The Effect of Implant Constraint, Ligament Sectioning and Radial Head Management on Joint Loading in Total Elbow Arthroplasty

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Introduction: Ligaments and osseous constraints are the static stabilizers of native articulations, however, joints that have undergone prosthetic replacement with the use of a semi-constrained, or linked, implant provide a potential third static stabilizer. In the elbow, the presence of competent collateral ligaments(1,2) and the radial head(3,4) would be expected to improve stability and decrease loading on the ulnohumeral articulation, thereby reducing eccentric wear of the polyethylene components. The purpose of this study was to determine the effects of the collateral ligaments, radial head, and implant linkage on wear-inducing loads in total elbow arthroplasty.

Materials and Methods: Eight cadaveric upper extremities (mean 73.5yrs; 5 male), amputated at mid-humerus with soft tissues intact were tested using a computer-controlled elbow motion simulator equipped with an electromagnetic tracking system. Humeral, ulnar, and radial components of a linkable elbow arthroplasty were positioned using a computer-assisted technique. Wear inducing varus-valgus bending and internal-external torsion loads were measured during flexion using a humeral component instrumented for different combinations of static stabilizers (Figure 1).

Results: There were no significant differences in the resultant load (of the two bending measurements) for dependent flexion with the arm in the vertical orientation regardless of the status of the ligaments, radial head or implant linkage (p>0.2). Loading was highest at 120° of flexion (p<0.05, Figure 2A). Radial head excision produced an increase in valgus angulation of the ulna but did not influence humeral component loading (p<0.05). For flexion with the arm in the valgus orientation, loading was lowest with the unlinked implant with ligaments and radial head intact (p<0.01, Figure 2B). There were no differences in varus-valgus angulation for any combination of static stabilizers (p>0.1). For flexion with the arm in the varus orientation, loading was also lower for the unlinked implant with ligaments and native radial head intact (p<0.05, Figure 2C). There were no differences in varus-valgus angulation for any combination of static stabilizers (p>0.2). Loading was higher in the varus and valgus orientations than for the dependent orientation (p<0.05).

Discussion: In addition to measuring kinematic changes, we have also measured changes in wear-inducing bending loads as a result of different combinations of ligament repair, radial head management and implant constraint. This is important, as although no significant changes in kinematics were observed with the arm in the varus or valgus orientations, changes in loading did occur. Similarly with the arm in the dependent orientation, changes were observed in kinematics but not in the bending loads. This is likely because in the dependent orientation the implant cannot create off-axis loads if it does not reach its varus-valgus limits, which was the case in this study. However, with the arm in the varus or valgus orientation and only passive motion, the linked implant does reach its VV laxity limits, thereby increasing bending loads. As in other studies, our results show that the radial head is an important valgus stabilizer of the elbow prosthesis employed in this investigation (1-4). Linkage of the articulation increases implant loading during passive flexion. This suggests that, when adequate bone stock and ligaments are available, an unlinked total elbow prosthesis should be considered, whilst preserving or repairing the collateral ligaments and preserving or replacing the radial head in order to minimize wear-inducing loads.


Figure 1: Flowchart of Stabilizer Combinations Tested. Note that once the ligaments were sectioned they were not repaired for the remainder of the tests. Combinations without either intact ligaments or a linked ulnohumeral articulation were not tested in the varus or valgus orientations due to gross instability.

A tracking receiver attached to the ulna recorded its position during active and passive flexion in the dependent orientation, and passive flexion in the varus and valgus orientations.

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Figure 2: Bending Load of the Humeral Component During Elbow Flexion. The mean resultant load (in N-mm) for (A) active motion in the dependent orientation, and for passive motion in the (B) valgus and (C) varus orientations. Combinations without either intact ligaments or a linked ulnohumeral articulation were not tested in the varus or valgus orientations due to gross instability.