# Japanese Finger Sleeves

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Sam Dudek, Nathan Hansen, Nathan Klauck, Ilia Mikhailenko, Mariamawit Tefera, Ben Willihnganz

Client: Mr. Pape Samb; Advisors: Dr. Justin Williams, Srihari Gopalan

## Problem Statement

Create a digital traction device using a Japanese finger trap mechanism to precisely pull patients' hand, wrist, and forearm into a neutral position while holding a stable static load. Device must be adaptable, autoclavable, and cost-effective.

## Motivation/Background

**Background**

- Hand injuries have a substantial share of workplace injuries in Dakar, Senegal (~30%) [1]
- Digital traction aligns small bone fragments during surgery, helping prevent neurovascular compromise and leading to better patient outcomes [2]

**Figure 1:** Digital Traction used in surgery [1]

**Competing Designs**

- MPR Hand Traction Systems provides effective hand stabilization, but lacks affordability needed for client's limited budget [3]
- Reisen Hand Traction provides stable static loads, but is heavy and non-adjustable [4]
- Arc Wrist Tower is a strong candidate for OR use, but lacks portability needed for casting procedures [5]

**Figure 2:** Reisen Hand Traction [4]

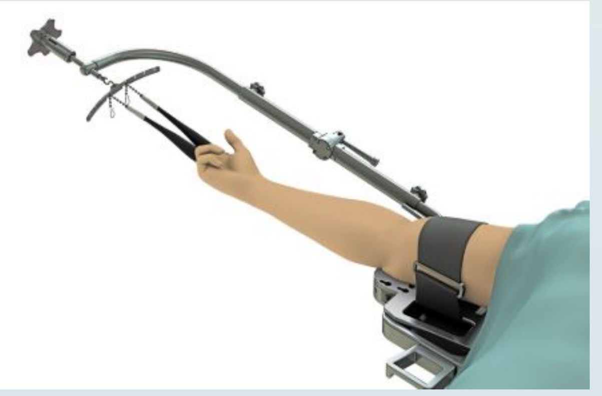


**Figure 3:** Acumed ARC Wrist Tower [5]

## Design Criteria

- Support arm for 50 minutes without slippage
- Provide traction force of 22-44 N per finger
- Minimize nerve/vessel compression
- Maintain strength through 50 use cycles
- Offer adjustable sleeve sizes to fit various finger diameters

## Final Design

**Final Design of Mechanical Body:**

- Height adjustment increases procedural versatility
- Attachment piece stabilized by 3D-printed stoppers
- Bead chain sets connect attachment piece to D-rings
- Stable hand support provided for full length of orthopedic operations

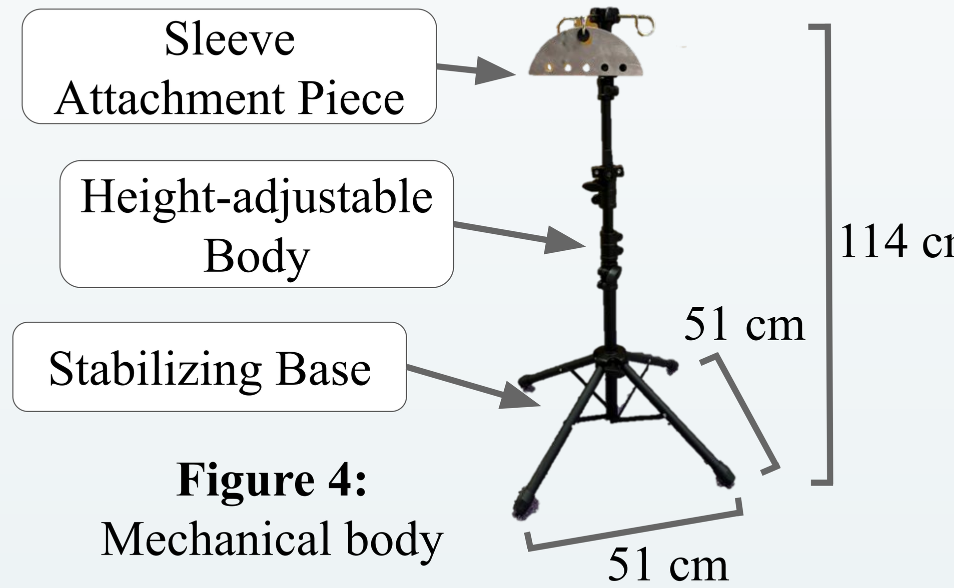



**Figure 4:** Mechanical body

**Final Design of Finger Sleeve:**

- Straps and stitched loops allows for "one size fits all" capability
- Adjustable hook and loop cinching straps securely grip the finger
- 3D-printed D-Rings enable load distribution across ballistic nylon strap

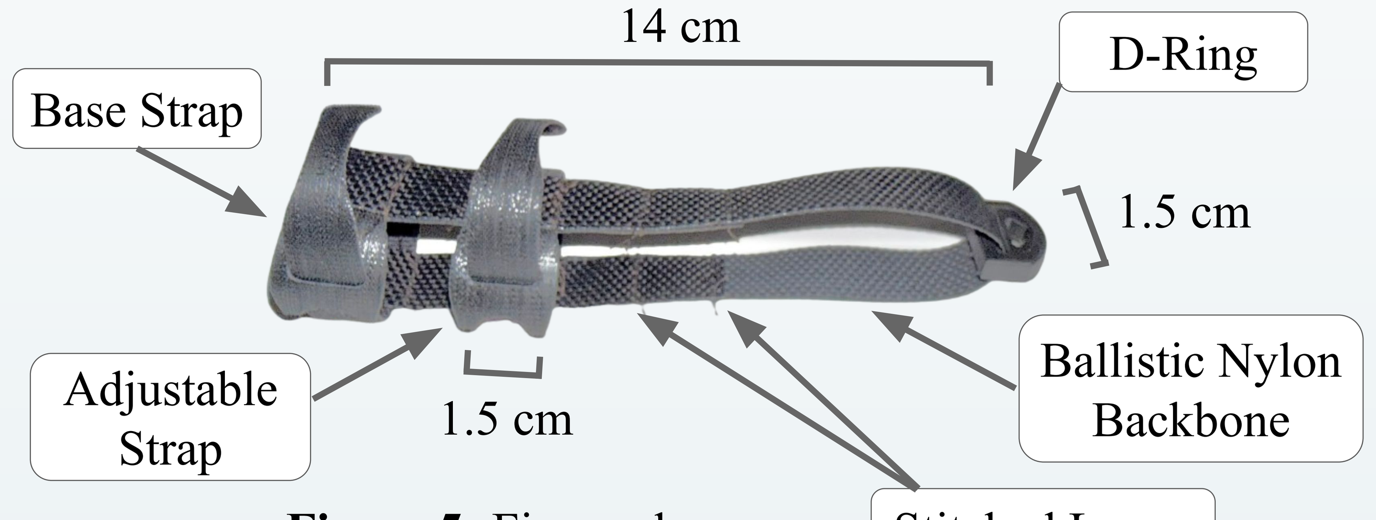



**Figure 5:** Finger sleeve

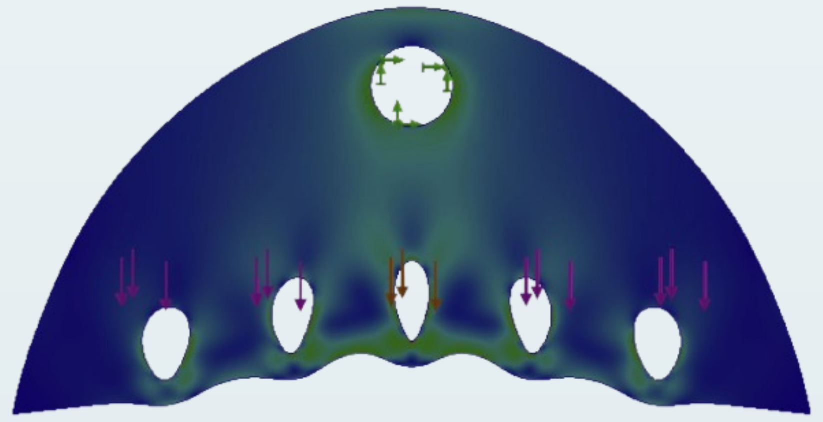
## Results and Discussion

### Finite Element Analysis (FEA) Test

__Goal:__ Determine if the mounting plate will fail from forces exhibited during regular use

- Maximum expected force is 44 N [2]
- Force applied to mounting plate using SOLIDWORKS FEA software
- Factor of Safety $\leq 4$ was considered a failure
- Max calculated stress was $5.2 \times 10^6$ N/m²; material's yield strength is $4.1 \times 10^7$ N/m²
- Whole structure passed FEA analysis and is considered adequate for our design

**Figure 6:** FEA Test on Mounting Plate: **Blue** = low stress, **Green** = moderate, **Red** = high



### Sterilized Tensile Strength Test

__Goal:__ Determine if ballistic nylon will be suitable for use after autoclaving

- Ballistic nylon retains strength properties up to at least 5 autoclave cycle
  - Elastic modulus significantly decreased
  - Failure strain significantly increased
  - Maximum stress significantly decreased, but still 6x criteria (20 MPa)

### Slippage Test

__Goal:__ Determine if a finger sleeve slips when under load

- When applied correctly finger slips on average less than 0.104 mm per minute
  - Results by finger size and length did not vary
  - 1 sleeve was under entirety of load
  - Capable of desired load strength and length

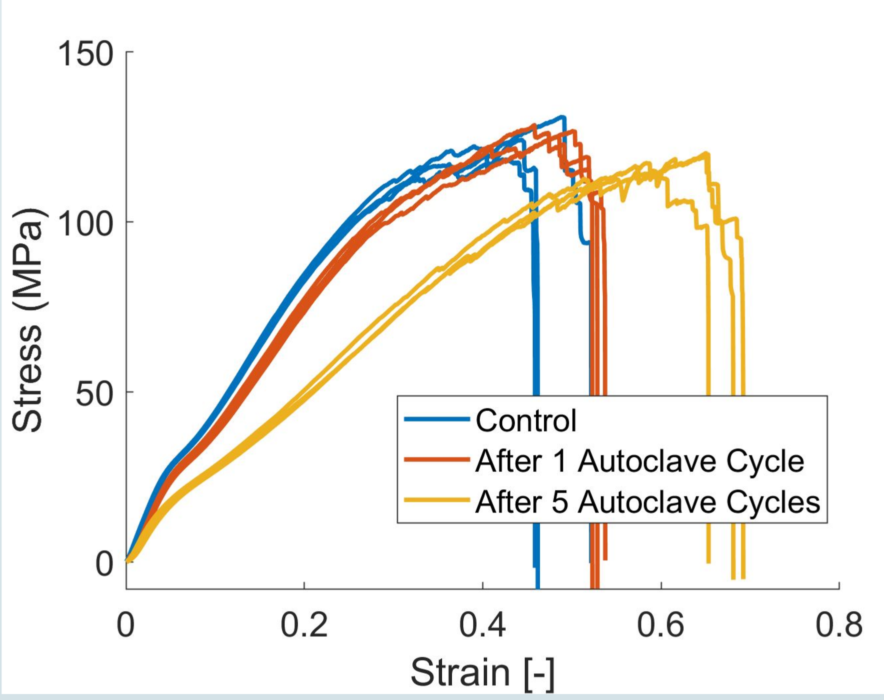



**Figure 7:** Stress-strain curve of ballistic nylon after autoclave

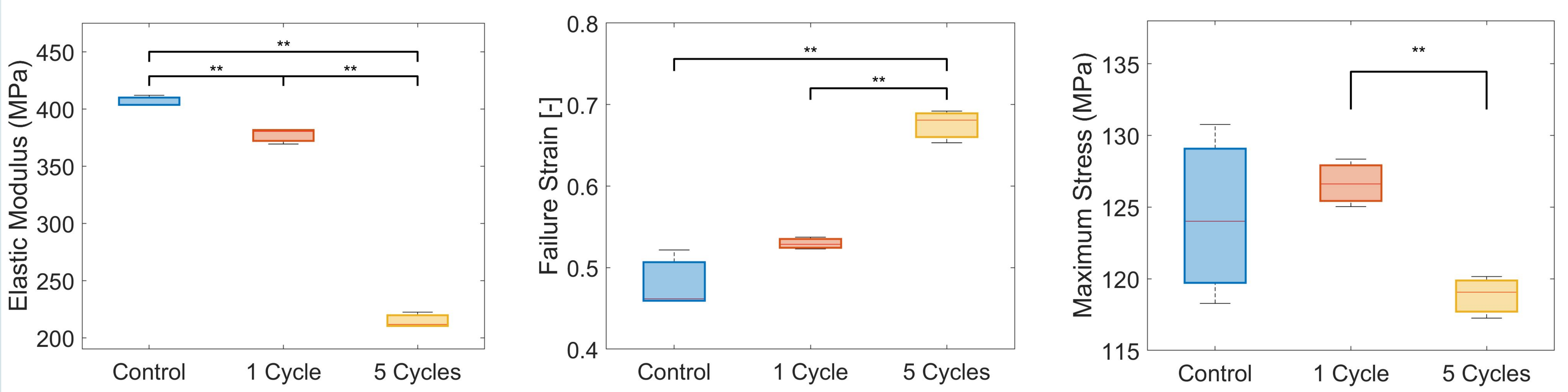



**Figure 8:** Following autoclave cycles: change in elastic modulus and failure strain (independent two-tailed T-tests); maximum stress (independent single-tailed T-test). Brackets: * = $p < 0.05$, ** = $p < 0.01$

## Future Work

- Vary stitching parameters (type, thread, density, pattern) to better optimize sleeve strength.
- Add stabilization options such as locking wheels or a bed clamp
- Test sleeve's reusability past 5 autoclave cycles
- Measure mechanical body's angle of deflection under various loads to ensure stability
- Test reinforcing materials (beads, silicone grippers) at stress points

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## References

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