J Shoulder Elbow Surg (2015) 24, 1926-1933

ELSEVIER

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

BASIC SCIENCE

Role of the interosseous membrane and annular ligament in stabilizing the proximal radial head

Ashley Anderson, MD, Frederick W. Werner, MME*, Emily R. Tucci, BS, Brian J. Harley, MD

Department of Orthopedic Surgery, SUNY Upstate Medical University, Syracuse, NY, USA

Hypothesis: The purpose of our study was to determine the relative contributions of the annular ligament, proximal band, central band, and distal band of the interosseous membrane in preventing dislocation of the proximal radius.

Methods: In part 1 of the study, 8 forearms were loaded transversely with the forearm intact, and the central band, proximal band, and annular ligament were sequentially sectioned to determine the percentage contribution of each structure in preventing transverse radial displacement. In part 2, 12 forearms were cyclically supinated and pronated while optical sensors measured radial and ulnar motion. Transverse radial head motion was computed as the distal band, central band, and proximal band (and annular ligament) were sequentially sectioned.

Results: In part 1, there was no significant difference in the percentage contribution of each structure in preventing radial transverse displacement. In part 2, only after sectioning of the central band did significant radial head displacement occur. Greater displacements occurred in supination than in pronation. Dislocation of the proximal radius occurred in 2 arms after sectioning of all 3 structures.

Discussion: Under pure transverse displacement, the central band, annular ligament, and proximal band equally contributed to stabilizing the radius. However, during forearm rotation, the central band contributed more to radial head stability than the annular ligament and proximal band. Our study contributes to our knowledge of forearm biomechanics, demonstrating the importance of the central band in providing proximal radial head stability. Forceful supination should be avoided after surgical procedures designed to stabilize the radial head.

Level of evidence: Basic Science Study, Biomechanics.

Keywords: Radial head dislocation; annular ligament; interosseous membrane

The interosseous membrane of the forearm is a complex structure that consists of the distal band, central band, and proximal band.[15] The majority of the literature on the stabilizing role of the interosseous membrane has focused on forearm axial stability[6,13] rather than on stability in the transverse plane. Pfaeffle et al[12] have shown that there are transverse force vectors resisting displacement between the radius and ulna; however, their study was similar to others

Funded by the Department of Orthopedic Surgery, SUNY Upstate Medical University.

This is a cadaver study, no specific Institutional Review Board approval was needed.

*Reprint requests: Frederick W. Werner, MME, Department of Orthopedic Surgery, SUNY Upstate Medical University, 750 E Adams St, Syracuse, NY 13210, USA.

E-mail address: wernerf@upstate.edu (F.W. Werner).

1058-2746/$ - see front matter © 2015 Journal of Shoulder and Elbow Surgery Board of Trustees.
http://dx.doi.org/10.1016/j.jse.2015.05.030

in that it measured the forces as a longitudinal compressive force was applied from the hand toward the elbow. Also, transverse loads are routinely applied to the radius during activation of the biceps muscle, which is both an elbow flexor and supinator.

The goal of our study was to determine what structures provide transverse stability when a forearm is rotating or when transverse load is applied directly to the radius, such as when the biceps muscle is activated. Clinically, this information could help to further define the structures that prevent transverse radial head dislocation in cases of forearm and elbow injury. Most reports on radial head dislocation focus on its occurrence in children,[9,11] especially in conjunction with a Monteggia fracture. However, radial head dislocation without any bone injury has been reported in both children[2,8,22] and adults.[3,4,14,18,20]

The specific purpose of this study was to determine the contributions of the annular ligament and the proximal, central, and distal bands of the interosseous membrane of the forearm in preventing transverse dislocation of the radius. We hypothesized that the proximal band, annular ligament, and central band provide support when transverse forces are applied to the forearm, such as when biceps muscle activation occurs.

Methods

Two separate biomechanical studies were performed to look at the role of the forearm stabilizing structures in preventing radial head dislocation.

Part 1: pure transverse separation

Eight fresh cadaver forearms (average age, 71 years; 5 male, 3 female) were dissected free of muscles and surrounding tissues until only the interosseous membrane, capsular structures, annular ligament, wrist, radius, ulna, and humerus remained. The ulna was then anchored in a customized aluminum channel proximally and distally by a pair of pins (Fig. 1). The ulnohumeral joint was left unrestricted. The radius was attached, again with a pair of transverse pins, to a plate that was attached to an MTS machine (MTS Systems Corporation, Eden Prairie, MN, USA) in neutral rotation with respect to the ulna. While a transverse preload of 30 to 40 N was applied to the radius, the plate was allowed to pivot before it was clamped to the MTS. In this manner, all interosseous structures were uniformly tensioned before testing. After the plate was secured to the MTS, its orientation was maintained during loading. Thus, when the bones were separated a given amount, each soft tissue structure was displaced the same amount, even as other structures were sectioned.

Before sectioning of any soft tissues, each radius was displaced transversely in a radial direction away from the ulna until a force of 150 N was reached and the displacement recorded. The soft tissues were preconditioned by transversely loading the radius 20 times under displacement control to this recorded displacement, first with the forearm intact and then again after sectioning of the central band, after sectioning of the proximal band, and again after sectioning of the annular ligament in a partially random sequence. In 4 specimens, the order of sectioning was proximal to distal (annular ligament first, then proximal band, and then central band). In the other 4 specimens, the order of sectioning was distal to proximal (central band first, then proximal band, then annular ligament). After sectioning of these 3 structures, the remaining structures included the distal band, the distal radioulnar ligaments, the wrist extrinsic ligaments, and the elbow capsular structures. During the final loading cycle while all structures were intact and after sectioning of each structure, the force required to achieve the initially determined displacement was recorded. As described by Stuart et al[17] in their study of dorsal/palmar stability of the distal radioulnar joint, by using the same displacement as each structure was sectioned, the percentage contribution of each structure in resisting transverse separation of the radius and ulna can be computed, independent of the order of sectioning. As Stuart et al[17] noted, this type of testing is based on a stiffness model in which the components of a joint are moved to a defined displacement while the resultant loads are recorded. The total restraining force represents the sum of the individual soft tissues supporting the joint. As each soft tissue is sectioned, the resultant decrease in restraining force reflects the relative contribution of that structure to the total restraining force. The percentage force contribution of the central band, proximal band, annular ligament, and remaining structures in preventing transverse displacement of the radius was therefore computed for each arm. Because each arm served as its own control, a repeated-measures analysis of variance at a level of significance of .05 was used to compare the percentage contribution of each structure. A post hoc test using a Bonferroni correction for multiple comparisons was used to examine differences between structures.

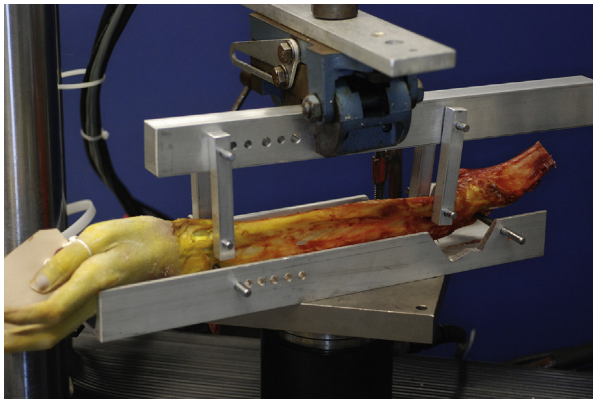

Figure 1 Experimental setup to apply transverse loading of the forearm. Radius and ulna were secured with pins through each bone with the forearm in neutral forearm rotation.

Part 2: dynamic forearm motion

Twelve fresh frozen cadaver forearms (average age, 75 years; 9 male, 3 female) were tested in a wrist and forearm servohydraulic simulator (Fig. 2).[5,19] Each forearm was pinned in 90° of elbow flexion with pins from the ulna into the humerus. The arm was further stabilized by a threaded rod cemented into the humeral midshaft and attached to the loading frame; by a plastic plate on which the elbow sat; and by a plastic fork surrounding the