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A Textile-Based Scaffold for Skin Replacements

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Abstract : The therapeutic treatment of extensive, deep wounds is limited. Autologous split-skin grafts are used as a so-called 'gold standard'. Most common deficits are the defects at the donor site, the risk of scarring as well as the limited availability and quality of the autologous grafts. The aim of this project is a tissue engineered dermal-epidermal skin replacement to overcome the limitations of the gold standard. A key requirement for the development of such a three-dimensional implant is the formation of a functional capillary-like network inside the implant to ensure a sufficient nutrient and gas supply. Tailored three-dimensional warp knitted spacer fabrics are used to reinforce the mechanically week fibrin gel-based scaffold and further to create a directed in vitro pre-vascularization along the parallel-oriented pile yarns within a co-culture. In this study various three-dimensional warp knitted spacer fabrics were developed in a factorial design to analyze the influence of the machine parameters such as the stitch density and the pattern of the fabric on the scaffold performance and further to determine suitable parameters for a successful fibrin gel-incorporation and a physiological performance of the scaffold. The fabrics were manufactured on a Karl Mayer double-bar raschel machine DR 16 EEC/EAC. A fine machine gauge of E30 was used to ensure a high pile yarn density for sufficient nutrient, gas and waste exchange. In order to ensure a high mechanical stability of the graft, the fabrics were made of biocompatible PVDF yarns. Key parameters such as the pore size, porosity and stress/strain behavior were investigated under standardized, controlled climate conditions. The influence of the input parameters on the mechanical and morphological properties as well as the ability of fibrin gel incorporation into the spacer fabric was analyzed. Subsequently, the pile yarns of the spacer fabrics were colonized with Human Umbilical Vein Endothelial Cells (HUVEC) to analyze the ability of the fabric to further function as a guiding structure for a directed vascularization. The cells were stained with DAPI and investigated using fluorescence microscopy. The analysis revealed that the stitch density and the binding pattern have a strong influence on both the mechanical and morphological properties of the fabric. As expected, the incorporation of the fibrin gel was significantly improved with higher pore sizes and porosities, whereas the mechanical strength decreases. Furthermore, the colonization trials revealed a high cell distribution and density on the pile yarns of the spacer fabrics. For a tailored reinforcing structure, the minimum porosity and pore size needs to be evaluated which still ensures a complete incorporation of the reinforcing structure into the fibrin gel matrix. That will enable a mechanically stable dermal graft with a dense vascular network for a sufficient nutrient and oxygen supply of the cells. The results are promising for subsequent research in the field of reinforcing mechanically weak biological scaffolds and develop functional three-dimensional scaffolds with an oriented pre-vascularization.

Keywords : fibrin-gel, skin replacement, spacer fabric, pre-vascularization
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