Shoulder stability after arthroscopic superior capsular reconstruction: computational analysis on the influence of the rotator cuff tear pattern

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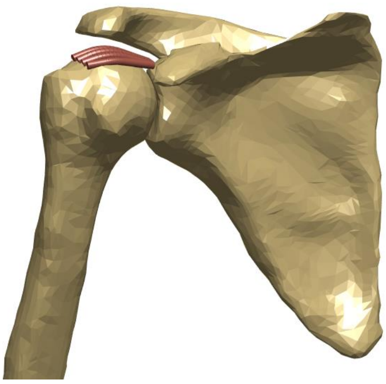
EXTENDED ABSTRACT

1 Introduction

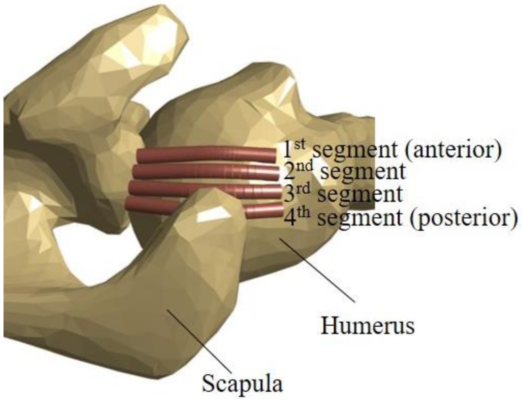
Arthroscopic superior capsular reconstruction (ASCR) was introduced for the treatment of irreparable rotator cuff tears (RCTs) [1]. These tears are associated with destabilization of the shoulder and of its physiological kinematics. In ASCR, a graft is positioned and fixed, in the pathway of the supraspinatus (SSP) tendon at an arbitrary shoulder position, with the aim of restoring the stability of the shoulder. The four most common patterns of RCTs in ASCR include an irreparable full-thickness tear of the following tendons: SSP; SSP + Subscapularis (SC); SSP + Infraspinatus (ISP); and SSP+SC+ISP [2]. Concomitant procedures during ASCR may be considered to restore the action of the SC or ISP: pectoralis major transfer (PMT) or latissimus dorsi transfer (LDT) for the SC insertion site; and LDT or lower trapezius transfer (LTT) for the ISP insertion site [3]. However, there is no biomechanical evidence regarding the role of the graft in ASCR for tears extending beyond the SSP tendon, in the anterior or/and posterior direction [4]; and the effectiveness of concomitant procedures during ASCR to restore the line of action of the SC or/and ISP. The aim of this study was to evaluate the influence of the RCT pattern on the stability of the shoulder after ASCR, with or without concomitant procedures applied.

2 Materials and Methods

A 3D musculoskeletal model of the upper limb was modified to simulate the ASCR procedure and estimate the stability of the glenohumeral (GH) joint [5]. The model is composed of 7 rigid bodies and 22 muscles of the upper limb (74 muscle bundles). The graft was modelled as a set of four parallel segments, as shown in Figure 1. The origin and insertion sites of the graft were chosen with the guidance of two orthopedic surgeons (C.A. and A.Â.), at the glenoid rim and SSP footprint, respectively. From a mechanical point of view, the segments were modelled as a series of passive elastic elements, whose material properties were based on previous experimental tests on fresh cadaveric fascia lata grafts [6]. A total of 45 shoulder positions of fixation of the graft (combining abduction, forward flexion, and axial rotation) were modeled to simulate different settings of ASCR, usually defined based on surgeons' experience. From the computational point of view, the shoulder position during graft fixation set the initial graft length.



(a)



(b)

Figure 1: Graft path for each segment in (a) anterior and (b) superior views.

The four most common RCT patterns were modeled by removing the muscles, affected by the irreparable RCT, from the model. The muscular and joint reaction forces were estimated based on inverse dynamics, considering motion capture data collected from the database of the Laboratory of Biomechanics of Lisbon. The population dataset consisted in 18 healthy subjects, and the motion capture data included four types of movements: abduction in the frontal plane, forward flexion in the sagittal plane, reaching behind the back, and combing the hair. The dynamic muscular distribution aimed to minimize muscle energy consumption, while ensuring the fulfilment of the equations of motion and the stability of the joints. The stability of the GH joint was estimated as the ratio between the GH reaction force components, augmented by the Lagrange multiplier associated with its constraint, which indicates the amount of additional muscular activity necessary to prevent dislocation of the shoulder. The PMT and LDT to the SC insertion site, and the LDT and LTT to the ISP insertion site, were defined with the guidance of two experienced shoulder orthopedic surgeons (C.A. and A.Â.). The comparison between the pre and postoperative condition was based on ANOVA and multiple comparison Tuckey's test (level of significance $p<0.05$).

3 Results and Discussion

For an isolated irreparable tear of the SSP tendon, ASCR increased shoulder stability ($p<0.001$) compared to the preoperative condition, and, for some shoulder positions of graft fixation, the postoperative condition presented a healthy stability condition (Figure 2). The fixation of the graft in the SSP+SC pattern leads to a degeneration of the shoulder stability ($p<0.05$), compared to the preoperative condition. These results provide biomechanical evidence to support the suggestion from orthopedic surgeons to not perform ASCR without repairing the line of action of the SC. For the SSP+ISP and SSP+SC+ISP patterns, our results showed a stability improvement; however, this improvement was not significant. The postoperative condition for these two RCT patterns is associated with increased muscular activity to prevent dislocation of the GH joint, which might not be tolerated in a physiological scenario. Our results, for tears extending beyond the SSP tendon, suggest the necessity to apply concomitant procedures that restore the transverse force couple (the SC and ISP lines of action).

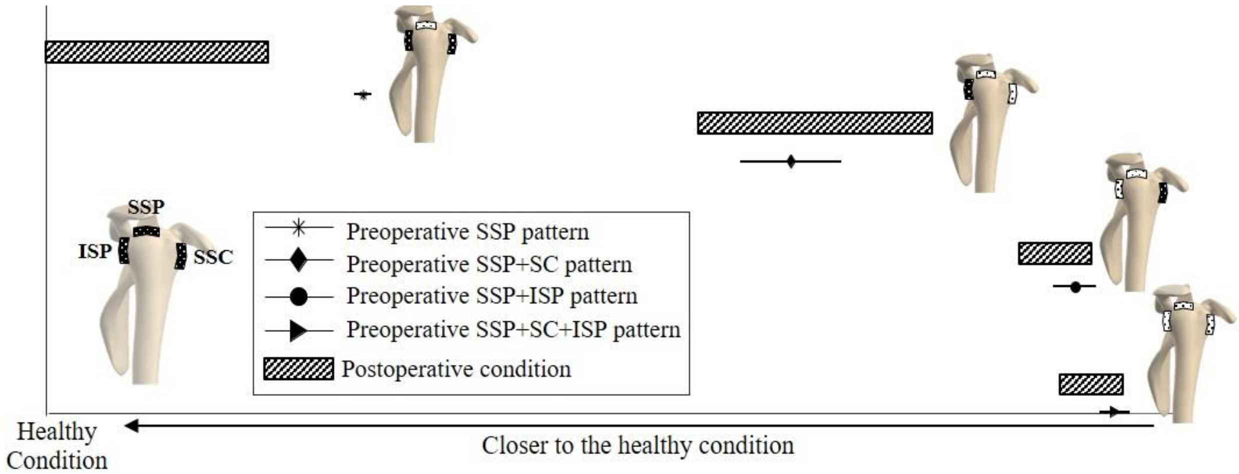


Figure 2 Multiple comparison test for the pre and postoperative conditions of the four RCT patterns simulated. For the preoperative conditions, the mean and standard deviation, considering the analyzed motion capture data, are shown; and for the postoperative conditions, shoulder stability range considering all shoulder positions for the fixation of the graft is shown.

4 Conclusion

The ASCR for patterns extending beyond the SSP did not produce a significant improvement in shoulder stability; and the graft was not able to compensate for the stability loss in the anterior or/and posterior direction.

Acknowledgments

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