Motor-Driven Assistive Brace for Humerus Fracture

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Introduction

Upper-arm fractures require specialized orthotics and individualized care. Rehabilitation of injuries such as a humeral fracture necessitate a tight-fitting brace to ensure proper healing. Without such care, nonunion of the fracture may occur, which may result in further complications including pain and surgery.[1] Many patients, especially elderly individuals, have trouble taking their brace on and off. Consequently, they often must visit a clinic to seek assistance in tightening their brace. Thus, a need exists for a brace which allows a patient to easily adjust to the proper position and maintain the fit required for healing.

Objectives

The main objective is designing a brace that is easy for an individual to handle while also maintaining a fit that promotes fracture fixation. The individual should be able to manipulate the brace with one hand and be able to tighten the brace without exertion. The ideal brace is comfortable and cost-effective.

Materials and Methods

Essential components of the brace include the microcontroller, circuitry, stepper motor, fabric liner, and nylon. User input to two buttons directs the motor to pull in different directions, resulting in tightening or loosening of the brace. The spool and through holes that guide the nylon were 3D printed.

The brace is limited by both hardware and software to not tighten past a certain point. The program controlling the motor can be set to either tighten to a set point, such as one determined by a clinician, or to a fit the user desires.

Testing was conducted with a sample of n=10 students. The first investigation compared two different lacing patterns to determine which provided the most support across the brace. The second investigation compared a patient manually adjusting the brace versus using the assisted brace. The third investigation compared using the assisted brace for a patient's dominant hand versus their non-dominant hand. Tests were performed using a force-sensing resistor to detect the compression force of the brace.

Results

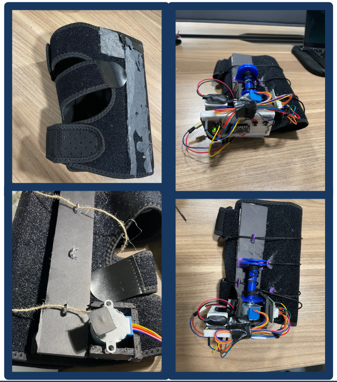

Figure 1—Brace Design

Top Left: Picture of unmodified upper-arm brace.
Bottom Left: Picture of motor-assisted brace with Pattern 1 configuration.
Bottom Right: Picture of motor-assisted brace with Pattern 2 configuration.
Top Right: Picture of motor-assisted brace with Pattern 2 configuration focusing on the supporting circuitry.

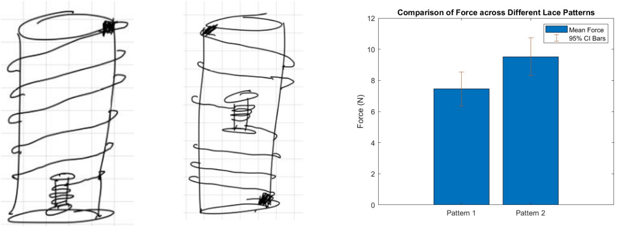

Figure 2—Different Threading Configurations
The leftmost image shows the first threading pattern used, with the nylon affixed to one end of the brace, wrapped around circumferentially, and affixed to the spool. The middle image shows the second threading pattern used, with the nylon affixed at both ends of the brace and to the centered spool.
The rightmost image is a bar graph showing the mean compression force in Newtons of each configuration with accompanying 95% CI bars. This shows that Pattern 2 likely provides more compressive force.

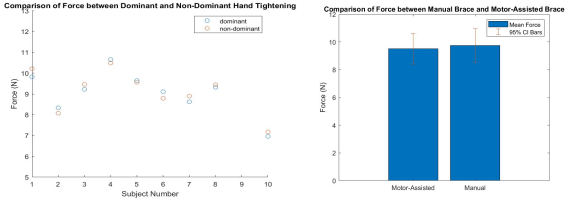

Figure 3 – Motor-assisted vs. Manual Tightening
The left plot shows the compressive force of the brace for each subject for both motor-assisted and manual tightening of the brace. The right plot shows the mean and 95% CI bars associated with each method.
From these results, our motor-assisted brace is able to mimic the tightening ability of healthy college students.

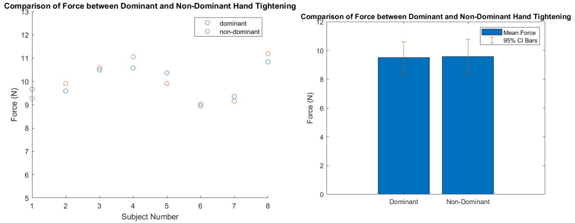

Figure 4 – Dominant vs. Non-Dominant Arm Usage
The above plots show the compressive force of the brace for dominant and non-dominant arm usage. From these results, we conclude that our brace is easy to use, with no different in output functionality between dominant and non-dominant arm usage.

Conclusion

We conclude that our motor-assisted brace provides compressive support equal to that of one manually tightened by healthy college-aged adults. We therefore predict that elderly adults with a broken humerus would also be able to provide better support for the healing of their fracture using our motor-assisted brace, with the additional benefit of ease-of-use. Although the prototype is currently bulky, future directions include miniaturizing the electrical components by developing the circuitry on a printed circuit board, and testing on an elderly population, which was unavailable in this initial stage of development.

References: [1] Koch PP, Gross DF, Gerber C. The results of functional (Sarmiento) bracing of humeral shaft fractures. J Shoulder Elbow Surg. 2002 Mar-Apr;11(2):143-50. doi: 10.1067/mse.2002.121634. PMID: 11988725. https://pubmed.ncbi.nlm.nih.gov/11988725/