Static-strain-induced adaptation of the fibrous periosteum

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Introduction
The mechanism by which fibrous tissues adapt in response to alterations in mechanical environment, e.g. during growth and wound healing, remains unresolved. We questioned how fibrous tissue adapts mechanically and biochemically in response to static strain. Periosteum of embryonic chicks was used as a model system.

Method
Periosteum of e15 chick Tibiotarsi was cultured for 3 days in a tensile tester at stretch levels ranging from 0.85 to 1.05 (for a detailed description, see caption fig 1).

After culturing, a standardized force-stretch curve was obtained from 0.75 stretch to failure at 0.1%/sec (fig 2). Native e15 periosteum was used as control. Mechanical parameters (transition and stiffness) and biochemical properties (DNA, GAG, collagen and HP cross-links) were used for comparison.

Results
The transition stretch always approximated the applied stretch after 3 days of culturing (fig 2). However, at lower applied stretches an offset is apparent.

Stiffness proportionally increased with applied stretch (fig 2 & 3). Stiffness of samples stretched to 1.05 was significantly higher compared to control (fig 3).

Fig 3. Stiffness is proportionally related to applied stretch (linear regression analysis; p<0.05; R² = 0.77). Asterisk represents a significant difference relative to e15 control (1-way ANOVA; bonferroni post-hoc test; p<0.05).

Significant decreases in collagen and HP cross-links were observed with applied stretch (fig 4). All stretch groups had significantly higher HP content relative to e15 control.

Discussion
Surprisingly, proportional increase in transition stretch and stiffness with applied stretch were inversely related to collagen and HP cross-link content. We therefore propose that the tissue adaptation mechanism is based on structural reorganization of the collagen network with highly aligned collagen at 1.05 stretch and less aligned collagen at 0.85 stretch. Subsequent cross-linking fixes the reorganized network, which can explain changes in mechanical properties. The incomplete transition shift in 0.85 stretched samples is attributed to fixation by cross-links that precedes network reorganization.

Conclusion
Applied static stretch is proportionally related to stiffness and transition stretch, however inversely related to collagen and HP cross-link content.

This insight improves our general understanding of growth and adaptation, useful for tissue engineering applications.

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