The Wettability of Intrasynovial and Extrasynovial Tendons

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Purpose: The surface properties of biologic materials are important to their observed physiochemical responses, mechanical interactions, and compatibility with other materials. The purpose of this study was to characterize further the surface properties of canine tendons, specifically how they interface with fluids—that is, their wettability.

Methods: Drop-shape analysis was used to study contact angles on intrasynovial and extrasynovial tendon surfaces. This standard goniometric method was used to estimate tendon-wettability properties.

Results: This study showed that extrasynovial tendon portions (particularly the dorsal sides) are more wettable than intrasynovial tendons. We also showed that trypsin digestion of tendon surfaces increases their wettability.

Conclusions: The wettability differences between intrasynovial and extrasynovial canine tendons may help to explain known differences in the propensities of these 2 different tendon types to form adhesions after surgery. (J Hand Surg 2006;31A:1136–1141. Copyright © 2006 by the American Society for Surgery of the Hand.)

Key words: Tendon, wettability, contact angle, friction.

Many patients with complex damage to intrasynovial tendons (tendons that reside within a synovial sheath) require the use of an extrasynovial tendon graft because intrasynovial graft donor tendons rarely are available.[1–4] The clinical results of tendon grafting often are marred by adhesions, which limit graft motion.[5–7]

Considerable research has been performed to investigate the healing and function of tendon grafts, primarily in the canine model.[5–9] Extrasynovial tendons are different histologically and anatomically from intrasynovial tendons, resulting in major differences in the way these 2 different types of tendons heal.[5,6] An understanding of these differences in healing is important for reducing the morbidity associated with tendon grafting.

When extrasynovial tendons are used in intrasynovial locations the fibrovascular adhesions and increased friction often limit the finger motion and function.[7] Extrasynovial tendon surfaces are different from their intrasynovial counterparts: they are rougher and have differently adapted gliding surfaces[10] with a filmy multilayered paratenon, whereas intrasynovial tendons have a single cell layer of epitenon.[11] Extrasynovial tendons have a higher gliding resistance[8] and experience more robust vascular ingrowth[5,6,9] than intrasynovial tendons.

One potential difference between intrasynovial and extrasynovial tendons that has received less attention is how their surfaces interface with fluids (ie, their wettability). Wettability is an important physical property of many material surfaces and has been shown to be an important determinant of the likelihood of cells to adhere to a surface *in vitro*.[12–14] Wettability is a function of many factors including the composition of the surface material, the solubility of surface polymer constituents, and surface roughness.[15] Although its components are complex, wettability can be quantified by a relatively simple test: the contact angle of a drop of water on the material surface. Less-wettable, or hydrophobic, interactions (reported in degrees) show more obtuse contact angles, whereas more-wettable, or hydrophilic, interactions show more acute angles (a flattened appearance of the droplet is typical). Thus the greater the contact angle the less the wettability of the material sur-

face.[16] The wettability of living tissues also may be important to properties such as lubrication or adhesion.[17]

We hypothesized that there is a difference in intrasynovial and extrasynovial tendon wettability that is related to the obvious differences in surface morphology between these 2 tendon types: a smooth glistening epitenon for intrasynovial tendons and a rougher paratenon for extrasynovial tendons. Therefore in this study we measured the wettability of canine tendons, comparing intrasynovial and extrasynovial tendon portions. Specifically we studied the volar and dorsal sides of the canine peroneus longus (PL), a purely extrasynovial tendon, and the flexor digitorum profundus (FDP), a tendon with intrasynovial and extrasynovial regions. To gain insight on the impact that noncollagenous tendon surface glycoproteins might have on surface wettability we measured the wettability of the same tendon specimens after their surfaces were treated with trypsin.

Materials and Methods

Specimens

Canine FDP and PL tendons were harvested from dogs that had been killed in the course of another Institutional Animal Care and Use Committee–approved study that investigated short-term drug effects on cardiovascular physiology, after which dogs immediately were killed humanely. Tendons were dissected immediately after the dogs were killed. They were kept moist in normal saline solution and studied on the dissection day to avoid autolytic surface degradation. The FDP tendons were harvested from the tendons' insertions (distal phalanx) to just proximal to the ends of the synovial digital sheath. The dissected FDP thus had both intrasynovial and extrasynovial portions (Fig. 1). The PL tendons were harvested from the lateral aspect of the canine hind legs. The PL is a purely extrasynovial tendon and its paratenon was excised surgically before the study, as often is recommended clinically.[18] Five different FDP tendons from 5 different dogs and 5 different PL tendons from 4 different dogs were used in this study.

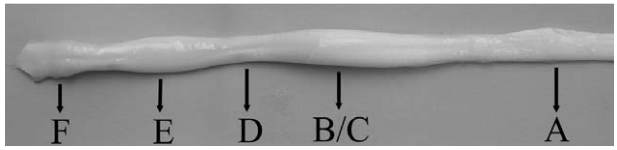

Figure 1. Volar view of canine FDP areas A, B/C, D, E, and F.

Canine FDP tendons within the digital sheath have been described as having discrete areas of specialization; the anatomic, histologic, and biochemical features change along the length of the tendon.[19] The FDP area F is just proximal to the tendon's insertion; FDP area E is a 5- to 7-mm–long area of fibrocartilaginous metaplasia at the level of the proximal interphalangeal joint; FDP area D is in contact with the proximal digital annular ligament; FDP areas B and C represent a 12- to 14-mm–long area of dorsal fibrocartilaginous metaplasia and palmar tendon, respectively, at the level of the metacarpophalangeal joint; and FDP area A is just proximal to and outside of the digital sheath. Flexor digitorum profundus area A (Fig. 1) and the PL tendons are considered extrasynovial because they do not reside within a synovial sheath. The dorsal and volar sides of the FDP and PL tendons were studied separately and compared with 1 exception: the dorsal FDP area F was not studied because it corresponds to the FDP tendon insertion to bone.

After the wettability of intact tendons was measured the tendons were digested by immersion in 5 mL of 0.25% trypsin (Sigma T0303, St. Louis, MO) dissolved in phosphate-buffered saline at 37°C for 2 hours. Trypsin and other nonspecific proteases do not digest collagen, which has its own specific proteases.[20] Immediately after digestion the treated tendons were washed and the wettability of all tendon areas on the volar and dorsal sides was remeasured.

Goniometry

The tendon specimens were mounted horizontally in the focal plane of a horizontal microscope (Olympus CK40, Center Valley, PA) with digital image capture capability and a light source. Drops (0.7 μL) of deionized distilled water (ddH_2O) were used as the contact-angle test liquid. It was added to test surfaces by the static/sessile method to avoid spheric distortion and inaccuracy[21] using a calibrated pipette (P2, Chang Bioscience, Castro Valley, CA) and hand support. This improved static droplet consistency. Sharp and focused baselines between the water–surface interfaces were established before image capture for accurate angle quantification. The images typically were captured approximately 10 seconds after the drop was added; the delay was needed to permit vibrations of the expelled water drop to dampen.[22] The contact-angle silhouette was imaged optically and the angle (on the left and right sides) was estimated by computerized goniometry using an algo-