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Cavitation Rheology as a Potential Method for *in vivo* Assessment of Skin Biomechanics

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Evaluation of the biomechanical properties of skin is essential for characterization of wound healing kinetics and cutaneous diseases. Available techniques require tissue excision and preclude serial tissue assessment, which limit *in vivo* monitoring of biomechanical changes. Cavitation rheology (CR) is a method for focal assessment of the mechanical properties of materials.(1) An air cavity is created at the tip of a needle inserted into a material and pressurized until the material yields by rapid elastic deformation (cavitation) or irreversible fracture. An incisional wound model was utilized to determine if this technique could discern differences in the mechanical responses of skin in various states.

In accordance with our Institutional Animal Care and Use Committee guidelines, a full-thickness incision was created in the dorsal midline of six Sprague-Dawley rats (The Jackson Laboratory, Bar Harbor, ME) and then closed with a subcuticular suture (4-0 Monocryl, Ethicon, Somerville, NJ). Rats were euthanized 28 days post-wounding and skin was harvested. Cavitation was achieved with a 34-gauge needle (PY2-72-0081, Harvard Apparatus, Holliston, MA) connected to a syringe pump (Nexus 6000, Chemyx, Stafford, TX) and real-time pressure sensor (Cajon Transducer 300psi, Swagelok, Solon, OH). (Figure 1) Air was injected in multiple incisional and surrounding unwounded areas and yielding pressures were recorded. The preferred pathway for yield is a product of material properties and length scale, which can be determined as previously described.(1) Cavitated tissues were excised and stained with hematoxylin and eosin in standard fashion. Statistical comparison of yielding pressures was made using a two-tailed t-test. Statistical significance was assumed when $p < 0.05$.

Incisional skin yielded at a lower pressure than unwounded skin (Figure 2). Sampled sites (n=36, 18 incisional and 18 unwounded) demonstrated a significant difference ($p < 0.01$) in the mean yielding pressure of 69 kPa and 79 kPa for incisional and unwounded skin, respectively. Histological analysis demonstrated a reliable cavitation plane at the dermal-

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Commercial Product List

4-0 Monocryl, Ethicon, Somerville, NJ
34-gauge beveled needle, PY2 72-0081, Harvard Apparatus, Holliston, MA
Nexus 6000 syringe pump, Chemyx Inc., Stafford, TX
Cajon Transducer 300psi, Swagelok, Solon, OH
Sprague-Dawley rats, The Jackson Laboratory, Bar Harbor, ME

subcutaneous junction, consistent with the realtime observation of maintenance in skin integrity.

Non-destructive methods previously developed to measure cutaneous biomechanical properties have not achieved widespread application.(2, 3) The gold standard of tensiometry has several limitations.(3) Tissue must be excised and sectioned leading to shear stress on samples. Accurate measurements may also be confounded by tissue slippage in tensiometer clamps and imprecise timing of wound breakage. Additionally, methods that rely upon stretch cannot isolate individual layers of cutaneous tissues and their different biomechanical properties.

CR has been used to describe the *ex vivo* biomechanical properties of other animal tissues. (4) We have demonstrated the ability to reproducibly measure the biomechanical properties of skin in various states, with results consistent with previous findings.(5) *Ex vivo* measurements of the biomechanical properties of skin may not accurately reflect *in vivo* properties,(3) and our future studies will use *in vivo* models to compare the *ex vivo* and *in vivo* biomechanical properties of skin as assessed by CR.

We propose CR as a non-destructive method to assess cutaneous biomechanical properties. CR may provide accurate *in vivo* evaluation of biomechanical changes during cutaneous wound healing or disease evolution.

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Figure 1.

A schematic representation of the experimental apparatus used for CR. The inset demonstrates the expanding cavity of air (blue circle) within the dermis. The deformational force generated by this cavity (blue arrows) is opposed by the intrinsic elastic properties of the dermis (brown arrows).

Figure 2.

Box plot demonstrating yielding pressures for incisional (left) and unwounded (right) rat skin 28 days post-wounding. Error bars represent $\pm$ standard deviation.