FUNCTIONAL ROTATIONAL STIFFNESS as VALGUS/VARUS STABILITY INDEX in ELBOW JOINT

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INTRODUCTION:

As a stability index, the translation stiffness was used to evaluate the shoulder stability [1], and elbow's biomechanical stability was evaluated in terms of torque and work [2]. Clinically "stiff joint" means that the joint have relatively narrow laxity in passive or active motion, i.e. reduced motion, and can be followed by pain after passing some amount of range of motion. But this clinical symptom is seldom quantified in objective methods. Even though the stiffness concept has been a most widely accepted stability criterion the mechanical engineering, it is rarely introduced in biomechanics. We hypothesized that the functional angular stiffness concept will demonstrate the effect of the olecranon osteotomy on the 3-dimensional kinematics and stability of the elbow joint.

METHODS

Seven capsuloligamentous elbows were prepared after resecting all soft tissues except capsuloligament. At three serial posteromedial olecranon resection stages of 0, 4, 8 mm, valgus/varus laxity was measured under varing elbow flexion (30°, 60°, 90°), external valgus torque (1, 2, 3 Nm), and external varus torque 3 Nm. The stability of elbow was evaluated with the functional valgus/varus stiffness.

The assumed central valgus/varus angle:

The angular and translational positions of the elbow were interpreted with the positions of the forearm relative to the humeral coordinate system that is determined with the two distal humeral epicondyles and central humeral shaft direction. The central valgus/varus angle was defined as the middle of the valgus/varus angular range of motion (ROM) which was formed by 3 Nm of valgus torque and 3 Nm of varus torque.

Functional Rotational Stiffness:

As a joint stability index, the functional stiffness was proposed. Functional angular stiffness was defined as the ratio of the final torque to the angular change from the central varus/valgus.

$k_\theta = \frac{dT}{d\theta}$: the rortational stiffness

$\therefore k_\theta^F = T / \triangle\theta$

$= (T^{int} + T^{ext}) / \triangle\theta$: the functional rortational stiffness

RESULTS

The assumed central varus/valgus position of intact specimen was 15°, 13.8°, and 12.1° at the flexion cases of 30°, 60°, and 90° respectively. As elbow flexes, the central valgus/varus position moved varus in all resection stages. And with 8 mm of olecranon resection, the central valgus/varus position moved varus at 60° of elbow flexion ($P<0.07$), 90° of elbow flexion ($P<0.05$).

Functional valgus/varus stiffness decreased very sensitively to the amount of parallel resections of the posteromedial olecranon at all flexion cases ($p<0.05$).

DISCUSSION

The resection of the posterior and medial edge we used was parallel to the proximal ulnar plane (PUP) that is determined by the ulnar shaft direction and the proximal ulnar medial-lateral direction. This was chosen because the posterior and medial edges are the areas where osteophyte overgrowth is seen in the throwing athletes elbow.

The joint stability index was objected to provide the continuous and absolute quantitative value in evaluating how much the joint is difficult to translate. The functional valgus/varus stiffness, uniquely defined in this study, is the integrated stiffness that was the valgus/varus laxity divided by valgus/varus torque whereas the angular stiffness is originally the instantaneous stiffness that is the incremental angulation divided by incremental torque. This functional rotational stiffness was very sensitive to the change of physical anatomical constraints. And the functional stiffness concept will provide useful quantification index for clinical joint stability diagnose.

REFERENCES

1) R. Oosterom et al, J Biomech 36(12):1897-1907.
2) Deutch et al, J Shoulder Elbow Surg 12(3):287-292, 2003.