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Strain shielding as a biomechanical mechanism in scar sheet therapy

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Abstract

Scar sheets are soft medical devices consisting of a thin, adhesive elastomeric layer that can be directly applied to a scarred tissue region to provide targeted, self-administered therapeutic action. While clinical evidence shows successful reduction of scar thickness, elevation, redness and stiffness in both physiological and pathological conditions, the corresponding mechanisms of action remain unclear [1]. Commonly invoked factors include enhanced tissue hydration alongside local thermal and electrical effects and there exists one single FDA-approved device specifically designed to relieve scar tension. Intriguingly, recent computational work [2] suggests that the stiffness and shape of dressings for fresh wounds might influence the transmission of physiological forces to the wound bed. Since this would significantly mitigate the activation of mechanobiological pathways [3], we wondered whether strain shielding might similarly contribute to the clinical effectiveness of scar sheets and how such effect might depend on both the sheet and tissue characteristics. The first part of the talk will focus on the deformability of representative commercial scar sheets under finite strains, as well as their tension-relieving action, which we characterised using custom-developed experimental setups. Our findings indicate lack of consensus on the ideal characteristics of scar sheets, which differed widely among the tested devices. Regardless, all measured

Young's moduli match or exceed typical values previously reported for abdominal and breast skin [4]. We reasoned that scar sheets might stabilise the underlying tissue - and thus mitigate the activation of corresponding mechanobiological signals – irrespective of their tension-relieving action. To substantiate this hypothesis, we leveraged computational simulations to analyse the biomechanical interplay between the sheet and the underlying tissue at physiological loading levels. To this end, we developed 3D finite-element models assuming isotropic, hyperelastic material behaviour and perfect sheet adhesion. We quantified the strain mitigation associated with sheet application as the ratio between the average tissue strain in a sheet-covered region of interest and a no-sheet baseline. Systematic variations of geometrical and mechanical model parameters indicate that such ratio depends on the relative stiffness between the two modelled material layers. Our simulations reveal a hyperbolic relationship between strain mitigation and relative stiffness, consistent with an idealised model considering scar sheet and the underlying tissue as two springs in parallel. Overall, our study contributes to advancing the understanding of the biomechanical factors underlying scar sheet therapy by identifying strain shielding as a previously unreported mechanism. Future work will leverage computational models of scarring mechanobiology [5] to predict how this design parameter influences clinical outcomes. In the long term, we envision that our analyses will inform the development of optimised sheets tailored to subject-, location-, or scar-specific tissue characteristics, paving the way for personalised scar management approaches.

Keywords:

Biomedical Technology Finite-Element Modelling Scar Mechanobiology

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