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Stress Distribution inside the Bone after Suture Anchor Insertion – A Simulation Study Using Three-Dimensional Finite Element Method

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Summary:

A marked stress concentration appeared around the superficial anchor threads, especially in the traction side. We assumed that the quality of subchondral bone was an important factor to predict the failure risk of the inserted anchors. In the middle range of the traction angles, inserting anchor at 90 degrees against the bony surface provided a less stress concentration inside the bone.

Abstract:

Introduction:

Suture anchors are commonly used during the arthroscopic rotator cuff repair. To reduce the risk of anchor failure after surgery, it is recommended to minimize the stress concentration inside the bone. The purpose of this study was to describe the stress distribution pattern inside the bone around the inserted anchor using three-dimensional finite element method. We further attempted to clarify the roles of the insertion angle of the anchors on the stress distribution inside the bone.

Materials and Methods:

Software for finite element (FE) analysis, Mechanical Finder (version 6.0, RCCM, Japan), was used for the current study. To standardize the analysis conditions, an isotropic FE model of a cubic bone (Young's modulus: 1380 MPa, Poisson's ratio: 0.3) was designed on the computer. The geometric data of the suture anchor (TwinFix, Smith & Nephew Endoscopy) was imported on the model, which was then inserted into the cubic bone model with two different angles (45 and 90 degrees against the bony surface). A traction force (100 N) was applied to the anchor at its two eyelets with 5 different directions (traction angle; 15, 30, 45, 60 and 75 degrees against the bony surface). The elastic analysis was performed and the distribution of the Drucker-Prager's equivalent stress inside the bone was calculated. Then, the highest value of stress concentration at each traction angle was compared between the 45 and the 90 degree-insertion models.

Results:

The area with high stress concentration was always seen around the thread of the anchor. Stress concentration was the most evident around the superficial anchor threads, especially on the traction side. Some stress concentration was also seen around the threads close to the tip of the anchor but mainly on the opposite side against the direction of the traction force. The highest value of the equivalent stress inside the bone was varied with the directions of the traction force. In the traction with 15 degrees against the bony surface, the equivalent stress was lower in the 45 degree-insertion model than that of the 90 degree-insertion model. On the other hand, 90 degree-insertion model represented lower value of the equivalent stress than 45 degree-insertion model in the traction with 30, 45 and 60 degrees. In 75 degrees of traction, it was almost identical both for the 45 and 90 degree-insertion models.

Discussion and Conclusion:

Although a number of authors have already reported the pull-out strength of various types of anchors, stress distribution pattern inside the bone after their insertion has not been clarified yet. The results of the current study clearly demonstrated that the marked stress concentration was seen between the superficial anchor threads and the bony surface, especially on the traction side. We assumed that the quality of subchondral bone was one of the most important factors to predict the failure risk of the inserted anchors. We also found that the highest value of the equivalent stress varied with the angles of the anchor insertion as well as the direction of the traction force. In the middle range of the traction angles, inserting a suture anchor at an angle of 90 degrees against the bony surface provided a less stress concentration inside the bone than inserting it at 45 degrees.