Linking Wrist to Hand: Simulating Grip Strength Deficits Following Surgical Wrist Redesign

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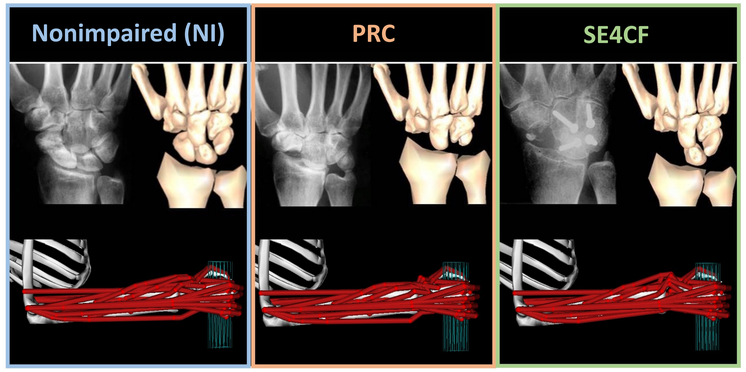
Introduction

Wrist osteoarthritis is one of the most common conditions encountered by hand surgeons [1]. The resultant degeneration of the wrist joint can limit motion of the hand and cause considerable pain during daily functional tasks [2].

Surgical salvage procedures, including proximal row carpectomy (PRC) and scaphoid-excision four-corner fusion (SE4CF) relieve pain, but significant decreases in grip force and wrist range of motion have been recorded [3].



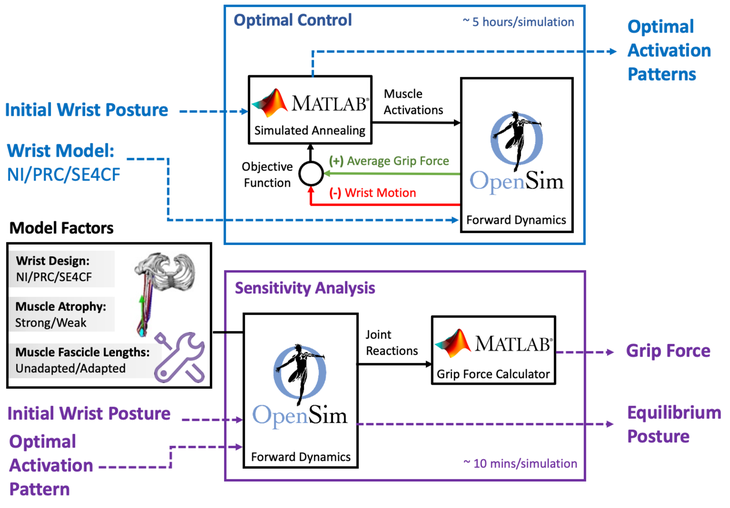
How does changing different biomechanical **factors at the wrist** affect **grip strength in the hand**?

Methods

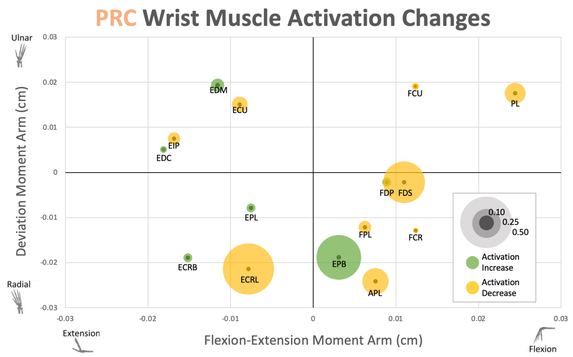
Activation patterns that produce maximum grip force in the **preferred wrist posture of nonimpaired populations** (NIOPT: 35° Ext., 7 ° Ulnar) were computed for each model using an optimal control framework [4,5].

A sensitivity study was conducted using a **forward dynamics approach**:

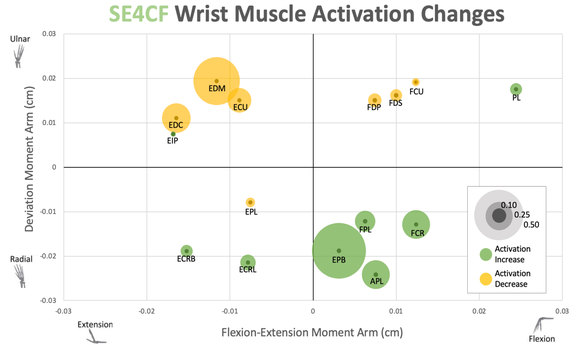
- **Muscle activations:** optimal control simulations
- **Simulated wrist redesign**: altered wrist bones, axes, moment arms [6]
- **Simulated disuse atrophy and fascicle length adaptation**: altered muscle parameters consistent with chronic osteoarthritis and surgical salvage [7]



Optimal Control Patterns

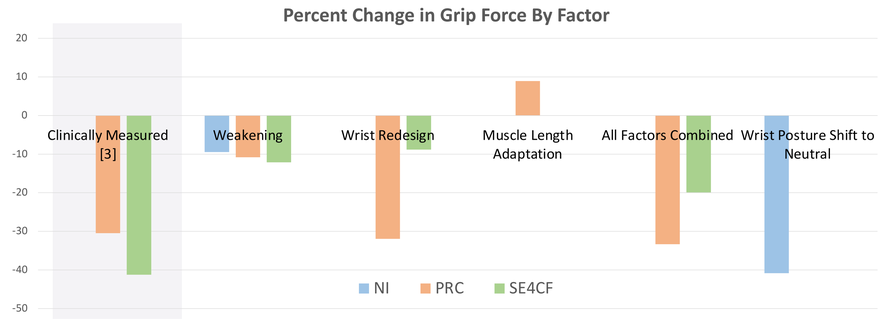


- **No particular activation bias** observed for wrist stabilization
- Increased activation of EPB, an **extrinsic thumb extensor**
- **Extrinsic finger flexors** (FDP and FDS) change in function from ulnar to radial deviators

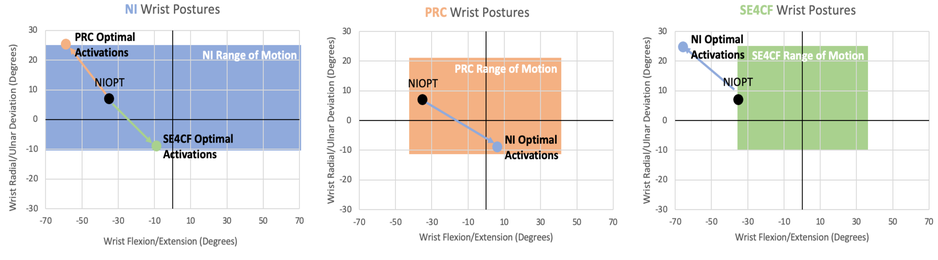


- Activation bias towards **radial deviators** was observed
- Increased activation of all **extrinsic thumb muscles**
- **No significant changes in function** of any wrist muscles

Sensitivity Analysis



- PRC grip force is most sensitive to **wrist redesign**; SE4CF is most sensitive to **weakening**
- Combining all factors **reflects clinical weakness** for the PRC, but **not** for the SE4CF

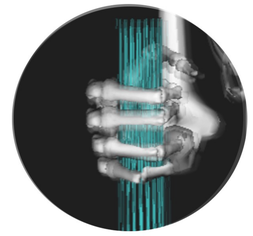


- Altering any factors without reoptimizing the activation pattern **changes wrist posture**

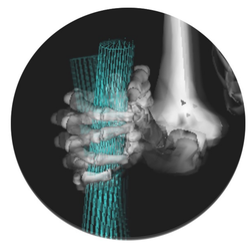
Discussion

- **The SE4CF wrist recruited extrinsic thumb muscles as radial flexors to stabilize the wrist.** It is unclear if relying on extrinsic thumb muscle for wrist stabilization during hand function is feasible.
- **Maximum grip capacity is most sensitive to wrist posture.** PRC and SE4CF patients are unlikely to choose the same extended posture for maximum grip as a nonimpaired person due to range of motion loss.

Wrist Models Superimposed in **Neutral Posture**



Wrist Models Superimposed in **NIOPT Posture**



- **More explicit definitions of wrist posture during clinical grip measurements are needed** to fully understand strength differences between clinical groups following wrist surgery.
- **Maintenance of wrist position during grip is highly sensitive to the activation pattern used.** New control strategies must be learned following biomechanical changes to maintain wrist stability.

Future Directions

Repeat Sensitivity Study in Neutral

- **Optimize activations of surgical models in neutral** to provide a direct comparison of grip force that limits range of motion effects
- **Penalize extrinsic thumb muscle use** to evaluate how control strategies without high thumb muscle activity affect grip force

Data Collection

- **Validate surgical optimal control** through EMG data collection
- **Examine adopted wrist postures** during functional grip tasks
- **Develop protocol for clinical maximum grip force measurements** that considers wrist posture**;** Collect grip data across wrist range of motion

Further research will improve understanding of the biomechanical connection between the wrist and hand. Understanding the effects of individual factors within a treatment can help us pinpoint areas for improvement in the procedure or supplemental rehabilitation techniques.

References & Acknowledgements

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