Tight Medial-Knot Tying May Increase the Risk of Re-tearing after Transosseous Equivalent Repair of Rotator Cuff Tendon

Hirotaka Sano, Masako Tokunaga, Moriyuki Noguchi, Takashi Inawashiro, Taichi Irie, Hiroo Abe. Sendai City Hospital, Sendai, Japan.


Introduction: Transosseous equivalent (TOE) suture is now widely used as the standard surgical technique for arthroscopic rotator cuff repair. In this method, some authors recommended adding knot tying for medial-row suture to increase the initial fixation strength of the torn tendon stump to greater tuberosity. However, other authors believed that the medial-knot tying knot may increase the risk of postoperative re-tearing. The purpose of the present study was to clarify the difference of the stress distribution pattern inside the repaired tendon between TOE repairs with and without medial knot tying. We further hope to clarify the influence of the compressive force applied to the medial the knots in the stress distribution inside the tendon.

Methods: I. Development of finite element (FE) models

Board-shaped model: To standardize the analysis conditions, we first developed a simple three-dimensional (3D) model of supraspinatus tendon as well as humeral head using computer graphics software, Metasequoia (version 3.1.4, tetraface Inc., Japan). This model was designed as having a board shape, which simulated a shoulder at hanging arm position. Suture threads were also modeled to recreate TOE repair with and without medial knot tying with this software. Then, the STL (stereolithography) data of these models were imported to the software for finite element method (FEM), Mechanical Finder (Extended Edition, version 7.0, RCCM, Japan). To simulate the suture anchor fixation, both ends of the suture thread were fixed to bone and a tensile force (20N) was applied to each suture thread along its direction to recreate repair tension. A tensile force (100N) was also applied to the proximal end of the supraspinatus to simulate muscle contraction force. The distal end of humerus was completely constrained.

Cadaver model: To confirm the analysis results of board-shaped model and to investigate the role of anatomical architecture of human shoulder, we also develop a cadaveric model of human rotator cuff tendon. CT data of the normal cadaveric shoulder (69-year-old male) were saved in Digital Imaging and Communications in Medicine (DICOM) format, which were imported to the software, Mechanical Finder, to develop a 3D-FE model of rotator cuff tendons attached to humeral head. The position of shoulder joint was hanging arm position as well. Then, the supraspinatus tendon was detached from the greater tuberosity to recreate a full-thickness rotator cuff tear. The suture threads were designed using the software, Metasequoia, to simulate TOE repair with and without medial knot tying. A tensile force (20N) was applied to each suture thread along its direction to recreate the tension applied during the fixation. A tensile forces was also applied to the proximal end of each cuff tendon to simulate shoulder abduction at hanging arm position (supraspinatus: 50.5N, infraspinatus: 22.5N, subscapularis: 63.3N) (1).

II. FE analysis and data interpretation
For both board-shaped and cadaver models, elastic analysis was performed. The distribution pattern of von Mises equivalent stress was compared between the models with and without medial knot tying. In cadaver model, a compressive load (20, 40, 60, 80 and 100N) was applied on the medial knots toward the tendon surface to clarify whether the suture tension during medial knot tying affects the stress distribution pattern inside the repaired tendon or not.

**Results:** For board-shaped model, a high stress concentration was seen around the sites of suture thread penetration in the repaired tendon. The area with high stress concentration was wider in the model with medial knot tying than that without medial knot tying (Fig. 1-a, b). Such stress distribution pattern was just identical to that in the cadaver models (Fig. 2-a, b). It was interesting to note that the von Mises equivalent stress inside the tendon increased with increasing the compressive force applied to the medial knot in this model (Table 1).

**Discussion:** Previous clinical studies revealed that the re-tearing of repaired tendon was frequently observed around the musculotendinous junction after TOE repair (2). In the present study, both the board-shaped and the cadaver models demonstrated the identical stress distribution pattern. The medial knot tying enhanced the stress concentration inside the tendon around the suture thread penetration. Since the sites of suture thread penetration in TOE repair locate close to the musculotendinous junction, we assumed that the stress concentration at this site might play an important role in the pathogenesis of re-tearing of repaired tendon. We also found that the von Mises equivalent stress at this site increased with increasing the compressive force applied to the medial knots. It seemed that the risk of re-tearing may further increase if surgeons give an additional tension during medial knot tying particularly using sliding-knot technique.

**References:**

**Figure legends**
Fig. 1-a, b: Stress distribution pattern in the board-shaped models
The model with medial knot tying (a) represents a wider area of stress concentration around the medial knots than that without knot tying (b).

Fig. 2-a, b: Stress distribution pattern in the cadaver models
The model with medial knot represents a high stress concentration around medial knots (a, white arrow). No such high stress concentration is seen in the model without medial knot tying (b).

**Significance:** The medial knot tying enhanced the stress concentration inside the tendon around the suture thread penetration. The equivalent stress inside the tendon at this site increased with increasing the compressive force applied to the medial knots.

| Relationship between the applied force to medial knots and the maximum von Mises stress |
|---------------------------------|--------|--------|--------|--------|--------|
| Applied force to the medial knot (N) | 20     | 40     | 60     | 80     | 100    |
| Maximum von Mises stress (MPa)     | 4.7    | 6.7    | 9.2    | 11.9   | 14.7   |