Mechanical testing of nerve guidance conduit materials for peripheral nerve repair

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INTRODUCTION: A long-standing challenge in the development of nerve guidance conduits (NGCs) is to achieve a balance between required mechanical strength to withstand physiological stresses whilst mimicking natural nerve biomechanics to support endogenous peripheral nerve repair. Currently, there are several FDA-approved NGCs [1], however the stiffness of these hollow tubes tends to be greater than that of a nerve since they must maintain a patent lumen [2]. Conversely, conduits with an internal framework of engineered tissue can have a reduced stiffness [3]. In this study, we carried out tensile tests to investigate the breaking force of a rat sciatic nerve and that of potential NGC replacement materials, in particular natural and synthetic membranes.

METHODS: Sciatic nerves were harvested from Sprague-Dawley rats (200 – 260 g). Nerves had a diameter of 1.33 ± 0.32 mm and a length of 20 mm. Two collagen-based membranes and a Poly Lactic Acid (PLA)-based material were also evaluated, namely CM-A, CM-B and PLA. Material thickness was determined using a contact angle measurement machine (CAM 200, KSV Instruments). Samples were then prepared by cutting the membranes into an hourglass shape with a width of 10 ± 1 mm, a height of 20 ± 1 mm and a central width of 5 ± 1 mm. Each membrane was hydrated in phosphate buffered saline for 5 minutes prior to mechanical testing. Tensile testing was performed with a 10 mm gauge length in uniaxial tension using a Bose Electroforce 3200 machine with an extension rate of 10 mm/min. Ultimate tensile stress (UTS) refers to the amount of force per unit of initial cross-sectional area at tensile failure.

RESULTS: Results reveal that CM-A is thinnest of the tested membranes, closely followed by CM-B, whereas the PLA-based membrane was the thickest (*Table 1*).

Figure 1 shows that the sciatic nerve has a UTS of 3.4 ± 0.4 N/mm^2, whereas a sheet of CM-A is considerably less at 0.9 ± 0.2 N/mm^2. The CM-B material has a break force that is greater than that of CM-A, 1.7 ± 0.2 N/mm^2. The PLA-based membrane has the greatest break force compared to the other membranes and most similar to a sciatic nerve, at 2.4 ± 0.3 N/mm^2.

Table 1. Thickness of prospective NGC materials.

Material	*Thickness, mm*
Collagen-based membrane A	0.29 ± 0.03
Collagen-based membrane B	0.33 ± 0.02
PLA-based membrane	0.37 ± 0.03

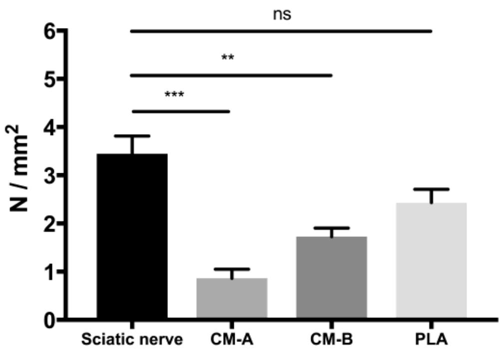

*Fig. 1: Ultimate tensile stress for sciatic nerve, CM-A, CM-B and PLA- based membranes. Data are means ± SEM, where n = 4. Statistical analysis was performed using one-way ANOVA, ns: non significant, **p<0.01, ***p<0.001.*

DISCUSSION & CONCLUSIONS: The UTS of the collagen membranes were approximately 75% (CM-A) and 50% (CM-B) less than that of a sciatic nerve, suggesting they may not be suitable as NGCs as a single sheet. Statistical analysis revealed significant differences between collagen-based membranes and sciatic nerve but no difference between the sciatic nerve and PLA-based membrane. Our data suggest that this particular PLA-membrane could be used as a potential NGC material for peripheral nerve repair. Future work would involve developing materials with similar properties to nerve.

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