Introduction: Repair site gap formation is a common occurrence following digital flexor tendon repair, with average gaps of 2-3 mm reported after early motion rehabilitation [1]. Gap formation has been associated with poor digital function [2] and delayed healing [3]. In order to improve repair site strength and minimize gap formation, multistrand suture techniques have been developed. The average ultimate force of multistrand techniques has been shown to be greater than the force of traditional two-strand techniques [4,5], but their resistance to gap formation has not been reported. Furthermore, no correlation between gap formation and the tensile force-elongation behavior of repaired tendons has been described. Our objective was to determine the resistance of four-strand and eight-strand suture techniques to gap formation during ex vivo tensile testing. We hypothesized: 1) that a 1 mm gap would form before ultimate force was attained, while a 3 mm gap would form after ultimate force, and 2) that an eight-strand repair would sustain higher force levels at 1 and 3 mm gaps than would a four-strand repair.

Methods: The flexor digitorum profundus tendons on the second and fifth digits of the right forelimbs of 15 adult dogs were cut and immediately repaired by either a four-strand or eight-strand suture technique. The fourstrand technique was a modified Kessler repair performed with double-stranded Supramid suture, while the eight-strand technique consisted of the four-strand repair performed twice (in orthogonal planes) using a continuous suture loop. A running epitendinous suture (6-0 Prolene) was performed on all tendons. After surgery, the forelimbs were immobilized in casts except during daily sessions of passive motion rehabilitation (10 minutes/day). Dogs were sacrificed on the tenth postoperative day and the repaired tendons dissected. Our institutional animal studies committee approved all procedures. For this study we analyzed the behavior of 16 tendons (8 of each repair type) that had no evidence of repair site gap. The tendon-distal phalanx specimens were tested to failure in tension (Instron 8500R). Force, elongation and repair site strain (determined using a PC Reflex motion analysis system with an accuracy of 0.01 mm) data were recorded at 60 Hz. Synchronized video records of the tests (including a calibrated ruler in the field) were obtained at 60 frames/sec using a digital VCR. Gaps were measured during playback of the video, and the times at the onsets of 1 and 3 mm gaps were noted (Fig. 1). The video analysis was repeated three times and the average times were recorded. These times were used to determine the force and strain levels at 1 and 3 mm gap. The precision of this technique was determined to be 3.5%.

Results: Ultimate (maximum) force was significantly greater for eight-strand (87 ± 16 N) than for four-strand (58 ± 5 N) repairs (p<0.001), whereas repair site strains at failure were not different (0.14 ± 0.03 vs. 0.13 ± 0.06, p = 0.61). A 1 mm gap typically formed prior to ultimate failure (when the elongation was 90% of the ultimate elongation), while a 3 mm gap occurred after failure (when the elongation was 120% of the ultimate elongation) (Fig. 2). The eight-strand repairs sustained significantly higher force at 1 mm gap than the four-strand repairs (p < 0.001), whereas the force sustained at 3 mm gap did not differ between repair types (p=0.81) (Fig. 3).

Discussion: We analyzed gap formation during ex vivo tensile testing of canine flexor tendons 10 days after suture repair. Our data support the following conclusions: 1) 1 mm gaps form near the ultimate failure point of the tendon, while 3 mm gaps form well after ultimate failure. 2) Up to the point of ultimate failure, the eight-strand repair is superior to the four-strand because it resists much larger forces, but after ultimate failure the eight-strand repair is comparable to the four-strand. 3) Multistrand suture techniques should be refined with the objective of sustaining high levels of force both before and after gap formation. 4) The average force of 40 N sustained after 3 mm gap formation is only 10 N greater than the force required for active digital flexion [6], indicating that the occurrence of a 3 mm gap in vivo may put a tendon at risk for rupture, regardless of suture type. 5) Techniques to monitor gap formation in vivo should be developed to identify tendons at risk for complete rupture so that the patient’s activity can be restricted.

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