Composite nanofibrous yarns enhancing human dermal fibroblast adhesion, growth, and ECM formation for surgical applications

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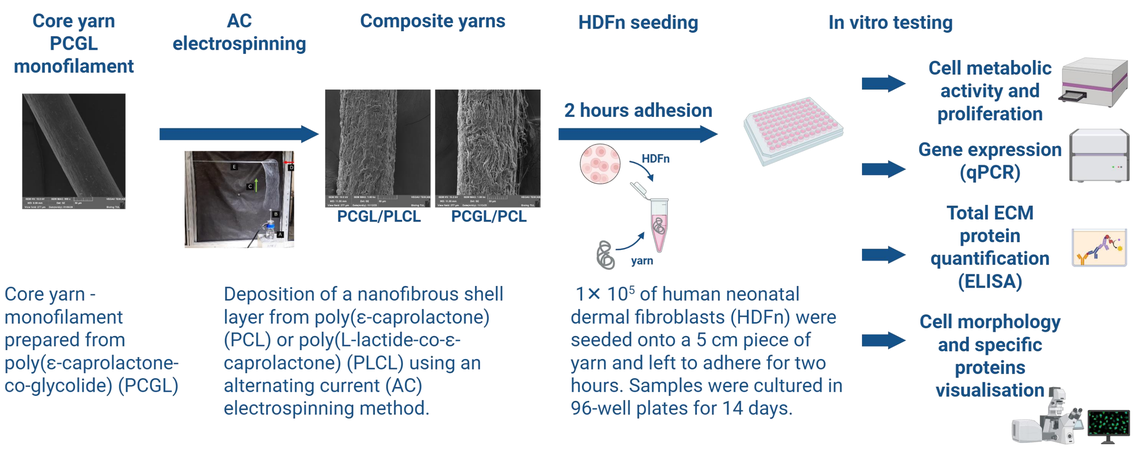
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INTRODUCTION:

Surgical sutures and fibrous implants are essential for tissue repair, yet their performance is often limited by poor tissue integration and insufficient regenerative support, as smooth monofilaments provide mechanical strength but lack bioactive surfaces for efficient cell attachment and extracellular matrix (ECM) formation. To address this, composite yarns combining a core providing mechanical strength with a nanofibrous coating prepared by alternating current electrospinning (AC electrospinning) have been developed. These nanofibrous structures mimic native ECM and enhance cell adhesion, proliferation, and tissue-specific function. In this study, we evaluated composite nanofibrous yarns consisting of a poly(ε-caprolactone-co-glycolide) (PCGL) monofilament core coated with poly(ε-caprolactone) (PCL) or poly(L-lactide-co-ε-caprolactone) (PLCL) nanofibers, focusing on their interaction with human dermal fibroblasts (nHDF). Cell adhesion, proliferation, and ECM production were assessed in comparison with a smooth monofilament control.

METHODS:



RESULTS:

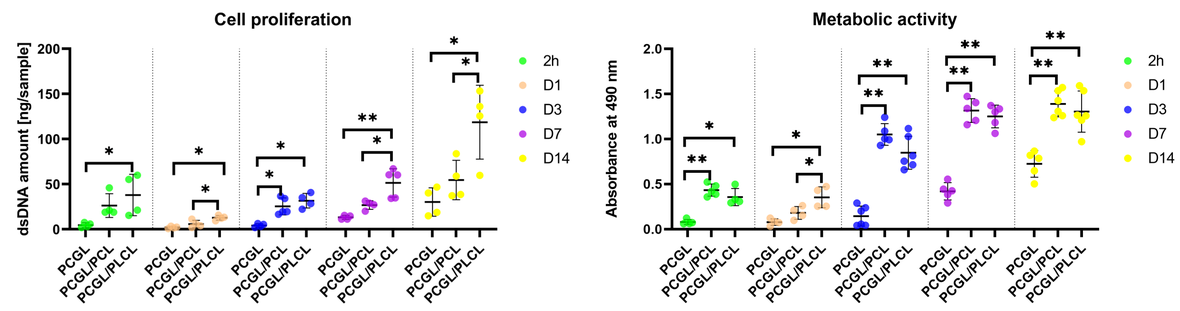


Fig. 1: Metabolic activity and proliferation of HDFn cultured on PCGL monofilament and composite yarns containing PCL (PCGL/PCL) and PLCL (PCGL/PLCL) nanofibers. Both metabolic activity (MTS assay) and proliferation (dsDNA quantification) were significantly higher on composite yarns compared to PCGL monofilaments. Statistical analysis was performed using GraphPad software (*p < 0.05, **p < 0.001).

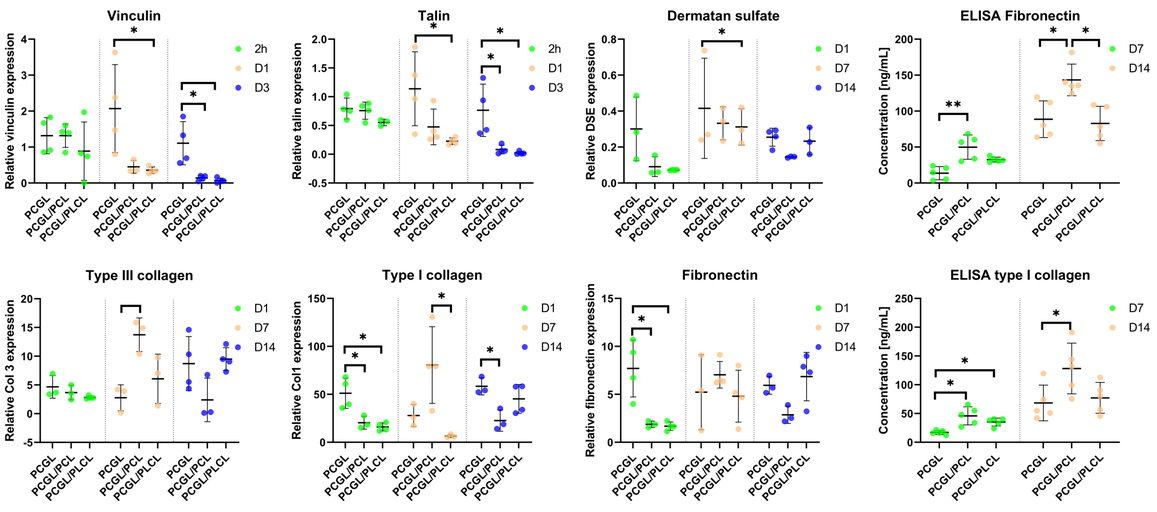


Fig. 2: Gene expression and total levels of adhesive and ECM proteins in HDFn cultured on PCGL monofilaments and composite yarns containing PCL (PCGL/PCL) and PLCL (PCGL/PLCL) nanofibers were evaluated by qPCR and ELISA. Although the expression of adhesive proteins (talin, vinculin) and selected ECM proteins (type I collagen, fibronectin, dermatan sulfate) was higher on PCGL monofilaments at early time points, total protein levels measured by ELISA on days 7 and 14 were significantly higher on PCGL/PCL composites. Statistical analysis was performed using GraphPad software (*p < 0.05, **p < 0.001).

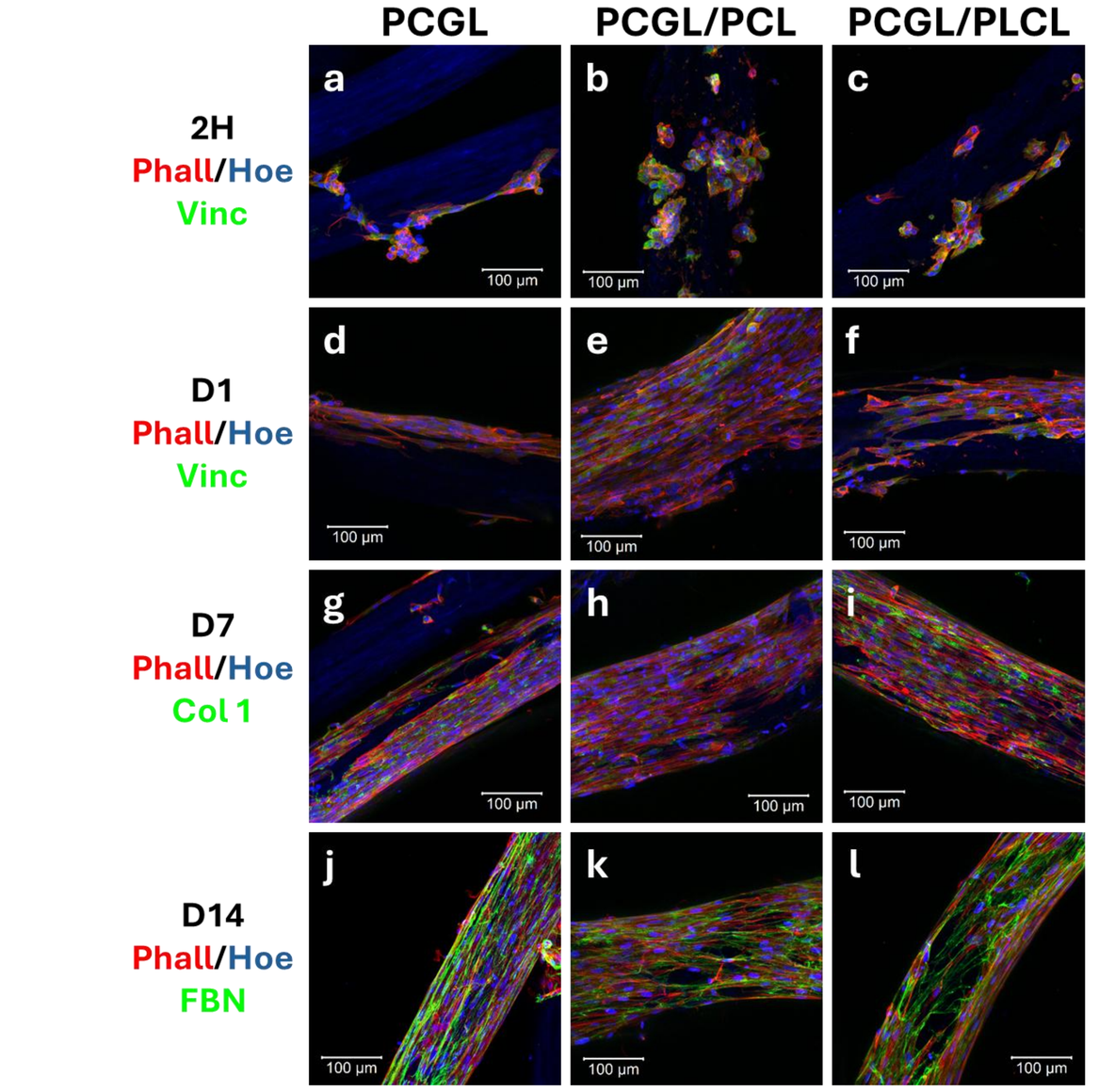


Fig. 3: Immunofluorescence staining and confocal microscopy visualisation of HDFn cultured on PCGL monofilaments and composite yarns containing PCL (PCGL/PCL) and PLCL (PCGL/PLCL) nanofibers. The cytoskeleton was coloured red (phalloidin), the cell nuclei were coloured blue (Hoechst), and the ECM components were stained using immunofluorescence (green). The adhesion marker vinculin was stained two hours (a, b, c) and one day (d, e, f) after seeding. ECM protein type I collagen (Col 1) was labelled on day 7 (g, h, i) and fibronectin (FBN) on day 14 (j, k, l). Scale bar: 100 µm..

DISCUSSION & CONCLUSIONS:

Nanofibrous coatings improved cell adhesion, spreading, and proliferation compared to the smooth PCGL monofilament, which showed lower overall biological performance. Both PCL and PLCL variants supported early cell attachment, consistent with their ECM-like architecture. Although DNA content increased only modestly over the 14-day culture period, microscopy confirmed ongoing cell proliferation and the gradual formation of confluent cell layers. Importantly, fibroblasts remained metabolically active and produced key extracellular matrix proteins, including fibronectin and type I collagen, with increasing deposition during culture. Overall, composite nanofibrous yarns promote cell adhesion and ECM formation, creating a favorable microenvironment for tissue regeneration and representing promising candidates for surgical applications.

ACKNOWLEDGEMENTS:

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