Prosthetic Material Properties Affect Neuroma Formation: A 6-Month Study

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Background: Our group is developing a regenerative peripheral nerve interface (RPNI) for closed-loop motor and sensory control of an artificial limb. Peripheral nerve interfaces can be compromised by neuromas, which are painful and cause signal interference. Our RPNI uses the conductive polymer poly(3,4-ethylenedioxythiophene) (PEDOT) to limit biofouling (1). Our null hypothesis is that neuroma formation is unaffected by the presence of PEDOT at three and six months.

Methods: Rat peroneal nerves were divided. The proximal stump was coapted to an acellular small intestinal submucosa (SIS). Two formulations of PEDOT were polymerized on the SIS: Dry PEDOT, a firm compound, and Wet PEDOT, a softer compound. Study groups were: Sham, Primary Repair, Divided Nerve, SIS, Dry PEDOT+SIS, and Wet PEDOT+SIS. Tactile sensitivity was evaluated with von Frey monofilaments at 3 and 6 months with histomorphometry at 6 months. Compliance of the PEDOT constructs was measured.

Results: The Divided Nerve group was more sensitive than the Sham group, implying a painful neuroma (2). Surprisingly, Dry PEDOT+SIS showed increased sensitivity when compared to SIS (0.013±0.017 vs. 0.22±0.33, $p<0.05$) at 90 days, but this difference diminished at 180 days. Sensitivity for the Wet PEDOT group was not increased (power=0.61, $\alpha=0.1$). The percent neural area of the Sham group was higher than the Divided Nerve group (50.2%±5.3% vs. 16.1%±5.7%, $p<0.01$), but no significant differences were found between the SIS group vs. either PEDOT group (Fig 1). Tensiometry indicated that the SIS with Dry PEDOT was significantly stiffer than the SIS with Wet PEDOT (11.9±5.9 vs. 3.48±2.1, $p<0.05$, Fig 2).

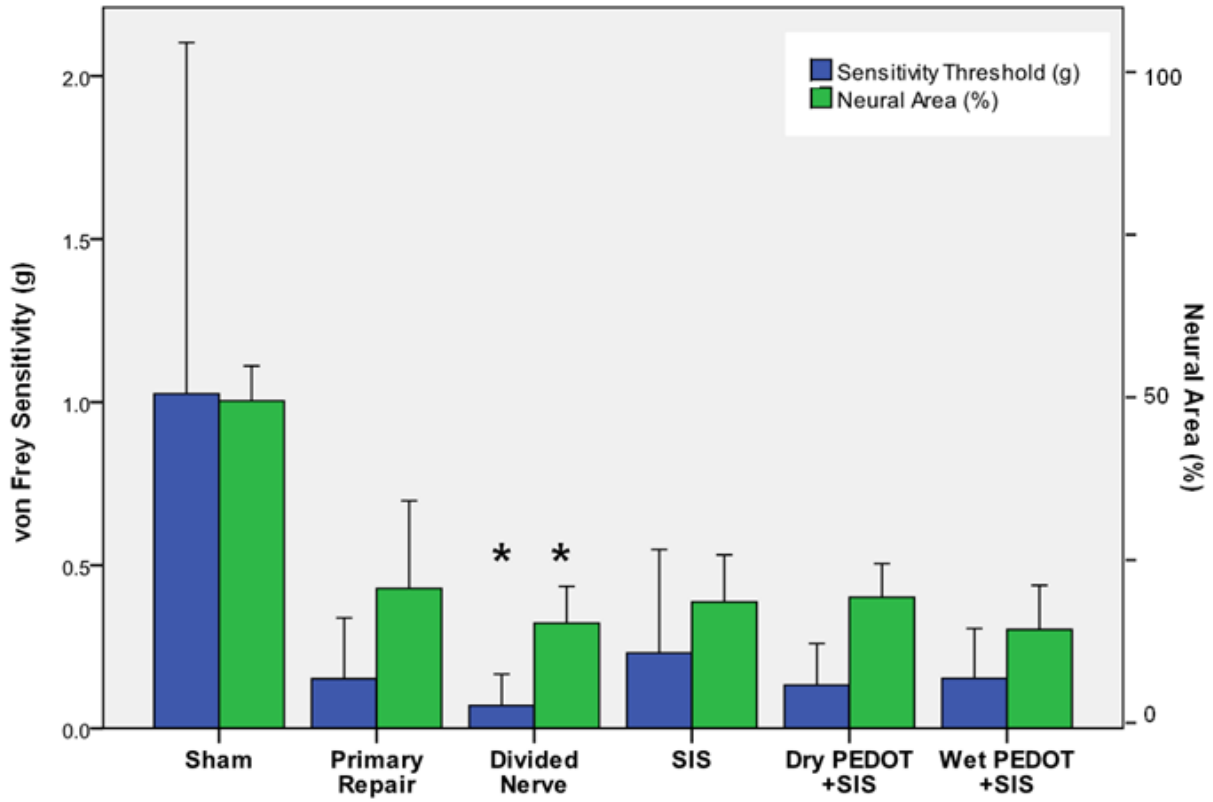

Figure 1. von Frey Thresholds and Percent Neural Area at 6 months. von Frey values represent threshold (g) at which animals respond to monofilament stimuli, lower values reflect higher sensitivity. Percent neural area represents neural tissue are divided by total sample area. For von Frey sensitivity, number of subjects are as follows: Sham = 8, Primary Repair = 6, Divided Nerve = 6, SIS = 7, Dry PEDOT+SIS = 7, Wet PEDOT+SIS = 8. For percent neural area, Sham = 2, Primary Repair = 3, Divided Nerve = 4, SIS = 4, Dry PEDOT+SIS = 3, Wet PEDOT+SIS = 2. Data represented as mean ± SD. *: more sensitive than Sham, $p < 0.05$. Abbreviations: SIS = Porcine small intestinal submucosa, PEDOT = poly(3,4-ethylenedioxythiophene).

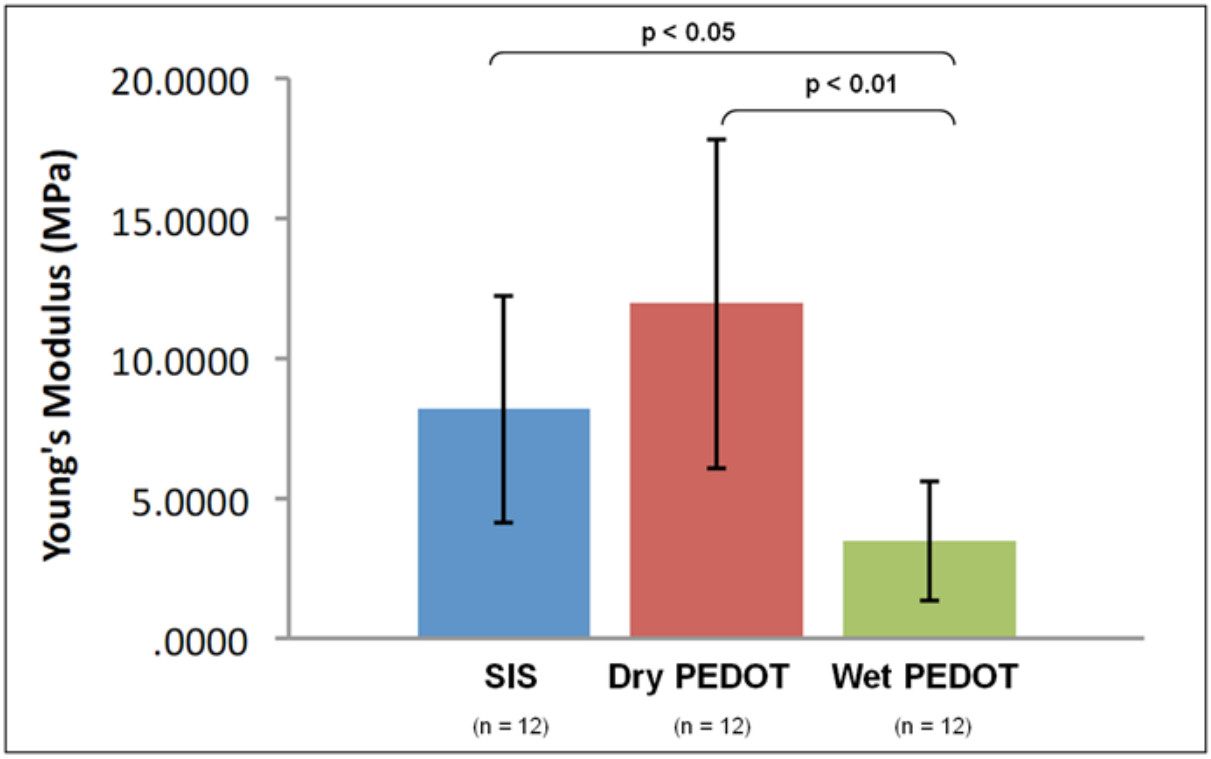

Figure 2. Stiffness of SIS scaffoldings. Higher values reflect greater stiffness. Data are represented as mean ± SD. SIS: Porcine small intestinal submucosa. PEDOT: poly(3,4-ethylenedioxythiophene).

Conclusions: Both the von Frey system and the histologic analysis quantitatively stratify rats with and without neuromas. Neuroma formation in the presence of Wet PEDOT was not different compared to SIS scaffolding alone; the polymer's mechanical pliability may contribute to this phenomenon.

References

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Acknowledgements

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