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Designing Three-Dimensional Piezoelectric Scaffolds for Neural Tissue Engineering

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Piezoelectric materials are a class of inorganic and organic materials that can transform electricity into mechanical force and vice versa. In crystals, piezoelectricity is explained by the displacement of ions in materials that have a nonsymmetrical unit cell. [1,2].

The overall objective is devoted to designing and developing a novel smart piezoelectric polymer scaffold belonging to the type of conducting and stimuli-responsive scaffolds dedicated to neural engineering applications. The smart scaffold will significantly improve the effectiveness and safety of medical nerve reconstruction procedures. Polyvinylidene fluoride (PVDF) was chosen as one of the most piezoelectric polymer with various piezoelectric crystal modifications, depending on the forming conditions.

PVDF (Mw = 180 000 g/mol) nanofibers were electrospun from 25% solution of dimethylformamide and acetone (DMF/Ac 4:1 weight ratio) at the positive voltage of 16 kV applied to the needle, feed rate 0.2 mL/h (3 mm needle) and collected on drum collector (diameter 40 mm) at a distance between the needle and collector 180 mm. Human adipose-derived stromal cells (ADSCs) were cultured in osteogenic medium on the piezoelectric PVDF scaffolds electrospun with different collector rotational speed (200, 1000, and 2000 rpm) and subjected to ultrasound stimulation (power 80 mW, frequency 1.7 MHz) for 30 minutes every 24 hours. ADSCs seeded on piezoelectric PVDF scaffolds without ultrasonic stimulation were used as a control for each group. In order to confirm the piezoelectric effect on ADSCs viability, PrestoBlue cell viability test was performed on days 3, 14, and 21. Results were statistically analyzed using the Student's t-test. The observations of fibers and cell morphology were conducted using Scanning Electron Microscopy (SEM), Fourier-transform infrared spectroscopy (FTIR), and Differential scanning calorimetry (DSC).

The application of various process parameters allows for electrospinning of thin PVDF fibers with the preferred spatial arrangement and high polar phases content. Our cellular studies under in vitro conditions show that such nonwovens constitute promising smart scaffolds for tissue engineering applications, especially when stimulated by ultrasounds in order to activate their piezoelectric properties. PVDF nonwovens stimulated by ultrasounds is advantageous for cell viability. The obtained preliminary results are promising from the perspective of tissue engineering applications.

References:
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