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Biomechanical comparison between the different techniques of suture-based coracoclavicular ligament stabilization: A finite element analysis

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Introduction and Background

Acromioclavicular (AC) joint injuries are common, particularly among athletes, with coracoclavicular (CC) ligament disruption often contributing to instability. While various surgical techniques exist, there is no consensus on the optimal method for CC ligament repair/reconstruction. Among these, suture-based techniques are gaining popularity, but their biomechanical properties remain unclear. The purpose of this study was to compare the biomechanical stability of different suture-based techniques for CC ligament stabilization using finite element analysis (FEA).

Material and Method

The three suture-based coracoclavicular (CC) ligament stabilization techniques—Model I: Double bundle, Model II: Single bundle, and Model III: Loop bundle—were modeled using 3D CAD data reconstructed from Geomagic Design X and modified in ANSYS SpaceClaim. Finite element models of the clavicle and scapula were meshed, and load conditions were applied at the acromion in three directions. Biomechanical testing included stability, failure load, and stress distribution analysis. Simulations were performed using ANSYS Workbench, and von Mises stress, displacement, and structural failure parameters were recorded and compared between models.

Results

Finite element analysis revealed that all three suture-based techniques provided comparable biomechanical stability when combined with AC joint repair. The double-bundle technique (Model I) demonstrated the lowest displacement in superior and anterior directions (-2.85 mm and -3.06 mm) and the highest stiffness (-35.10 N/mm and -32.70 N/mm). All three models showed similar ultimate failure loads (~243 N). However, without AC repair, the loop technique (Model III) showed significantly increased displacement (up to -4.56 mm anteriorly), reduced stiffness (as low as -21.92 N/mm), and elevated von Mises stress (up to 147 MPa), indicating reduced mechanical stability compared to the anatomical techniques.

Conclusions

For high-grade acromioclavicular joint injuries, the AC repair combined with non-anatomical suture repair of the CC ligament using the single-bundle or loop techniques provide comparable biomechanical stability, resistance to failure load, and stiffness when compared with anatomical suture repair technique.

