Viscoelasticity, viscoplasticity and mechanobiological response of fibrous tissues: current concepts

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Background
Mechanobiology lies behind many injuries affecting fibrous tissues (FT), such as tendons, ligaments and fascias. It may therefore provide a significant contribution to the development of optimal healing strategies. There are still significant gaps in knowledge regarding if and how tissue response to biophysical stimuli is affected by viscoelasticity and viscoplasticity. Our main objective was to examine, through an exhaustive literature review, if and how viscoelasticity and viscoplasticity of live FT could influence tissue mechanobiological response.

Methods
We examined the current knowledge and hypothesis behind the origins of viscoelasticity and viscoplasticity in FT, their mechanobiological response and mechanotransduction pathways and carried out a synthesis of the results. We developed a simplified model (Fig. 1) to describe the dynamic competition between repair, enzymatic degradation and mechanical degradation of the extracellular matrix, which depends on tissue quality, as well as tissue viscoelasticity and viscoplasticity. Finally, we examined different stimulation parameters that could influence the mechanobiological response of live fibrous load-bearing tissues because of viscoelasticity and viscoplasticity.

Results
The key points are summarized as: 1) The molecules network forming the extracellular matrix (ECM) is responsible for the tissue macro-mechanical behaviours; 2) Because of their viscoelastic or viscoplastic macro-mechanical behaviours, FT mechanical reaction to biophysical stimuli is influenced by the type of stimulus input and the stimulus history; 3) Under macroscopic biophysical stimuli, ECM molecules are subjected to stress and strain, and could thus undergo mechanical degradation (MD). Changes to mechanical properties and ECM structure related to MD in FT are non-linear over time and heterogeneous across the tissue; 4) When FLBT are subjected to macroscopic biophysical stimuli, these stimuli are scaled down to microscopic biophysical stimuli which are, in turn, transformed into biochemical signals that the cells can sense. In response to these signals, the cell can degrade the ECM via enzymatic degradation (ED) or repair (R) it and 5) The tissue global mechanobiological response is the result of competitive dynamics between degradation and repair leading to an inverse-U relationship between stimulation and tissue quality.

Conclusion
Our analysis showed that viscoelasticity and viscoplasticity of live FLBT could influence tissue mechanobiological response, but experiments are required to confirm it. The impact of viscoelasticity and viscoplasticity may prove to have significant implications for in vivo clinical applications.

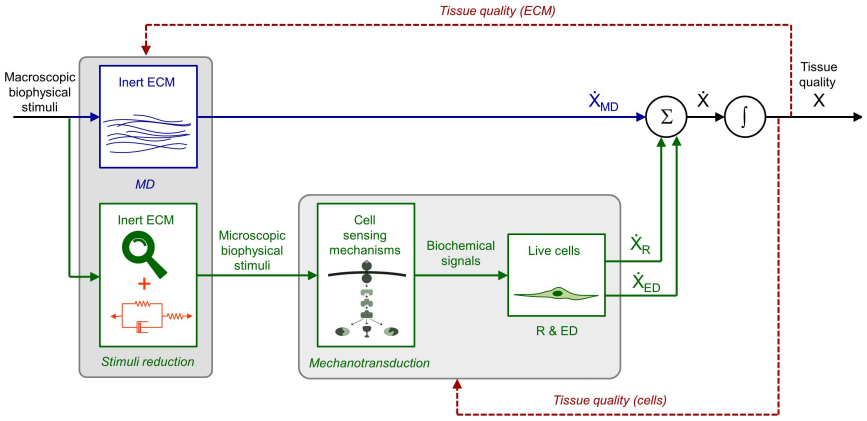

Figure 1: Block diagram model of the mechanobiological response of fibrous load bearing tissue under biophysical stimuli including the impact of viscoelasticity/viscoplasticity. (R stands for repair, ED for enzymatic degradation, MD for mechanical degradation of the extracellular matrix.)

References

Near a hundred articles were used in this study. Because of the restricted space, we were not able to list them all. However, a complete list of references will be available upon request to the authors.

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