Introduction: Many techniques of flexor tendon repair have been described, with the modified Kessler technique being the most frequently used and the preferred technique of many surgeons. Some investigators have suggested the use of minimal or no distal (i.e., more than the usual two) suture techniques to reduce the risk of rupture of the repair with early active motion. Such techniques have been shown to have greater breaking strength in vitro (1) but at the expense of increased the work of flexion, an indirect composite measure which includes not only the friction associated with tendon gliding, but also joint friction and the work of moving the mass of the distal part of the digit(2). So (0.5). Each method was able to isolate the resistance within the tendon sheath, which is the only resistance directly affected by the tendon repair. This study reports the isolated frictional resistance between the repaired tendon and tendon sheath in a canine model, using several commonly employed repair techniques.

Materials and Methods: 36 forepaws were harvested from 18 adult mongrel dogs. The dogs, which weighed 21-27 kg, had been sacrificed for other purposes. The second, third and fourth digits of each forepaw were used; in each digit the proximal phalanx, flexor digitorum profundus (FDP) and superficialis (FDS) tendons and A2 pulley were preserved, and all other tissue dissected away. The gliding resistance between the FDP and A2 pulley, FDS and bone was measured using the method of Uchiyama et al (3). The proximal phalanx (with PIP joint, A2 pulley, and FDP) was mounted on a custom jig with a 500gm weight attached to the distal end of the FDP tendon. A mechanical actuator attached to the proximal FDP pulled the tendon at a rate of 2mm/sec against the weight and then reversed at the same rate to simulate flexion and extension. All specimens were kept moist throughout testing by immersion in a saline bath, which was incorporated into the testing jig.

The FDP tendons were then lacerated to 80% of their transverse section (4) at the level of the proximal interphalangeal joint, and each tendon was then repaired with one of the following five randomly assigned core suture techniques: 1) Kessler, 2) Modified Kessler, 3) Savage, 4) Lee, and 5) MGH. All suture techniques were reinforced with a circumferential epitendon simple running suture. A sixth group was repaired with the running suture alone, without a core suture. A 50 Ticon suture was used for all core sutures except the MGH, which used a 50 nylon suture. The epitendon running suture was sutured with a 60 nylon suture in all cases. In order to investigate the gliding characteristics after tendon repair, all suture knots and loops were located on the tendon surface facing the A2 pulley, and the laceration was positioned so that it would pass beneath the A2 pulley during testing. The gliding resistance of the sutured tendon was then measured as in the intact state. After the resistance tests, the repaired tendons were removed from their sheath and mounted on an Instron testing machine, using specially-designed clamps to secure the tendon ends. The tendon was distracted to failure at a rate of 20mm/min and the gap formation between the tendon ends was measured continuously by a linear displacement sensor (MicroStrain, Burlington, VT).

Figure 1

Results: In intact tendons, there was no significant difference in the gliding resistance by digit. Comparing suture methods, the gliding resistance of the Savage, Kessler, and MGH repairs were all significantly higher than the gliding resistance of the running suture alone, or the modified Kessler and Lee suture methods (p<0.05). The modified Kessler had significantly less gliding resistance than the Lee repair, while the running suture alone had significantly less resistance than any of the five core suture techniques (all p<0.05). There was no significant difference between the Savage, Kessler, and MGH Knots and loops outside the tendon repair site may carry a cost: the breaking strength of these repairs in vitro (which does confirm greater strength in the multistrand repairs) is already well described in complete laceration models; our desire to have as near perfect apposition as possible, so that the design of the specific repair techniques would be, as much as possible, the only variable; and, finally, our plans to study these repairs in vivo as well, where a partial laceration model will allow active mobilization. All repairs included a running epitendon suture, based on previous work, which showed that repairs without this suture had unacceptably high friction(6). We were concerned that without this epitendon suture, the effect of triggering of the laceration on the pulley would completely overshadow any effect from the different repairs. Based on this study, we conclude that, in this in vitro dog model, the modified Kessler core suture has less gliding resistance under the A2 pulley than do the Savage, Kessler, Lee, and MGH core sutures. We further conclude that all loops and knots outside the tendon surface have the effect of increasing frictional resistance. We believe the strength of this study is its direct measurement of tendon gliding resistance, at its most critical area – under the A2 pulley where most tendon adhesions occur. Further, we have included not just the FDP and A2 pulley, but also the FDS and bony interaction, giving a more complete picture of frictional resistance in this area. The weaknesses of this study are that it does not measure the entire intact tendon sheath; that it is an in vitro study; and the fact that animal results may not mimic the human situation. We plan to study these tendon repairs in vitro in human tendons and to extend this study to in vivo canine experiments in the future.

Discussion: Of the core sutures studied, the modified Kessler had the least resistance to tendon gliding. This study shows that the stronger, multistrand flexor tendon repairs, such as the Savage and MGH, and those repairs with knots, such as the Kessler, outside the repair site may carry a cost: increased gliding resistance beneath the A2 pulley. The running suture alone had the least resistance to gliding, suggesting that each incremental violation of the tendon surface by a suture has a frictional cost, at least in our in vitro model. Our decision to use a partial laceration model was based on three considerations: the breaking strength of these repairs in vitro (which does confirm greater strength in the multistrand repairs) is already well described in complete laceration models; our desire to have as near perfect apposition as possible, so that the design of the specific repair techniques would be, as much as possible, the only variable; and, finally, our plans to study these repairs in vivo as well, where a partial laceration model will allow active mobilization. All repairs included a running epitendon suture, based on previous work, which showed that repairs without this suture had unacceptably high friction(6). We were concerned that without this epitendon suture, the effect of triggering of the laceration on the pulley would completely overshadow any effect from the different repairs. Based on this study, we conclude that, in this in vitro dog model, the modified Kessler core suture has less gliding resistance under the A2 pulley than do the Savage, Kessler, Lee, and MGH core sutures. We further conclude that all loops and knots outside the tendon surface have the effect of increasing frictional resistance. We believe the strength of this study is its direct measurement of tendon gliding resistance, at its most critical area – under the A2 pulley where most tendon adhesions occur. Further, we have included not just the FDP and A2 pulley, but also the FDS and bony interaction, giving a more complete picture of frictional resistance in this area. The weaknesses of this study are that it does not measure the entire intact tendon sheath; that it is an in vitro study; and the fact that animal results may not mimic the human situation. We plan to study these tendon repairs in vitro in human tendons and to extend this study to in vivo canine experiments in the future.

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References