Tendon-lengthening in continuity: Description of a new method of helical cutting

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INTRODUCTION:
Additional tendon length is occasionally needed for the surgical reattachment of retracted tendons and for lengthening of intact but contracted tendons. To achieve additional length with the known techniques such as the z-plasty, the tendon needs to be cut through entirely and loses its continuity. The purpose of this study was to develop a new method for tendon lengthening, where continuity is preserved and a high amount of additional length is achievable.

The first hypothesis was that tendon lengthening by helical cutting (Figure 1) is feasible and that some tensile force capacity can be preserved.

The second hypothesis was that the length and tensile capacity can be controlled by choice of the angle of the helical cut.

The third hypothesis was that the new method is comparable or superior to the mostly used z-plasty procedure for tendon lengthening.

Figure 1. Schematic illustration of the helically cut tendon resulting in additional length

METHODS:
The study was designed as an experimental study on fresh slaughtered calf Achilles tendons ex vivo. A mathematical formula \( \text{L}_{\text{ach}} = \left( L - \pi \sqrt{a^2 + c^2} \right) / 2 \times \tan(\alpha / 57.3) \times \alpha \) was developed to predict the additional length that can be gained depending on the cut angle in degrees (\( \alpha \)), radius (\( a \)) and initial length (\( L_i \)) of the tendon. Theoretical length increase was predicted based on the above formula. Calf Achilles tendons (n=35) were harvested immediately after slaughter and 5 tendons were assigned to groups I to VII.

To define the center of the tendon, a size 0 PDS suture was inserted longitudinally in the center of the tendon using a hollow needle. The tendon mid-substances were cut within a defined initial zone of length 5cm, and to a depth defined by the previously inserted PDS-suture. A template was used to achieve the intended cutting angle. Angles of 60° (group I and IV), 45° (group II and V) and 30° (group III and VI) were cut. In group IV to VI mattress suture stitches were made along the cutting lines using a size 0 PDS suture on a 5N longitudinal pre-tension template was used to achieve the intended cutting angle. Angles of 60° (group I and IV), 45° (group II and V) and 30° (group III and VI) were cut. In group IV to VI mattress suture stitches were made along the cutting lines using a size 0 PDS suture on a 5N longitudinal pre-tension of the tendon. The mean length increase of the helical cuts was used to define the intended length of group VII, where a z-plasty with a longitudinal cutting length of 5cm was performed followed by suturing of the overlapping arms using 2 to 3 mattress stitches with size 0 PDS resulting in a final length of 7cm. Maximal tensile force (Fmax) and additional achieved lengthening at Fmax (LFmax) were determined for each tendon using a materials testing machine (Zwick 1456, Ulm Germany). Data were statistically analyzed using ANOVA for inter-group differences and Spearman-correlation for cut angle to additional length relations at a significance level of p<0.05.

RESULTS:
Tendon lengthening by helical cutting allowed for controlled tendon lengthening and considerable tensile load bearing could be preserved. The maximal tensile force was found in tendons of group IV (Figure 2), while achieving a sufficient LFmax (Figure 3). The smallest Fmax, which was tolerated, was found in group III (30N±7.6N) at LFmax of 179%±80%. The tendons which were cut helically and sutured (group IV to VI) could achieve higher Fmax than the helically cut tendons without suturing (group I to III). The length and tensile force could be partially controlled by choice of the angle of the helical cut; In the groups for which the cut tendons were not sutured, LFmax was negatively correlated to the cut angle (r=-0.66, p=0.010) and positively correlated to the Fmax (r=0.72, p=0.003). If the helical cut tendons were sutured, there was no correlation of LFmax and cut angle (r=-0.01, p=0.96), but strong positive correlation of Fmax and cut angle (r=0.89, p=0.0001). The theoretical maximal achievable length, calculated using the mathematical formula were 35%, 86% and 189% for 60°, 45° and 30° cut angle, respectively. The experimental results of the helical cut tendons (group I to III) were 67%±22%, 67%±19% and 179%±80% with 60°, 45° and 30°, respectively.

Helical cut tendon could achieve higher amount of additional length and tensile strength than tendons lengthened using z-plasty; in group VII, a LFmax of 72%±10% was achieved by a Fmax of 70N±15N. Other than in groups III and IV, where the cut angle was 30°, resulting in 179%±80% and 113%±10%, respectively, significant higher tensile force capacities (from a minimum of 80N±54N in group II to maximally 222N±62N in group IV) was achieved.

DISCUSSION:
Helical cutting of tendons allows lengthening tendons to an amount not possible with conventional methods. The lengthened coil-shaped tendon remains in continuity and has the potential to withstand considerable loads also without additional suture reinforcement. A further important advantage is that the lengthening can be performed continuously and be stopped when the desired amount of lengthening is achieved.

This was an ex vivo investigation. The behavior of the helical cut tendon in vivo is not known. However, the preservation of continuity might be favorable not only in regard to high tensile forces but also to healing. Further research is needed to evaluate the behavior of tendons undergoing this elongation technique in vivo. Further, performing the helical cut was technically challenging; small irregularities in the cutting line could not be avoided and partly weakened the tendon. However, even with the simplest surgical technique reliable results were achieved in vitro and all three working hypotheses could be confirmed.