Improved Insertion of Floating Microelectrode Arrays in Brain with an Ultrasonic Vibration Insertion System

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NeuralGlider® CORTICAL — Neural Implant Inserter

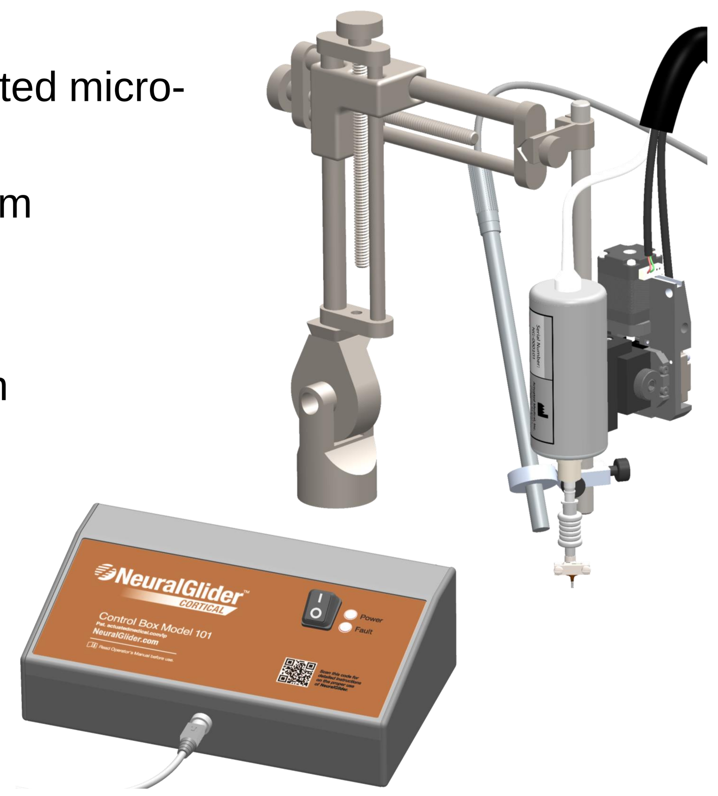
Introduction

Penetrating electrode arrays provide localized access to neural signals in the brain with high temporal and spatial resolution. We have previously shown that ultrasonic vibration of fixed microwire electrode arrays during insertion improves insertion accuracy and reduces insertion force and tissue dimpling, without interfering with electrode integrity or performance. Adapting the approach to floating arrays (FAs)—designed to float with the brain to reduce relative micromotion at the brain-implant interface—offers specific challenges related to effective coupling and post-insertion release. We have developed several reversible coupling approaches to efficiently couple vibration between the NeuralGlider-Cortical Inserter system and several FA types. Results support the feasibility and potential of the insertion system for improving insertion mechanics of a wide range of implant types.

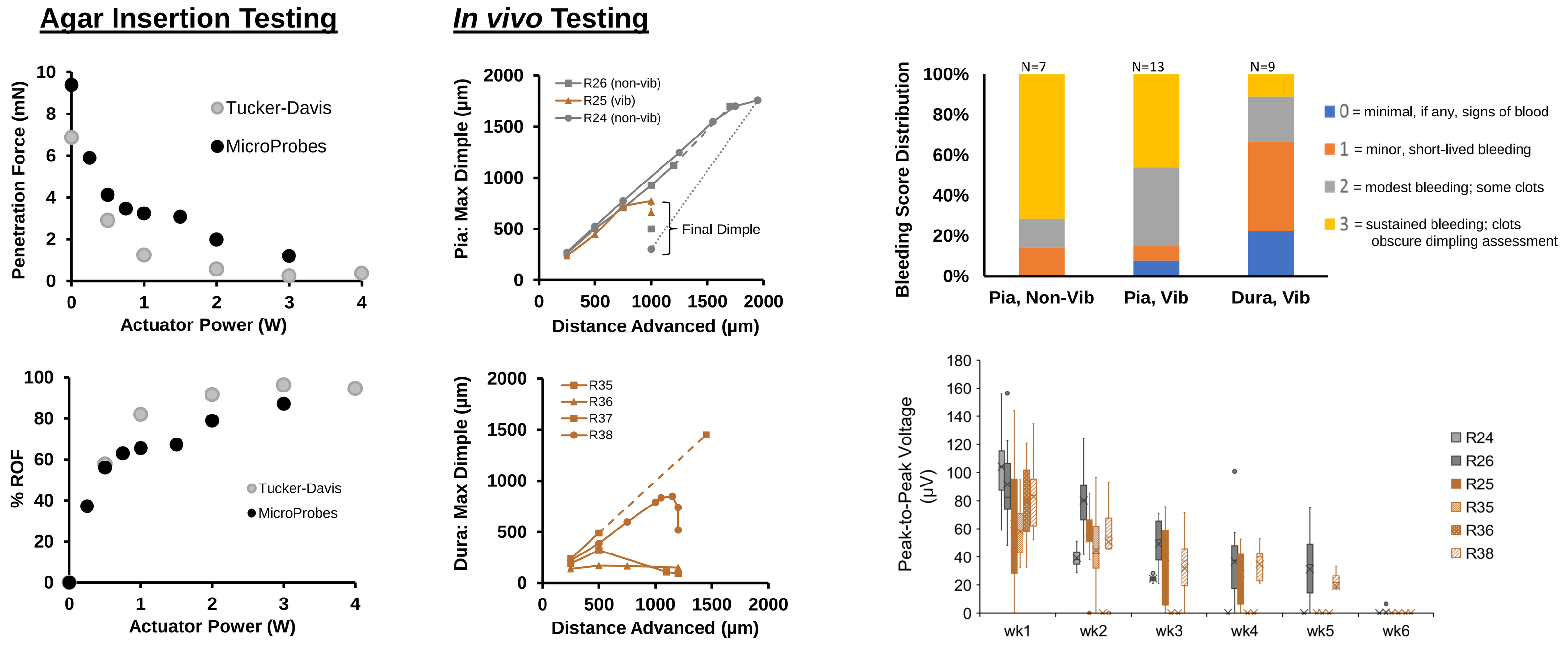
+ **NeuralGlider-Cortical® uses ultrasonic micro-vibration to reduce the insertion force and dimpling during microelectrode array implantation.**

NeuralGlider-Cortical® Inserter

+ Ultrasonic actuator produces axially-directed micro-vibrations in shanks during insertion
+ Closed loop micro-positioner stage (0.5 μm resolution) mounts to stereotaxis
+ RoHS compliant control box
+ Low profile USB microscope camera, with stereotaxis mount included
+ LabVIEW-based GUI for control of the micro-positioner and actuator while recording position data
+ Compatible with range array styles (e.g. silicon, microwire)



Prior Results with Fixed Microwire Arrays



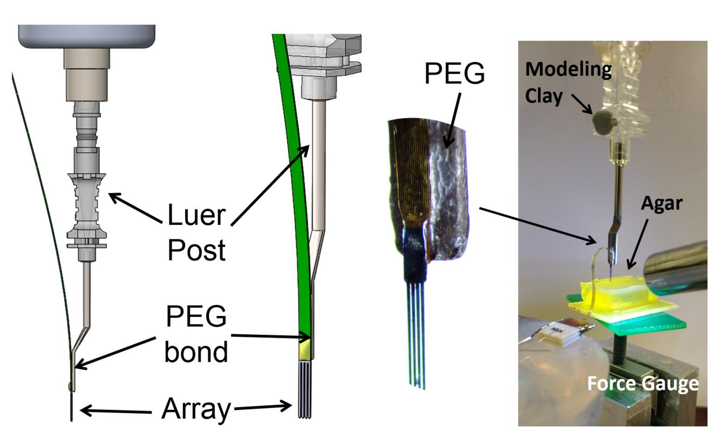
Insertions into agar cortical model (0.5% base with 0.85% top layer): The force required to penetrate the model surface (top) decreases with increasing actuator power (bottom), for both Tucker-Davis Technology and MicroProbes microwire arrays.

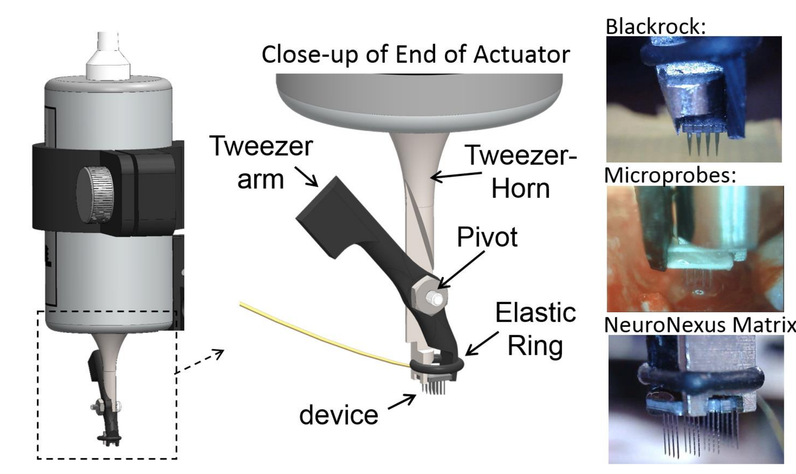
Insertions in vivo, rat: Non-vibrated (gray) insertion through the pia significantly dimples cortical tissue, while vibrated insertions (orange) showed reduced dimple (top). Insertion through the dura is only possible with vibration (orange).

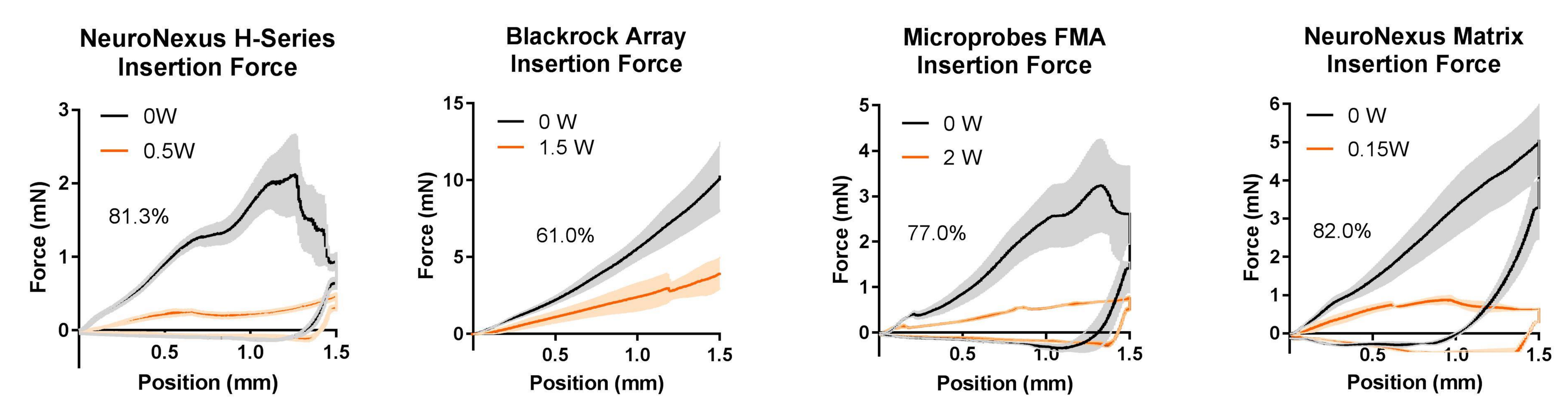
Insertions in vivo, rat: Non-vibrated insertion through the pia causes more severe bleeding than vibrated insertions through pia and dura (top). Electrodes implanted with vibration through dura and pia demonstrated similar quality electrophysiology recordings as non-vibrated insertions, indicating vibration does not damage electrodes or neural tissue.

Coupling to Floating Arrays

Coupling strategies are dependent on the array form. Planar arrays lacking backplates can be bonded with polyethylene glycol (tissue-safe and water-soluble) to a luer-lock coupler post (left). Alternatively, a 'tweezer' mechanism (right) can grip with sufficient force to transmit vibration.



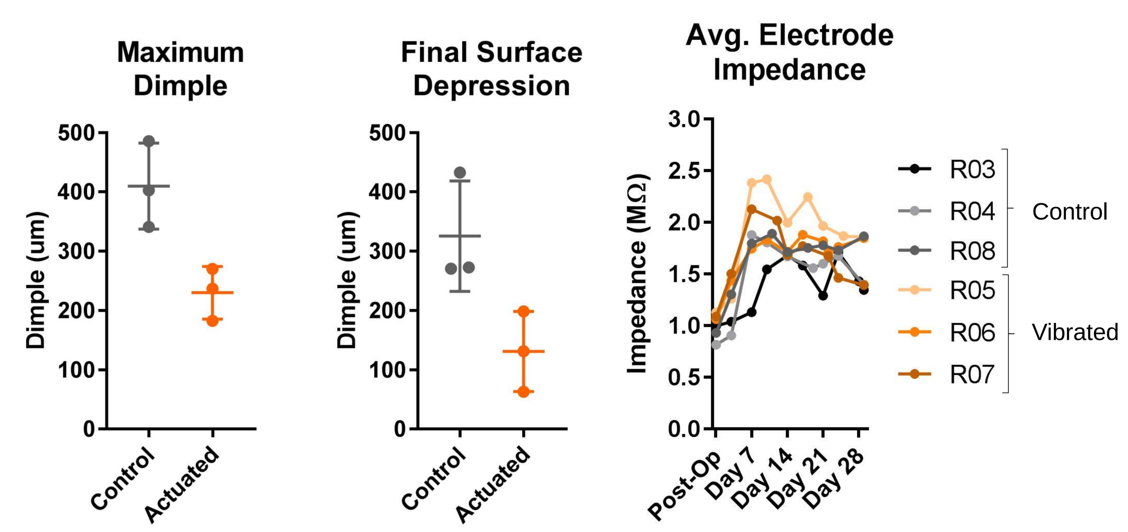


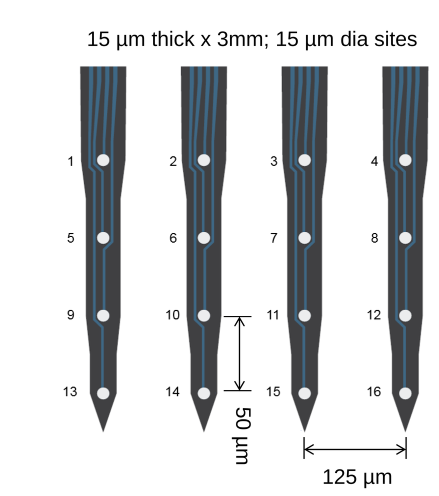


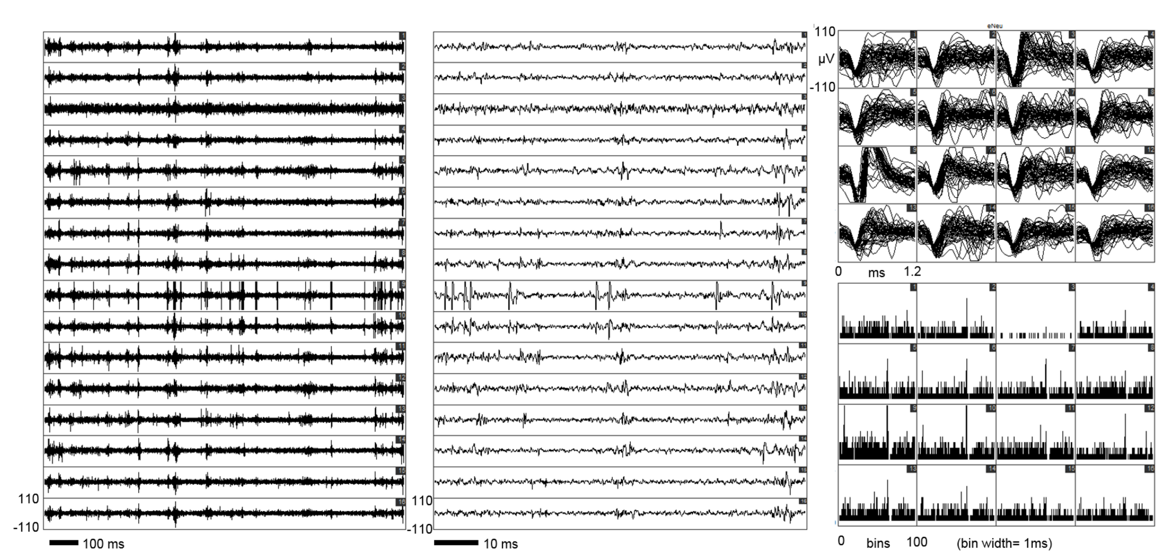
Insertions into agar model (0.5% base with 1.5% top layer)

In vivo studies – Planar Floating Arrays

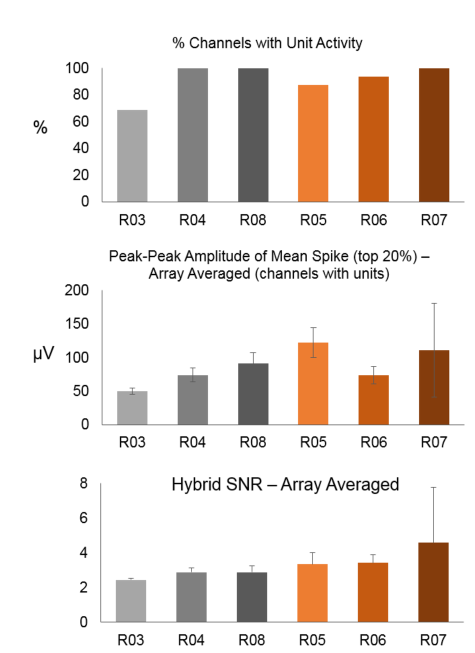
+ **NeuroNexus Arrays** – 4 shank silicon arrays, 16 electrode sites, inserted 1-1.25 mm into rat barrel cortex. Reduced dimpling and cortical surface compression (p<0.01) with vibration, without impairing electrode function. Histological analysis ongoing.







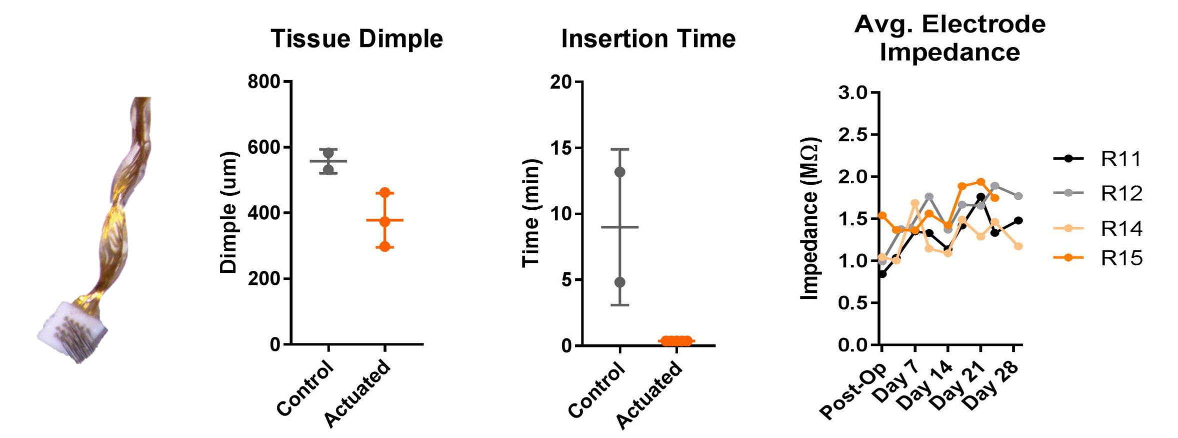
Sample of post-op neural recordings from probe inserted into barrel cortex of rat (R07) with microvibration. Upper right: spike waveforms crossing 4SD threshold. Bottom right: PSTH histograms from whisker flick stimulation delivered at 1 Hz.



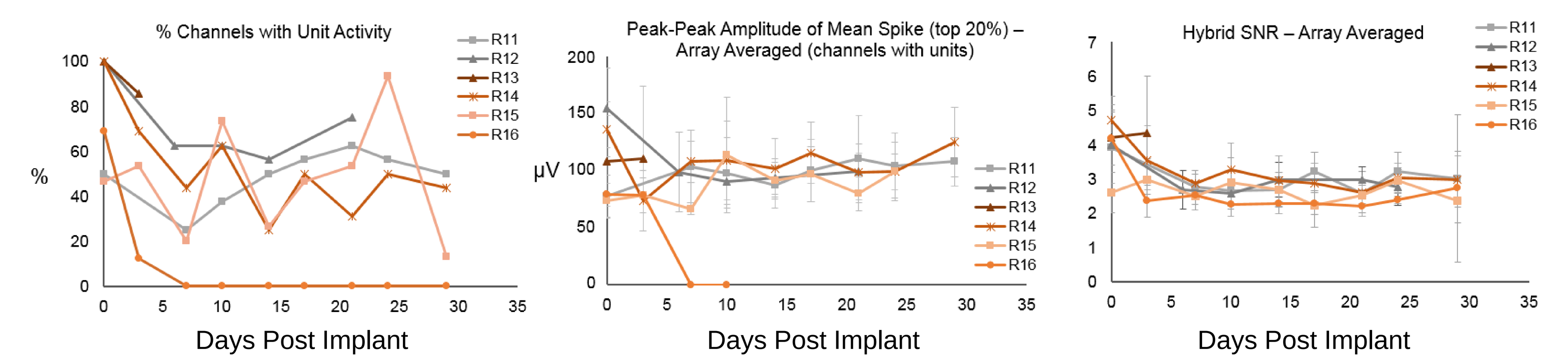
Immediate post-operative recording performance was similar in this study.

In vivo studies – 3D Floating Arrays

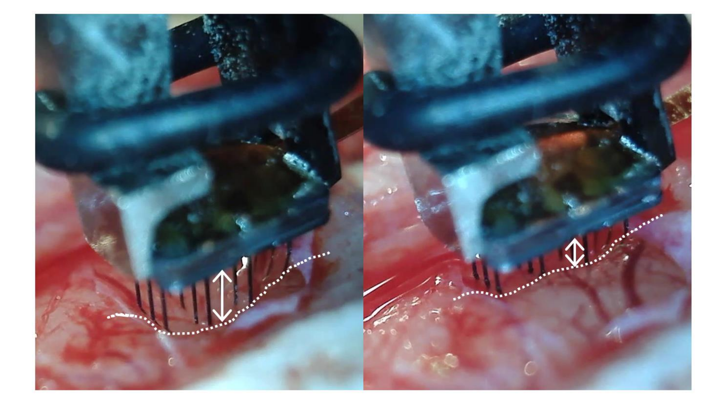
+ **Microprobes FMAs** – 16-shank microwire arrays, inserted 1 mm in rat barrel cortex. Reduced insertion time (p<0.01), bleeding incidence, and some dimple reduction with vibration. Histological analysis ongoing.



Primary studies show that recording performance was comparable for vibrated (actuated) and non-vibrated (control) array insertions, supporting overall safety of approach.

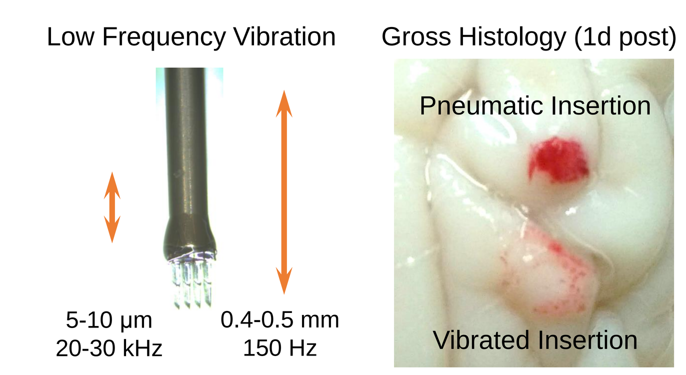


+ **NeuroNexus Matrix Arrays** – Early testing shows potential for vibration to facilitate uniform insertion. Further study is underway to optimize the technique and evaluate outcomes.



Non-vibrated Vibrated

+ **Blackrock Arrays** – Low frequency, higher amplitude vibration was more effective than ultrasonic for insertion of 4x4 unwired arrays in pig cortex.



Conclusions and Future Directions

+ Ultrasonic micro-vibration by the NeuralGlider Inserter safely improves insertion of microwire and silicon floating arrays
+ The NeuralGlider Inserter enables the insertion of microwire arrays and some silicon arrays through dura, which may simplify future neural implant procedures for some devices
+ Iterative coupler mechanism design is needed to enable universality of the NeuralGlider Inserter
+ Beginning to explore insertion of polymer-based and ultra-fine shank probes that are challenging to insert and highly prone to buckling – initial results are encouraging
+ Evaluate in higher animal models (e.g. non-human primates); Analysis of electrophysiological and histological data ongoing

Acknowledgments

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