MECHANICAL BEHAVIOR OF NERVE CONDUITS BASED ON OXIDIZED POLYVINYL ALCOHOL AND CARBON NANOTUBES

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Introduction

Nerve conduits (NCs) based on bioresorbable polymers represent a promising alternative to nerve autografts, being currently the gold standard in the treatment of severe peripheral nerve injuries. Since the outcomes associated with commercially available devices are not fully satisfactory, there is interest in designing innovative NCs to overcome their limitations. To this purpose, NCs based on oxidized polyvinyl alcohol (OxPVA) already proved their ability in sustaining axonal regeneration in pre-clinical studies [1]. In the present study, OxPVA was combined with multi-walled carbon nanotubes (CNTs) to confer enhanced electrical properties that are expected to encourage material-neuron interactions and promote nerve regeneration [2]. Possible modifications in the mechanical properties, due to the CNTs incorporation, were here investigated analyzing the OxPVA+CNTs NCs tensile behavior through uniaxial tensile test. Indeed, NCs should be able to bear sutures, to provide anti-compression protection, but also to have suitable ability to withstand the strain generated during limb activities, thus protecting the new axons.

Material and methods

OxPVA solution was obtained through a partial oxidative reaction (oxidation degree: 1%) in accordance with a previously published protocol [1]. Hence, once the CNTs were covalently functionalized with benzenesulfonate groups to allow their dispersibility in water, the hybridization with OxPVA solution occurred through mechanical embedding (0.1 wt% of CNTs).
The NCs were fabricated by cast-molding technique (Figure 1A). Briefly, the hydrogel solution was sucked into a stainless-steel cylindrical mold (internal diameter: 2.1 mm) and a coaxial stainless-steel plunger (external diameter: 1 mm) was placed into to create the internal lumen of the conduit. Cross-linking of the polymer occurred by six freeze-thawing (FT) cycles (F at -20°C for 6 h and T at room temperature (RT) for 1 h).
For uniaxial tensile tests, samples of OxPVA and OxPVA+CNTs NCs (4 samples/group) with a free length of 1 cm were let thaw for 1 h at RT, immersed in phosphate buffer saline solution. The tests were performed at strain rate of 0.5 % s^{-1}, up to 50 % strain in hydrated conditions using the Bose ElectroForce® Planar Biaxial Test Bench instrument (TA Instruments, New Castle, USA). In view of future *in vivo* trials, the same test was performed on 4 samples of sciatic nerve excited from two Sprague-Dawley rats (Authorization n. 837/2019-PR, 09 December 2019) used as controls.

Results and discussion

The results of preliminary uniaxial tensile tests are shown as nominal stress σ_n vs. nominal strain ε for two NC samples (OxPVA and OxPVA+CNTs) and for one sciatic nerve sample (Figure 1B). It can be observed that the curves σ_n-ε of OxPVA and OxPVA+CNTs NCs have almost superimposable trend. Moreover, the NCs are able to withstand deformation in the physiological strain range [3] without fracturing.
Although many studies reported an increase in the polymer stiffness due to CNTs inclusion, no differences were detected here comparing the mechanical behaviour of OxPVA and OxPVA+CNTs. This feature may descend from the low CNTs concentration within the hydrogel. Previous preclinical studies demonstrated that OxPVA NCs guarantee structural support *in vivo*, resisting to suture and physiological loads, and allowing morpho-functional regeneration/recovery of the nerve in animal model of disease (gap: 5 mm) [1]. According to the data in the present study, the absence of significant difference in tensile behaviour after the addition of CNTs allows us to assume that also OxPVA+CNTs NCs would be able to provide for an adequate mechanical behaviour *in vivo*.

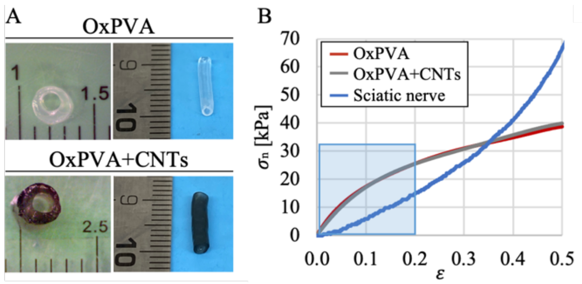

Figure 1: (A) NCs optical microscope images: cross-sectional and lateral views; (B) Uniaxial tensile behavior of two samples of OxPVA and OxPVA+CNTs NCs and of a sample of sciatic nerve. The blue square highlights the range of rat sciatic nerves physiological deformations.

References

1. Stocco E et al, Sci Rep, 8(1):604, 2018
2. Homaeigohar S et al, Carbohydr Polym, 224:115112, 2019
3. Boyd BS et al, J Orthop Res, 23(4):764-70, 2005