajectory and pain.

Fig 1. The current cable-driven assistive glove has the cable running parallel to the dorsal finger (i.e., constant cable support heights throughout the length of the finger) [3].

OBJECTIVES

- To optimize the cable support design for applications of proper joint opening torque across the three finger joints, while minimizing joint compressive force and pressure on the skin/soft tissue.

METHODS

Modeling of the index finger and glove

Assumptions

- Confined in 2D (sagittal plane)
- The center of mass of each phalanx is at the mid point
- Constant cable tension
- No friction between the cable supports
- Two adjacent supports have the same height

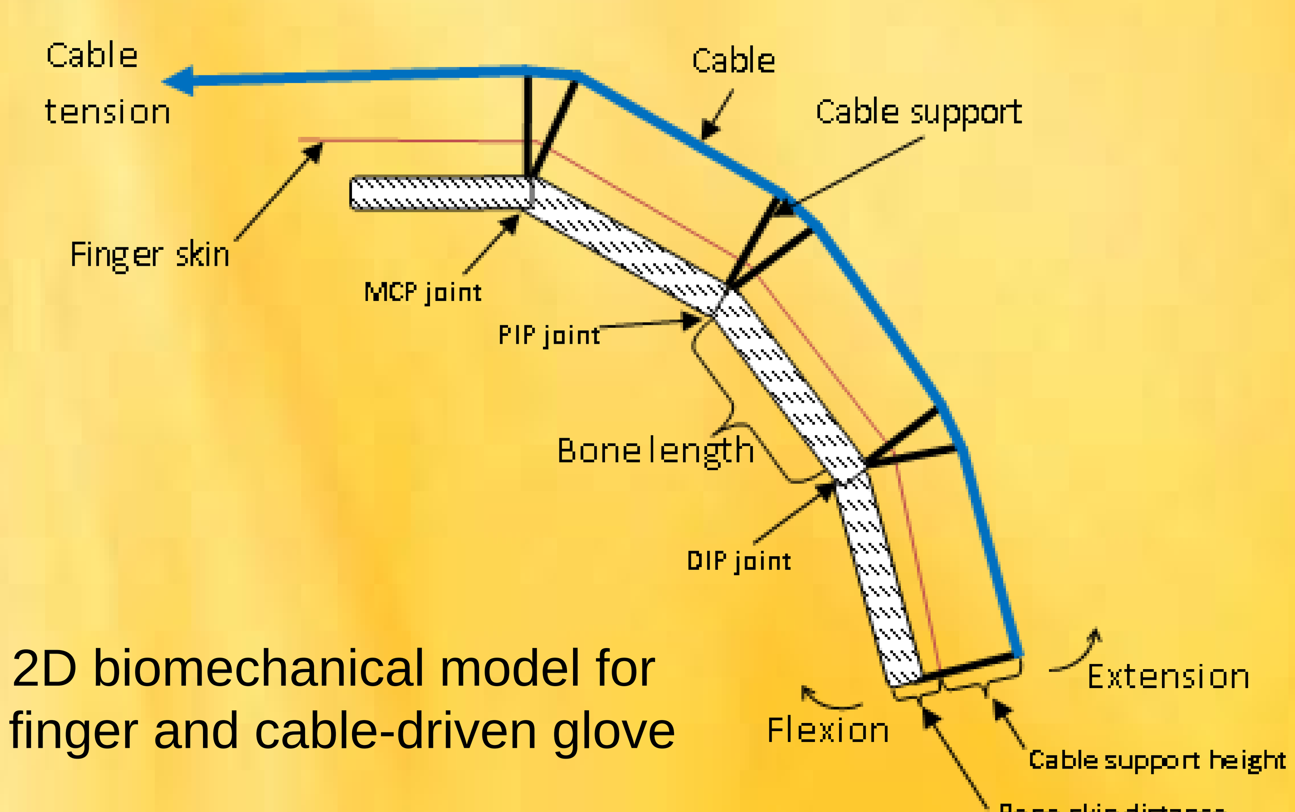

Fig 2. 2D biomechanical model for Index finger and cable-driven glove

Mechanical properties of the index finger

Table 1. Mechanical properties of the index finger

	DIP	PIP	MCP
Joint Stiffness (Nm/rad) [4]	0.27	0.49	0.63
Joint Damping (Nms/rad) [5]	0.008	0.011	0.014

	Distal Phalanx	Middle Phalanx	Proximal Phalanx
Length (mm) [5]	24	31	49
Mass (g) [5]	3.8	6.3	19.6
Moment of Inertia (g mm^2) [5]	200	580	4540

Interaction between the cable and support

- Curved supports have force interaction with the cable on the curved surface
- The interaction may have benefits in generating moments
- The interaction may cause additional pressure on the finger skin

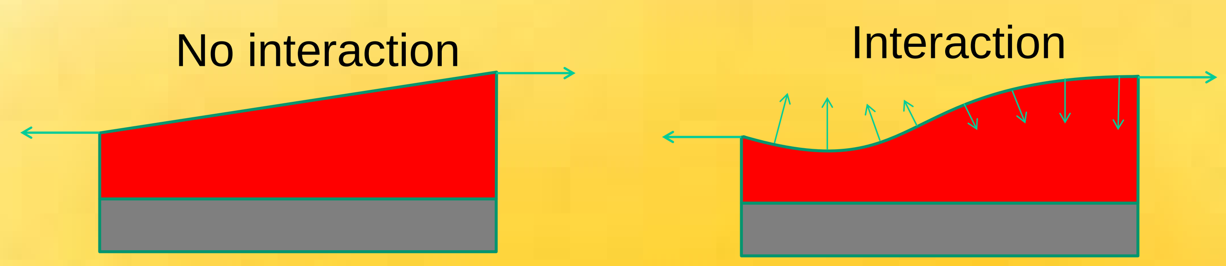

Fig 3. Example of interaction force with curved surface

Equation for interaction force

$$F(s) = T\frac{d\theta}{ds}$$

$$F(s) = T\frac{\frac{d^2y}{dx^2}\cos^2\theta}{\sqrt{1+(dy/dx)^2}} = T\frac{d^2y}{dx^2}\left|\cos^3\theta\right|$$

$$M = \int r \times F(s)\,ds$$

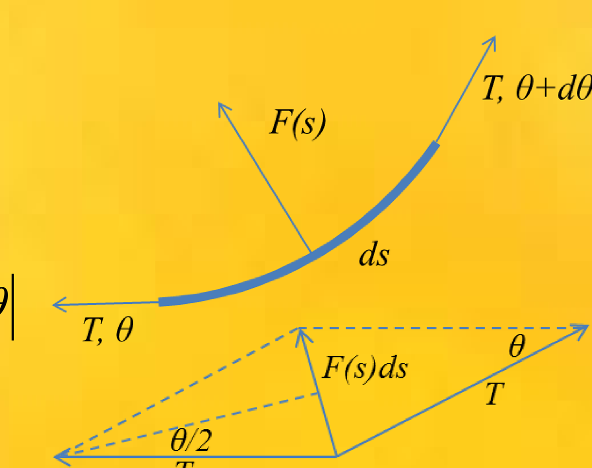

Fig 4. Derivation of equation for interaction force

Cable support shape exploration

- The following 4 families of shape function were explored to optimal cable support shape

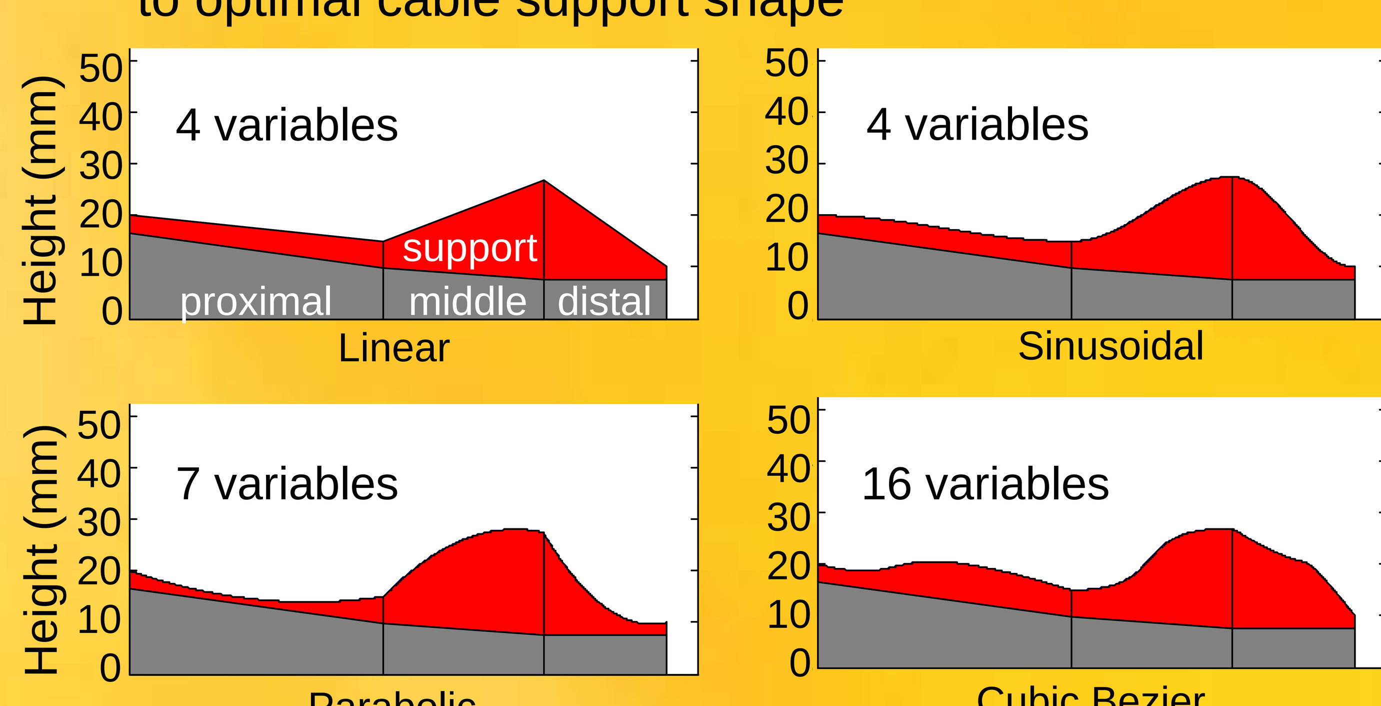

Fig 5. Examples of 4shape families of cable support

Optmization criteria

$$\min_{shape,T}\left[\frac{M_{pinch}}{5Nm} + \frac{pressure}{500kPa} + \frac{F_{Compression}}{300N}\right]$$

subject to

$$\max(\text{cable support height}) \le 1cm$$

$$\text{resting posture} \le \text{posture to grab a can of soup}$$

$$(\text{MCP}:7.5°, \text{PIP}:18°, \text{DIP}:22.5°)$$

RESULTS AND CONCLUSION

- Optimal support design for each shape function was found (Fig.6, Table 2)
- Variable support heights could reduce
  - ✓ required cable tension
  - ✓ required efforts to pinch
  - ✓ discomofrt due to external pressure
- Cubic Bezier shape design was found to be the optimal support design for a cable-driven assistive glove.

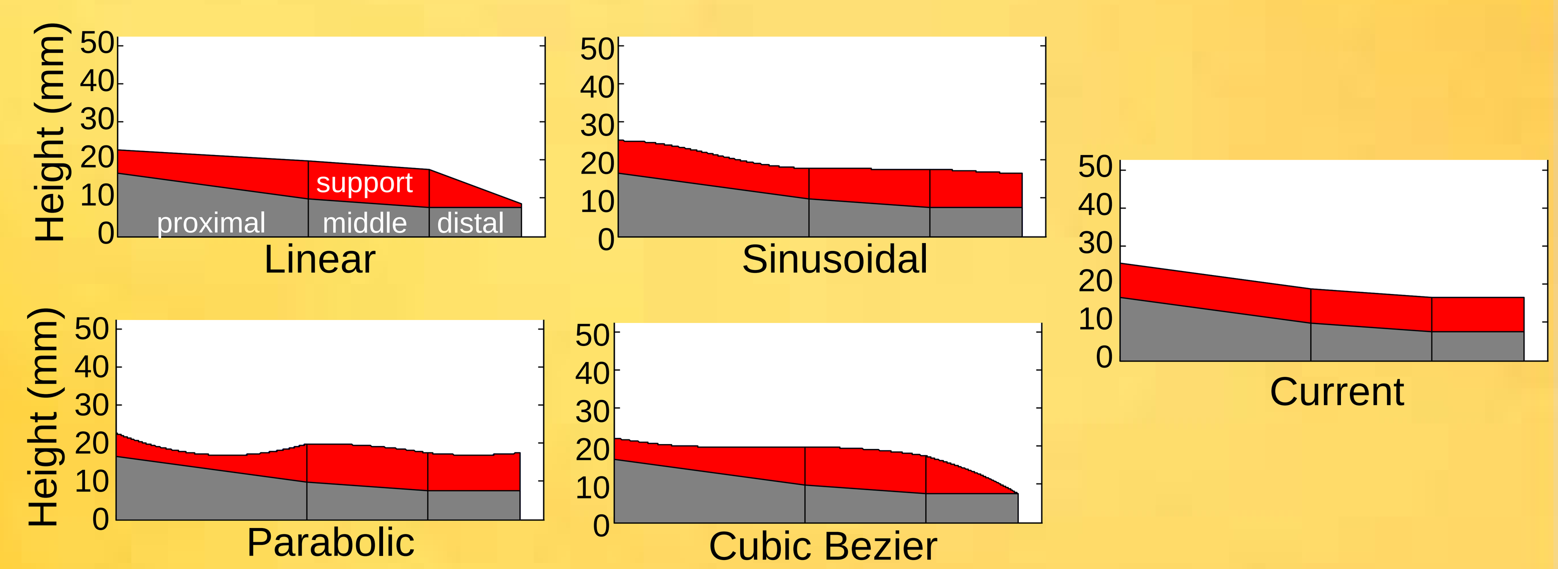

Fig 6. Optimal support design for each shape function

Table 2. Outcomes of optimal design for each shape function

	T (N)	M (Nm)	Press (kPa)	Fcomp (N)	Total
Linear	6.2	0.31	3.85	29.1	0.167
Sinusoidal	6.2	0.31	4.45	29.9	0.170
Parabola	6.2	0.31	3.5	29.1	0.166
Bezier	6.2	0.31	2.95	29.0	0.164
Current	9.2	0.46	6.15	21.8	0.177

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