Assessment of the mechanical properties of nano-cellulose constructs designed for auricular cartilage engineering

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Like any cartilaginous tissue the external part of the ear, the auricle, cannot regenerate once damaged. The state-of-the-art for auricle reconstruction is surgical reconstruction with autologous cartilage. Tissue engineering (TE) is a potential alternative that would advantageously minimize the amount of harvested cartilage. The TE auricle should allow for daily activities (e.g. sleeping, wearing earphones), therefore adequate mechanical properties are key. The various biodegradable scaffolds investigated in literature showed poor mechanical properties after in vivo implantation due to inadequate degradation rates. Nano-cellulose (NC) is a non-biodegradable biomaterial, and is therefore a promising scaffold material for ear reconstruction. This study aims to characterize the mechanical properties of various NC constructs and compare them to human auricular cartilage to decide the best candidate for auricular TE.

Materials and Methods

Human auricular cartilage (n=5) is harvested during repair surgery. Three different NC scaffolds are produced by bacterial synthesis: 5%-NC (95% water, n=5), 2%-NC (n=7), microporous NC (n=6). 5x5 mm$^2$ samples are tested in stress-relaxation indentation (5%-strain steps with 30 minutes relaxation) on a Zwick-Z005 machine (10 N load cell, Ø0.9 mm indenter). Material properties, instantaneous ($E_{in}$), equilibrium modulus ($E_{eq}$) and maximum stress ($\sigma_{\text{max}}$), are computed.

Results

Native auricular cartilage has a higher $E_{eq}$ (1184.6 ± 676.4 kPa) than 5%-NC (194.7 ± 49.0 kPa) and 2%-NC (92.5 ± 42.5 kPa). Microporous NC was too soft to be measured in the system.

Discussion and Conclusions

NC mechanical properties are highly tunable, with stiffness ranging from < 15 kPa up to 200 kPa, where 5%-NC scaffolds have the greatest potential for TE. In future, the scaffold strength will be improved with higher cellulose concentrations. Extracellular matrix production after in vivo implantation of cell-seeded scaffolds will further strengthen the mechanical properties of the constructs, making them a relevant choice for auricular TE efforts.

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