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The effect of the arthroscopic augmentation of the subscapularis tendon on shoulder instability and range of motion: A biomechanical study

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ABSTRACT

Background: Anterior shoulder dislocation is common. The treatment of recurrence with glenoid bone defect is still considered controversial. A new arthroscopic subscapularis augmentation has recently been described that functions to decrease the anterior translation of the humeral head. The purpose of the presented study was to examine the biomechanical effect on glenohumeral joint motion and stability.

Methods: Eight fresh frozen cadaver shoulders were studied by use of a force guided industrial robot fitted with a six-component force-moment sensor to which the humerus was attached. The testing protocol includes measurement of glenohumeral translation in the anterior, anterior-inferior and inferior directions at 0°, 30° and 60° of glenohumeral abduction, respectively, with a passive humerus load of 30 N in the testing direction. The maximum possible external rotation was measured at each abduction angle applying a moment of 1 Nm. Each specimen was measured in a physiologic state, as well as after Bankart lesion with an anterior bone defect of 15–20% of the glenoid, after arthroscopic subscapularis augmentation and after Bankart repair.

Findings: The arthroscopic subscapularis augmentation decreased the anterior and anterior-inferior translation. The Bankart repair did not restore the mechanical stability compared to the physiologic shoulder group. External rotation was decreased after arthroscopic subscapularis augmentation compared to the physiologic state, however, the limitation of external rotation was decreased at 60° abduction.

Interpretation: The arthroscopic subscapularis augmentation investigated herein was observed to restore shoulder stability in an experimental model.

1. Introduction

Shoulder dislocation is a common injury in young and active patients (Owens et al., 2007) with an incidence rate of 1.7%. Without surgical treatment, the recurrence rate in young patients is unacceptably high (70.3%) (Gigis et al., 2014). However, after arthroscopic Bankart repair, a recurrence rate of 13.1% was still reported in young patients (Gigis et al., 2014) and, in a systematic review, an odds ratio of 12.71 (Longo et al., 2014) was measured. After more than one dislocation, different pathologies are involved in the problem of instability: bone loss of the glenoid (Saito et al., 2005), Hill-Sachs defect with potential engaging at the glenoid rim (Purchase et al., 2008), capsular insufficiency (stretched capsule (Osmond-Clarke, 1948)) and elongation of the subscapularis tendon (Symeonides, 1972).

In the early 20th Century, Putti and Platt inaugurated (independently from one another in Italy and England) an open shoulder soft tissue stabilization procedure, using the subscapularis tendon. This procedure is performed as follows: release of the subscapularis tendon at 2.5 cm medial of the insertion at the lesser tuberosity, open the capsule and suture the medial border of the lateral stump to the capsule tissue, and at least suture the lateral border of the medial subscapularis tendon laterally. Osmond-Clark was the first who described the procedure (Osmond-Clarke, 1948). After the first encouraging results, late complications such as osteoarthritis and the limitation of external rotation were reported (Ahmad et al., 2005; Hawkins and Angelo, 1990). Different modifications of the Putti-Platt procedure were described in the following years (Symeonides, 1989). Bristow (Helfet, 1958) and Latarjet (1954) both described a non-anatomical procedure using the conjoined tendon (biceps and coracobrachialis tendon) with the attached coracoid. The difference was that Bristow used just the conjoined tendon with the

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tip of the coracoid and Latarjet used the attached bone block, passed the conjoined tendon through the subscapularis tendon, and fixed the bone block at the glenoid. This procedure solves the problem of the bone loss, capsular insufficiency and elongation of the subscapularis tendon (i.e. the triple effect). With the development of arthroscopic surgery and instruments, it has become more popular to perform this procedure arthroscopically. However, although high complication rates after the early Bristow procedures (Artz and Huffer, 1972; Fee et al., 1978; Iftikhar et al., 1984) as well as after the arthroscopic Bristow-Latarjet procedure (Griesser et al., 2013a, 2013b) were reported, their popularity increased, especially in France and in German-speaking countries. Moreover, the indication depends on the surgical tradition of the countries. The pathological problems of a stretched capsule and elongation of the subscapularis tendon are the main problems related to the recurrence of instability (Symeonides, 1972). Recently, biomechanical studies have reported that the sling effect of the subscapularis is the main effect of stabilization after the Latarjet procedure (Giles et al., 2013; Wellmann et al., 2009; Wellmann et al., 2012).

Therefore, Johnson (1986) reported an arthroscopic technique using the subscapularis tendon to address the capsule-labral insufficiency. This procedure has been developed using the effect of the subscapularis tendon to stabilize the shoulder, thus avoiding a high complication rate, especially the major complication of nerve palsy. However, this procedure was abandoned due to complications related to the metal staple used for tendon fixation to the glenoid edge.

Recently, four techniques have been described in which the subscapularis tendon was used to treat anterior capsulolabral insufficiency. The first technique, described by Denard et al. (2011), consisted of a subscapularis flap used to augment the Bankart repair, whereas the second technique, described by Chaudhury et al. (2014), consisted of a complete tenodesis of the tendon and its advancement and fixation to the medial border of the glenoid neck using a large number of anchors. The third technique described by Blasiak et al. (2016) used a split of the subscapularis tendon which was detached from the distal part and fixed at the anterior glenoid rim. Fourth technique was presented by Klungsoyr et al. (2015) in a cadaver study. The "sling effect" was used to stabilize the shoulder using a hamstring graft and enhancing the anterior rim of the glenoid with the same graft.

Based on the procedure of Johnson (1986) a new arthroscopic technique consisting of an upper third subscapularis tenodesis at the anterior border of the glenoid rim combined with a Bankart repair, especially of the anterior-inferior capsule (Maiotti and Massoni, 2013) was developed. This technique was named *arthroscopic subscapularis augmentation* (A.S.A.). The recently published clinical results with a follow-up of 31.5 months are encouraging (Maiotti et al., 2015). They found in a group of patients with anterior shoulder instability and an anterior glenoid bone loss of <25% good clinical results (Rowe score 94.1 SD 6.7) with a low recurrence rate of 3.3%. No limitation in internal rotation as well as in abduction and flexion were found. In contrast there were a difference of 6° in external rotation with the arm at the side of the trunk and 3° with the arm at 90° of abduction, to the contralateral side. This limitation is not influencing sports activity and the patients did not complain on limitation.

However, there is still a discussion over whether the procedure stabilizes the shoulder and limits external rotation. Therefore, biomechanical testing is required to examine (i) the stabilization effect of the A.S.A., and (ii) the motion in the glenohumeral joint. The purpose of the presented study was to examine the biomechanical effect of this new augmentation technique on glenohumeral joint motion and stability. It was hypothesized that the translation after the A.S.A. is comparable to an injury-free shoulder, and the limitation of external rotation is <10° in 60° abduction.

2. Materials and methods

Eight human cadaver shoulder specimens were tested in a robot based shoulder simulator. Translational stability and range of motion of each specimen was tested in four different configurations: physiologic, Bankart lesion with bony defect, A.S.A. and Bankart repair.

2.1. Preparation of the specimens

After receiving local IRB approval (No. 2640-2015), eight shoulders (4 male, 4 female) without evidence of rotator cuff tear and shoulder injury in their medical history were investigated (four right and four left shoulders). The mean donor age was 47.7 SD 8.7 years. The specimens were fresh-frozen and stored at a temperature of −20 °C until experiments. The specimens were thawed at room temperature for 24 h prior to testing. The medial scapula margin was dissected through the soft tissue, without dissecting parts of the musculus subscapularis. The scapula was then potted and fixed in a customised box by use of a cold curing three-component casting resin (Rencast FC52/53 Isocyanate, FC53 Polyol, DT982, Gössl&Pfaff GmbH, Karlskron/Braulach, Germany).

Afterwards, a K-wire was positioned parallel to the epicondyle axis 15 cm distal of the edge of the acromion. The humerus was then resected approximately 20 cm distal from the acromion edge, and potted in a brass cylinder using the same casting resin. The scapula of the specimen was mounted rigidly at the testing apparatus using thread rods. Neutral rotation of the glenohumeral joint was defined as a 10° internal rotation of the epicondyle axis (K-wire at the humerus) to the mounting tower (Fig. 1). The brass humeral cylinder was mounted to the robot using two threaded rods through an additional cylinder that was fixed on the wrist of the robot (Fig. 2). The humeral and global coordinate systems were defined as has been previously described (Hurschler et al., 2004). For testing, the head was centered in the glenoid. Anterio-posterior and superior-inferior translations were measured by defining the location of geometric center of the humeral head to be zero at the starting point of each test. The starting point was re-established by the robot before each test condition.

2.2. Test setup and protocol

The setup consists of a force-guided industrial robot (KR15/1, Kuka GmbH, Augsburg, Germany) fitted with a six-component force-moment sensor (FMS) (KMS60, IpeA GmbH, Berlin, Germany) to which the humerus was attached, as described above. The robot applies force and moment-controlled motion and loads to the glenohumeral joint. The robot is capable of applying controlled loading by interpreting the load and moment data provided by the FMS (closed-loop control). The robot/FMS system enables measurement of motion with a resolution of 0.1 mm and measurement of joint loading with a resolution of <0.3 N force. During translation a normal force of 20 N were applied by the rotator cuff (Poppen and Walker, 1978; Veeger et al., 1991). Therefore, the humeral head was centered in the glenoid cavity at each abduction and rotation angle by an axial compressive load of 30 N. The testing protocol includes measurement of glenohumeral translation in anterior, anterior-inferior and inferior direction at 0°, 30° and 60° abduction in the frontal plane, respectively, with a humerus load of 30 N in the testing direction. Because the scapula was fixed, 60° glenohumeral abduction was assumed to correspond to 90° abduction of the arm (Debski et al., 1999). The protocol was repeated in neutral (0° external rotation) as well as 20° of external rotation.

During testing, the glenohumeral joint was free to translate in the mediolateral, superoinferior and anteroposterior direction, while rotation, flexion and elevation were held constant. In a further testing step, a torsional moment of 1 Nm was applied to the humerus to measure the range of motion (RoM) in external rotation (Fig. 3).