THE EFFECT OF A SIMULATED EXTENSION OSTEOTOMY AND LIGAMENT RECONSTRUCTION ON THE LAXITY OF THE HUMAN THUMB CARPOMETACARPAL JOINT

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INTRODUCTION Functional restoration of joints that are damaged by OA is a daily challenge that faces orthopaedic surgeons. The thumb carpometacarpal (CMC) joint is arguably one of the most important joint of the hand, and OA of this joint can cause significant debilitating effects on the patient’s activities of daily living (ADL). The etiology of OA of this joint has not been fully elucidated, though it has been proposed clinically that CMC joint laxity is a major factor in the progression of OA in this joint [1-3]. Several surgical techniques exist that seek to reduce the pain associated with OA, and also to increase the functionality of the arthritic CMC joint during ADL. Two of these techniques are an extension osteotomy of the 1st metacarpal [4, 5] and a ligament reconstruction procedure developed by Eaton and Littler [6]. The Eaton and Littler ligament reconstruction is one of the most common forms of surgical treatment for CMC joint instability without significant OA. In long term assessment studies, the outcome from this procedure has been found to be favorable with relief of pain and restoration of function [1, 6]. Extension osteotomy has also been reported to significantly reduce symptoms of OA and to restore pinch and grip strength [4, 5]. In this study, we propose to quantitate the effects of these two procedures on thumb CMC joint laxity using our custom-designed precision CMC joint laxity tester [7] (25 μm linear, 0.02° angular accuracy). The goal of the study is to compare the laxity of normal CMC joints, to those with a simulated extension osteotomy and laxity of a joint with extension osteotomy and ligament reconstruction in the common functional position of lateral pinch.

METHODS

Preparation Twenty-five fresh frozen human cadaveric specimens (average age 41, range 18-55) were radiographed at the CMC joint and selected for stage 1 or stage 2 OA [8]. The hand was pinned into a position of lateral pinch, two k-wires were passed through the trapezium into the trapezoid and an external fixation system was used to inhibit motion between the 1st and 2nd metacarpals. The trapezium, 1st metacarpal, trapezoid and 2nd metacarpal were removed from each specimen en-bloc, with care not to violate the thumb CMC joint capsule. The distal end of the 1st metacarpal was fixed in a specimen holder using surgical PMMA and k-wires. The proximal end of the trapezium-trapezoid-2nd metacarpal complex was fixed in a similar manner. The joint was irrigated with physiologic saline solution throughout preparation and all subsequent steps to prevent dehydration. Testing The specimen was mounted into our laxity tester, and the external fixation device was removed. Ten cycles of preconditioning were performed in all directions, loading the joint to ±100 N in the radial-ulnar (RU) and dorsal-volar (DV) directions, ±1.25 N-m in pronation-supination (PS), and 111 N in distraction (Dst). A compressive force of 10 N was applied across the joint for all directions except distraction. During loading, all directions except distraction and the direction being tested were rigidly locked to prevent motion. Testing of the joint was performed in an identical manner to the preconditioning procedure.

Surgical Simulations To simulate the effect of a surgical osteotomy of the 1st metacarpal, the joint was placed in a position of flexion. Two levels of flexion angle (10° and 15°) were chosen to simulate the effect of an extension osteotomy for each joint. A modified simulated Eaton and Littler ligament reconstruction was performed on each joint by using a plastic sheathed flexible steel cable in lieu of the flexor carpi radialis tendon. The steel cable prevents creep during the laxity test. In addition, the simulated ligament reconstruction was separated into an anterior (dorsal) portion and posterior (volar) portion for the study. Simultaneous placement of both the anterior and posterior reconstructions constituted a total ligament reconstruction. The previously described preconditioning and testing procedures were repeated for each flexion angle and each step of the ligament reconstruction. The testing order of simulated extension osteotomy (10° and 15°) and simulated ligament reconstruction (anterior, posterior and total reconstruction) was randomized for each specimen.

Data Analysis The last 3 cycles of testing were isolated from each dataset and divided into 4 distinct regions, a toe and linear region in the negative direction and a toe and linear region in the positive direction [7]. Distraction is composed of only positive toe and linear regions.

RESULTS Laxity results for the RU, DV, PS and Dst directions are displayed in Figure 1. We found that all surgical simulations significantly reduced joint laxity in the DV direction. In addition, the total ligament reconstruction and the simulated 15 degree extension osteotomy significantly reduced laxity when compared to the normal joint in all directions tested. The 10 degree extension osteotomy reduced laxity in DV, similar to the effect of a 15 degree extension osteotomy. The anterior reconstruction reduced laxity only in DV and RU, while the posterior reconstruction reduced laxity only in DV. Both the anterior and posterior reconstructions reduced laxity in a similar manner in all directions except RU, where the anterior reconstruction reduced joint laxity.

CONCLUSIONS We have investigated two surgical techniques that are clinically used to treat early stage OA of the thumb CMC joint. The extreme levels of both procedures (15 degree extension osteotomy and total ligament reconstruction) significantly reduced the overall laxity of the joint. The intermediate levels of both procedures (10 degree extension osteotomy, anterior and posterior ligament reconstructions) did not reduce laxity as consistently (See Figure 1). Surgical reduction of joint laxity may explain the clinical improvement of hand function and reduction of pain that has been found with these two procedures [4]. We have developed a new device, the CMC joint laxity tester, to evaluate surgical repair techniques which aim to stabilize the CMC joint. This study is the first quantitative assessment of the effect of a simulated ligament reconstruction and extension osteotomy on laxity of the thumb CMC joint.

REFERENCES: