LETTER
TO THE EDITOR

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Multilevel Multiplane Two-Strand Technique for Flexor Tendon Repair: A Theoretical Proposal and Physical Considerations

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SUMMARY
This report speculates a new type of two-strand flexor tendon repair, which incorporates the advantage of multiple anchor points of multistrand techniques. This article also highlights importance of considering comparative physics in tendon repair.

KEY WORDS
Flexor tendon; repair; suture; multistrand; two-strand.

To the Editor,
biomechanically proven superiority of modern multistrand repairs has led to some distancing from the classical two-strand techniques (1). The essential requirements for the ideal flexor tendon repair include easy atraumatic suture placement and sufficient strength of the tendon anastomosis to allow early mobilization and to prevent gapping (2). In multistrand repairs, these prerequisites are somewhat contradictory, because repair complexity and traumatization increase with the number of the core sutures, *i.e.*, with repair strength (3). Another drawback of multistrand repairs is that it is difficult to equalize tension between separate core sutures. Differential loading of individual strands weakens the repair (2) and may produce gapping. Furthermore, an excessive amount of foreign material within the tendon is undesirable.
The main advantage of the multistrand repairs is that they have a larger number of anchor points (3) compared to two-strand techniques. Betz *et al.* have shown that integration of the latter feature into Zechner two-strand repair (which includes locking loops of Kirchmayr-Kessler-type repairs (**figure 1A**)) by insertion of additional blocking loops significantly strengthens the tendon juncture (4). A problem with this modification may be that the suture loops are positioned on the same axis (**figure 1B**), which suggests that, differently from multistrand repairs, the same fiber bundles of the tendon are loaded, because tendons are comprised of longitudinally oriented collagen fibers (5, 6). This may contribute to damage of the anchored fiber bundles and to consequent repair gapping. This drawback of two-strand multilevel repairs could be eliminated by inserting the loop pairs in different transversal and/or sagittal planes. Possible designs of enhanced two-strand repairs are shown in **figure 1C,D,E**. Central (and/or volar) placement of the second pair of loops (**figure 1C,E**) may be technically simpler than outer (and/or dorsal) placement (**figure 1D**), because it is usually more difficult to manipulate the tendon at levels further from the juncture site.
Most of the available tendon repair techniques have been clinically used without preceding experimental testing, and biomechanical analyses of tendon repairs largely come without explanation by relevant physics. The laws of mechanics (7) suggest that any additional loop-strand pair results in corresponding spatial distribution of tension within the tendon (**figure 2**). However, this rule may not apply if additional loops are inserted on the same fiber bundle, because the loop that is closer to the tendon junction prevents transmission of force to the next loop. Why then did longitudinal arrangement of locking loops in the experiment by Betz *et al.* strengthen the two-strand tendon repairs (4)? The reason may be that there are multiple interconnections between tendon fibers (5, 6) and that during repair only a part of the same fibers is anchored along the same line of suture. Also, when

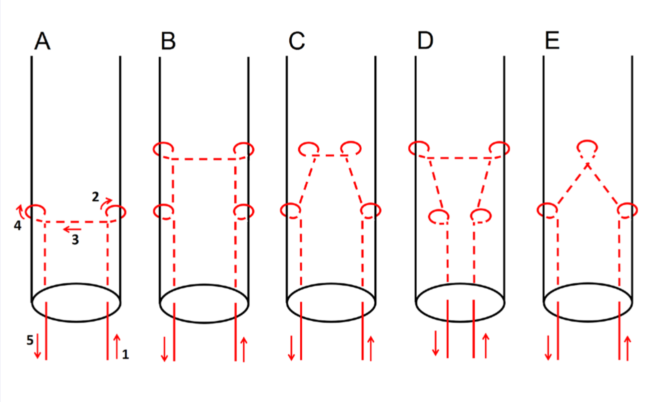

Figure 1. The principle of enhancement of classical two-strand flexor repair with additional anchoring loops.

(**A**) Suture pathway in Kirchmayr-Kessler-type two-strand repair; (**B**) In a double-level single-plane two-strand repair with blocking loops used by Betz *et al.*; **(C-E)** In possible designs of double-level double-plane two-strand repair.

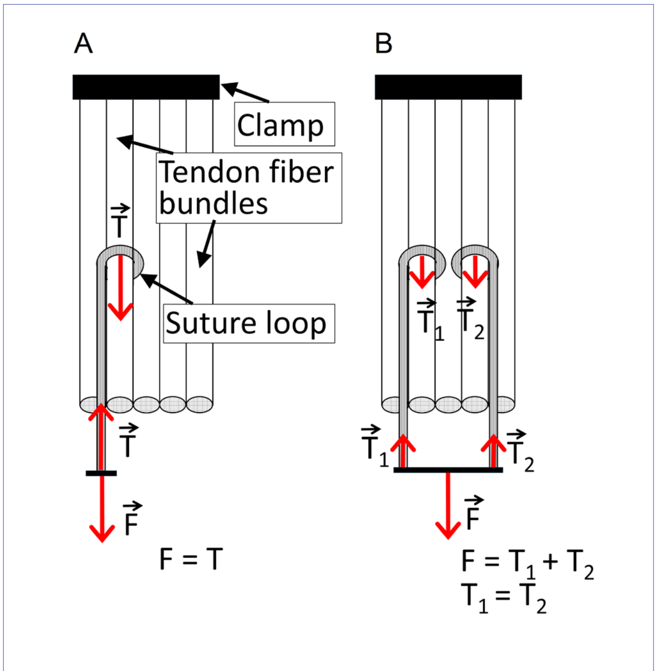

Figure 2. Simplified physics of forces acting on anchor points in tendon repair.

(**A**) Distribution of forces in a single strand and single anchor point; (**B**) Distribution of forces in two strands with single anchor points. The interfaces between the suture loops and the corresponding fiber bundles are supposed to represent solid bonds. Otherwise, all components of the depicted system are frictionless and weightless. It is of importance that continuous flexible connectors (in this diagram represented by fusion of suture and the anchored bundle of tendon fibers) transmit tension without change in its magnitude (see, *e.g.*, figure 5.25 in Ling *et al.* (7)). F: dragging force; T: tension force.

one of the loops fails, the other loop can prevent gapping. These considerations justify multidimensional placement of suture loops. Histological analysis of structure of tendon parts directly unaffected by suturing may be of value for definitive explanation of tendon repair physics and results of biomechanical testing. The mechanistic concept of multilevel multiplane two-strand repairs encourages relevant experimentation, which may result in a considerable clinical alternative to current multistrand techniques.

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DATA AVAILABILITY

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CONTRIBUTIONS

VM contributed entirely to this work.

CONFLICT OF INTERESTS

The author declares that he has no conflict of interests.

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