BIOMECHANICAL EVALUATION OF ULNAR COLLATERAL LIGAMENT RECONSTRUCTION OF THE ELBOW USING THE DOCKING TECHNIQUE

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INTRODUCTION

In the functional range of elbow flexion (approximately 20^0 to 120^0) the anterior bundle of the Ulnar Collateral Ligament (UCL) has been shown to function as the primary stabilizer against valgus stresses [1,2]. Injuries to this ligament are common among throwing athletes. Surgical reconstruction of the UCL is frequently performed using the Docking technique [3] and has achieved successful results. Biomechanical studies have been conducted in the past to evaluate the effect of this and other types of reconstruction surgeries on elbow mechanics [4]. Reconstruction has been suggested at 30 degrees of elbow flexion as well as at greater degrees of elbow flexion (90 degrees) approximating the elbow flexion position during throwing. No quantitative biomechanical data exists to provide guidelines for the appropriate elbow flexion angle at which surgical reconstruction should be performed. This study is based on the hypothesis that the Biomechanical characteristics of the reconstructed elbow, including valgus laxity, load to failure in valgus and kinematic coupling between ulnar deviation and valgus rotation are significantly affected by the flexion angle at which the surgical reconstruction was performed. The goal of this study is to evaluate the validity of this hypothesis and identify a biomechanically optimal flexion angle at which surgery should be performed.

METHODS

Testing was conducted on 12 matched pairs of non-embalmed cadaver elbows using a four-degrees-of-freedom loading system (Figure 1) described in details in a previous study [4].

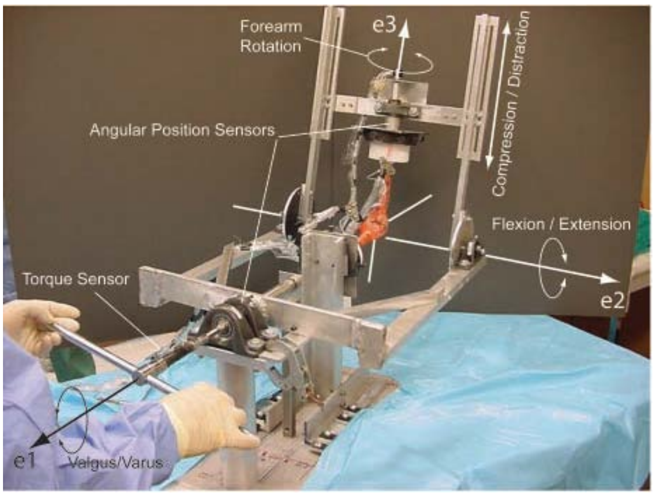

Figure 1: Four-degrees-of-freedom (flexion/extension, varus/valgus, forearm rotation, and compression/distraction) loading system. The device allows positioning of the elbow at various degrees of flexion while loading the elbow in valgus and measuring the applied torque, valgus angulation, and forearm rotations.

Sub-failure valgus loads were applied to the native elbows at different flexion angles of 30, 60, 90 and 100 degrees. During load application, the applied valgus moment, valgus rotation and forearm rotation were measured through the device. The insertion-to-insertion initial length and elongation of the anterior, central, and posterior bands of the anterior bundle of the UCL were simultaneously recorded with an opto-electric kinematic data acquisition system (Optotrack 3020). The anterior and posterior branches of the surgical reconstruction were measured in a similar manner. The elbows were then loaded to failure in valgus at 90 degrees of flexion. Docking technique was then used to perform the surgical reconstructions using the Palmaris Longus auto-graft. For each matched pair, one of the elbows was reconstructed at 30 degrees of elbow flexion, while the contralateral elbow was reconstructed at 90 degrees of elbow flexion. Biomechanical testing consisting of the sub-failure valgus loading followed by loading to failure was then repeated.

RESULTS AND DISCUSSION

The load to failure of the native UCL averaged 20.1 Nm (range: 6-34 Nm) while the load to failure after UCL reconstruction using the Docking technique averaged 4.6 Nm (range: 2-10 Nm). This result suggests that the surgical reconstruction restores less than 25% of the intact load to failure. However, the testing condition in this study does not account for healing and biological integration of the reconstruction into the bone. There was no significant difference in load to failure of the UCL reconstructions performed at 30 degrees of elbow flexion (avg. = 4.86 Nm; range: 3-6.1 Nm) compared to those performed at 90 degrees of elbow flexion (avg. = 4.35 Nm; range: 1.8-10 Nm). Valgus laxity was found to decrease as the flexion angle increases from 30^0 to 100^0. This may be due to tightening of the UCL or to increase in bone-to-bone interaction. This property was observed both in the intact as well as in the surgically reconstructed elbows (Figure 2). It is further observed (Figure 2) that the valgus laxity of the elbows reconstructed at 30^0 was closer to the intact elbows than those reconstructed at 90^0.

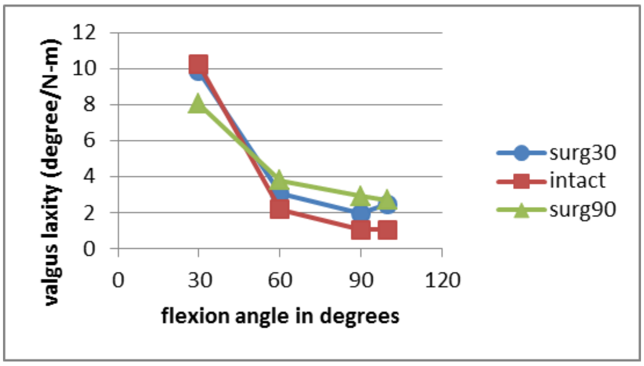

Figure 2: The relationship between valgus laxity and flexion angle for the three conditions (intact, surgically reconstructed at 30^0 and surgically reconstructed at 90^0).

The results for the kinematic coupling found that as the elbow moved from 90^0 of flexion to 30^0 of flexion, coupling of forearm rotation with valgus motion progressed from supination to pronation. This coupling pattern is consistently seen in the overhead throwing motion of the athlete. This kinematic coupling therefore may be an important passive mechanism assisting performance of overhead throwing movements such as when throwing a baseball. This coupling pattern was observed both in the intact and the surgically reconstructed elbows. However the elbows reconstructed at 30 degrees of flexion more closely resembled the kinematic coupling pattern of the intact elbow (Figure 3).

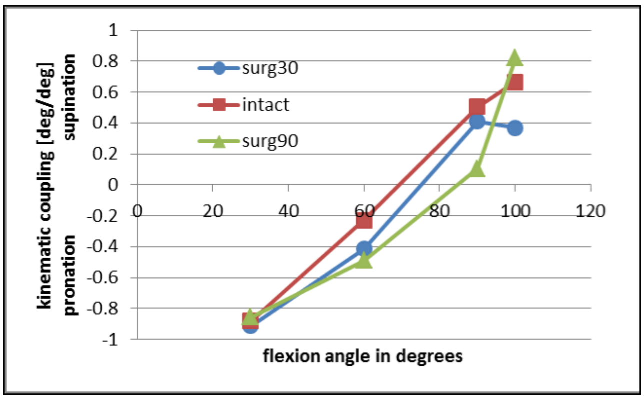

Figure 3: The relationship between kinematic coupling of the elbow and flexion angle for the three conditions (intact, surgically reconstructed at 30^0 and surgically reconstructed at 90^0).

The results also indicate that for the intact elbow as it moves from 30^0 of flexion to 90^0 of flexion the anterior band of the UCL shortens, the central band remains almost isometric and the posterior band lengthens (Figure 4). Similarly, for the surgically reconstructed elbow, during this motion, the anterior portion of the reconstruction shortens while the posterior portion lengthens.

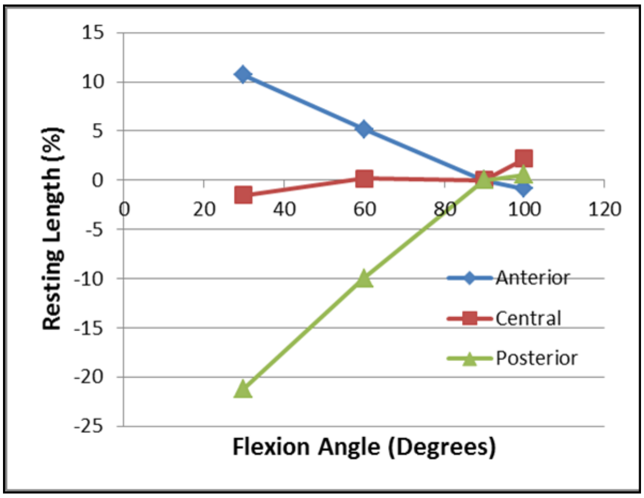

Figure 4: Changes in resting length of the anterior, central and posterior bands of the UCL as function of the flexion angle of the elbow. The resting length is expressed as percentage of the resting length at 90 degrees of flexion.

CONCLUSIONS

Biomechanical properties of the elbow joint in valgus including laxity, kinematic coupling and resting length of parts of the UCL are strongly influenced by flexion angle. Furthermore, the kinematic coupling of the intact elbow seems to provide a passive mechanism to assist the overhead throwing motion. Therefore loss of the ability of athletes to pronate at the end phase of the throwing motion may be indicative of disruption of this mechanism due to onset of UCL injury.

The results of this study support the main hypothesis that the Biomechanical characteristics of the reconstructed elbow are significantly affected by the flexion angle at which the surgical reconstruction was performed. Finally, This study suggests that surgical reconstruction performed at 30 degrees of elbow flexion provides improved functional results than similar reconstruction performed at 90 degrees of elbow flexion.

ACKNOWLEDGEMENTS

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