Nerve Elongation Device: A Potential Therapeutic Approach in Peripheral Nerve Repair

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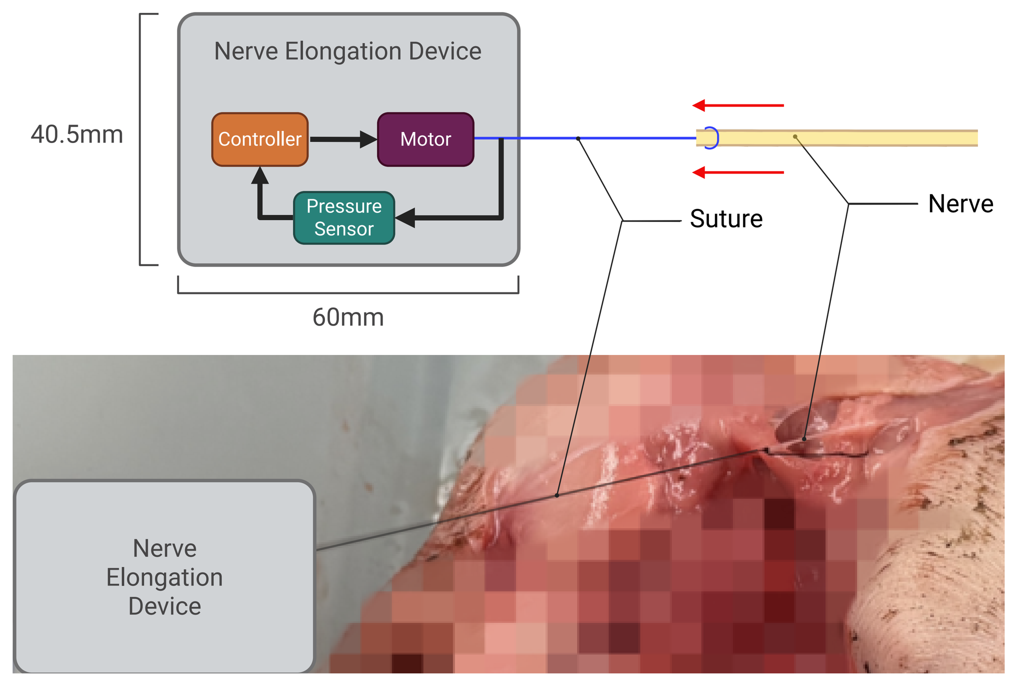
INTRODUCTION

- Peripheral Nerve Injuries (PNI) is known to affect more than 20 million people in the US [1] .PNI can lead to muscle atrophy, motor dysfunction, sensory deficits, and chronic pain affecting the quality of life and potentially leading to long-term physical disabilities, psychological and social impacts [2], [3], [4], [5].
- Despite the advances in novel interventions such as autografts, allografts, scaffolds and guided conduits , there still remains a critical need for reliable and clinically translatable nerve regeneration strategies to attain a fully functional restoration [6].
- Nerves are physiologically subjected to intrinsic tension during growth, development and functional movements [7]. As external stress is applied to peripheral nerves, they have the capacity to elongate and aid in nerve repair and regeneration thereby [8], [9].

We have developed a nerve elongation device, equipped with a closed loop system, with the hypothesis that the device would allow controlled stretching of nerves under desired tensile forces to expedite nerve repair and regeneration processes.

METHODS

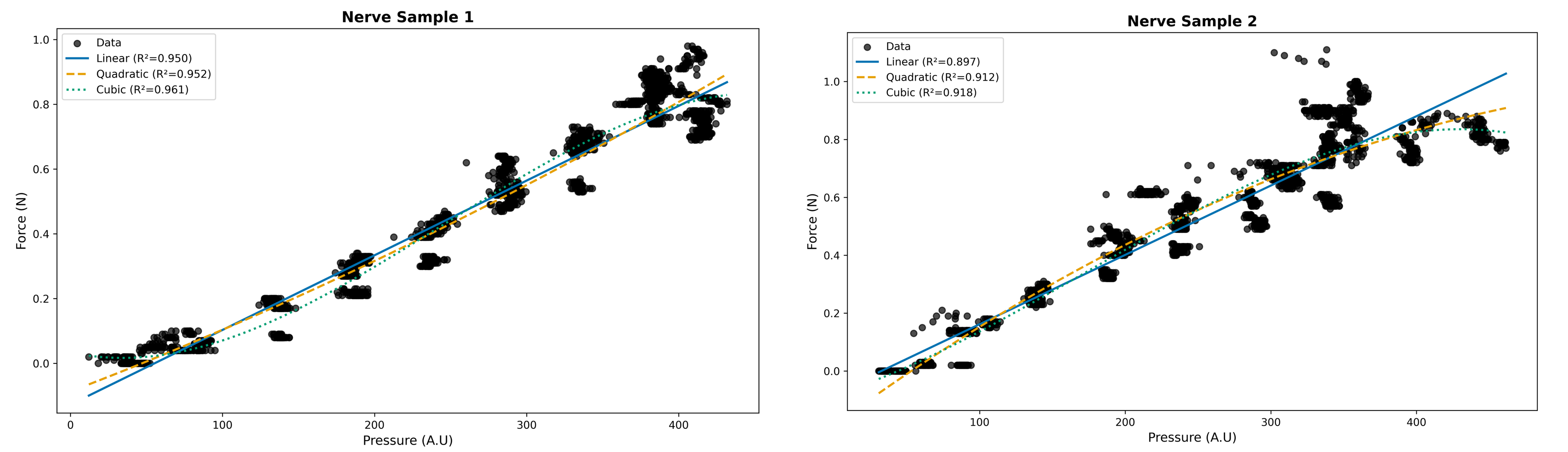


Fig(1): Illustration of an experimental nerve elongation system on a pig cadaver, with a closed-loop interface

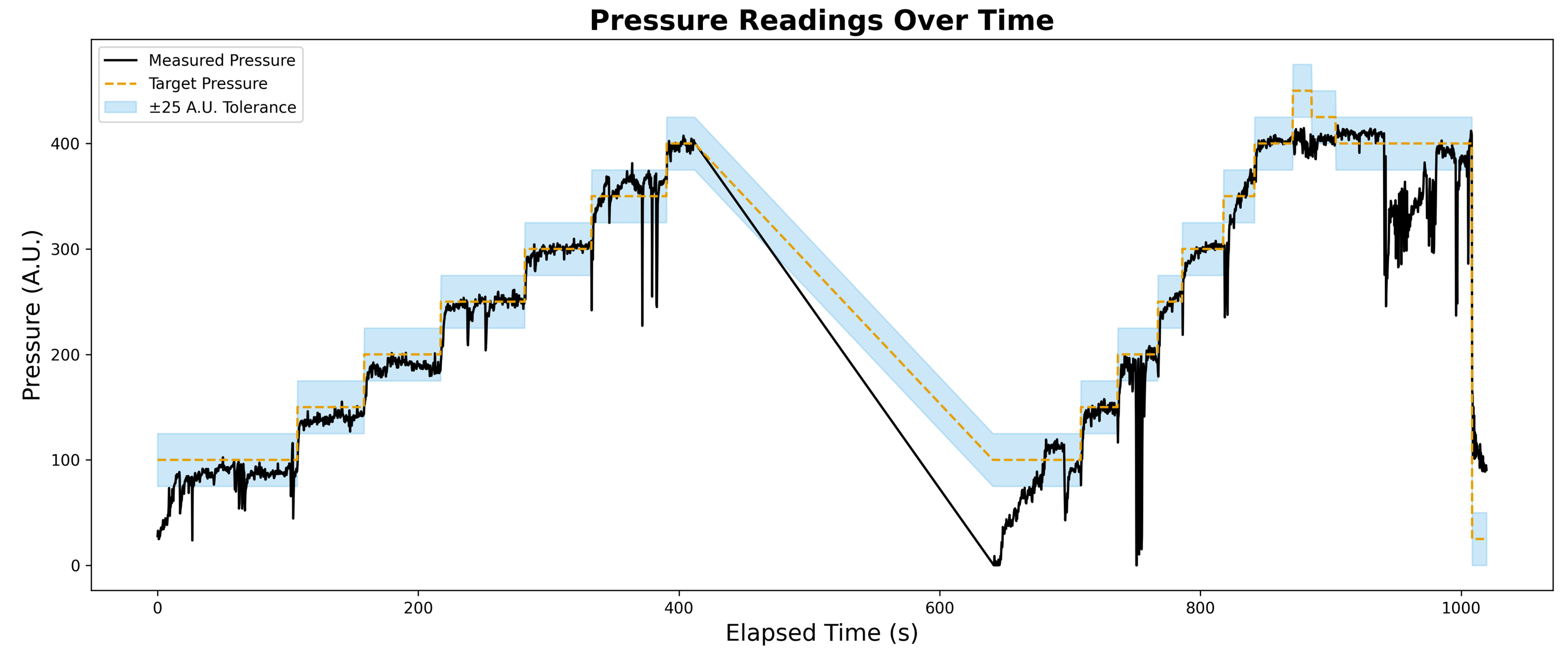
The nerve stretching device is enclosed in a custom 3D-printed housing and designed to autonomously apply controlled tension to an attached nerve sample. A surgical silk suture interfaces with the tissue and is routed through a series of guiding and tensioning components before exiting the device. A miniature stepper motor provides bi-directional actuation, allowing precise adjustments in length and tension during stretching protocols. A custom housing integrates actuation, guidance, and force-sensing components into a closed-loop control system. Changes in suture tension were detected by an onboard pressure sensor, which provided continuous feedback to maintain a constant applied load. Control signals and data acquisition were managed by a microcontroller-based circuit and logged to a connected PC in real time.

The device was designed to autonomously apply and release controlled tension on a suture connected to the distal end of excised porcine nerves. Peripheral forelimb and hindlimb nerves of varying diameters were harvested post-mortem. Each sample was secured distally to the device and proximally to a calibrated force gauge such that the applied tension and the device's pressure sensor readings could be recorded simultaneously.
For each nerve, three trials were conducted, each consisting of 10 sequential loading stages. Tension was increased stepwise from an initial load to a peak, then symmetrically decreased, while corresponding forces (N) and pressure values were recorded at each stage.
The device was also assessed *in situ* on porcine cadavers with surgically exposed peripheral nerves and the system variables were recorded over time.

RESULTS



Fig(2): Scatter plots of pressure sensor values (Arbitrary Units, A.U.) versus. force gauge readings (Newtons, N) recorded with the nerve samples

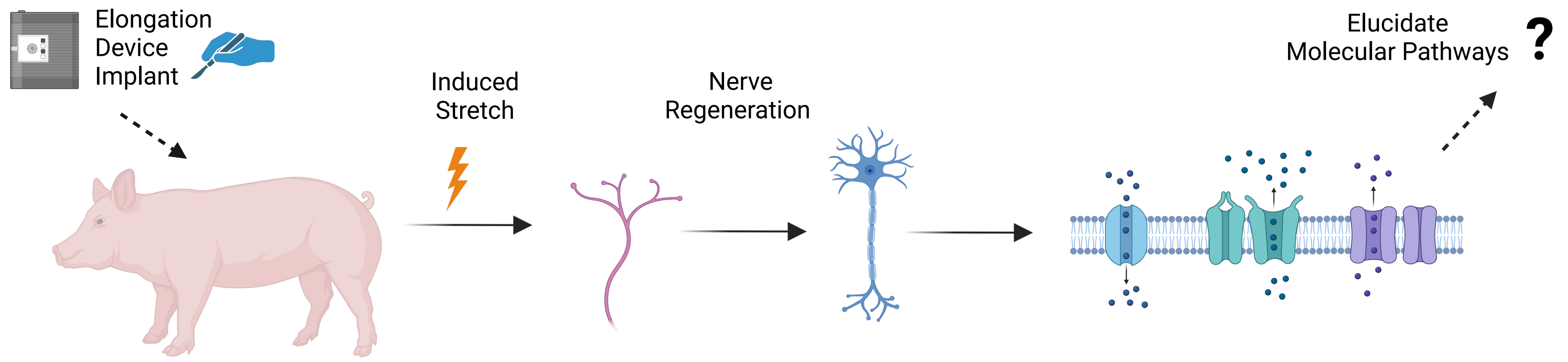


Fig(3): Line graph of the pressure values recorded on the system at various time stamps

DISCUSSION

These preliminary results establish a proof-of-concept that peripheral nerves can be stretched reproducibly at a constant tension in a controlled manner. The *ex vivo* stretching of nerve samples, combined with simultaneous recording of tensile values and their corresponding pressure values in the system, allowed the evaluation of multiple regression models. The cubic regression model best represented the force-pressure relationship in the system .The modeling approach will allow us to remain within a predictive range of tension while monitoring real time data from the pressure sensor integrated in the system.

Our next steps will involve *in vivo* implantation to assess the device's effects on nerve regeneration in a live subject. We will examine elongation results with a broader range of nerves (spinal accessory, sciatic, tibial, common peroneal, pudendal) to test the device's ability in maintaining tension at situations that closely mimic clinical scenarios. Further analyses with histology, electrophysiology, and motor function tests will highlight the similarities and differences between regeneration techniques including nerve elongation, autografts, and end-to-end suturing. Additionally, we aim to investigate the neuronal molecular pathways mediated by proteins that respond to mechanical stimuli as controlled tension is applied to peripheral nerves.



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