THE RADIAL HEAD COMPONENT IN UNLINKED TOTAL ELBOW ARTHROPLASTY

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Introduction

The goals of reconstructive total joint arthroplasty are to provide motion with stability, relieve pain, and correct deformity. Total elbow arthroplasty has been a valuable procedure for patients with rheumatoid arthritis, post-traumatic arthritis, osteoarthritis and failed reconstructive procedures of the elbow. Current unlinked total elbow prosthetic designs have achieved high success rates in meeting these goals for the rheumatoid patient in both short and long-term follow-up studies. However the main concern with unlinked total elbow arthroplasties is instability. The design of prosthetic implants should be based on a detailed understanding of the anatomy and biomechanics of the elbow including its motion and the forces applied to the joint surfaces. The role of the radial head has never been clarified in TEA surgery. With unlinked implant designs, stability relies not only on the geometry of the prosthesis but also soft tissue structures. The major drawbacks of an unlinked prosthesis are postoperative dislocation and implant loosening. The rates of dislocation in patients who have rheumatoid arthritis have ranged from 5-15 per cent. Although the radial head is an important contributor to stability in the normal elbow, there exists little information on the role of a radial head component in maintaining the kinematics and stability of the elbow following prosthetic replacement.

Instability of an unlinked TEA is attributable to a number of factors, including the design of the prosthesis, the quality of the bone stock, the integrity of the ligaments, and the position of the prosthesis. The current focus of the unlinked design is restoration of normal kinematics without compromise of stability. The Sorbie-Questor™ unlinked total elbow prosthesis (Wright Medical Technology, Inc., Arlington, Tennessee) was designed based on the premise of replicating normal anatomic surface geometry of the elbow, theoretically, which should improve joint stability and reduce the risk of dislocation. This most recent TEA design differs from those in current use in that it comes with a radial head component.

The purpose of this study was to investigate the contributions of the radial head component on the kinematics and stability of the Sorbie-Questor anatomic total elbow arthroplasty. Our hypothesis was that this anatomic total elbow arthroplasty, when precisely positioned at implantation, would demonstrate motion patterns comparable to those of the normal elbow, but that stability would depend on the implantation of the radial head component.

Materials and Methods

Ten fresh-frozen cadaveric elbows with no radiographic evidence of osteoarthritis were used. Each specimen was mounted in a testing fixture which permitted the elbow to flex-extend in a horizontal or vertical plane while keeping the humeral shaft parallel to the floor. This system allowed neutral, varus and valgus loads to be applied to the elbow. Weights attached to sutures placed through the biceps, brachialis, and triceps tendons simulated low, medium, or high loads. These balanced loads were selected to simulate in vivo muscle forces acting across the elbow.

Measurement System and Data Reduction

A Fastrak 3-Space electromagnetic tracking device was used to measure and record three-dimensional positional data with 6 degrees of freedom in real time at 30 Hz. The sensors were attached to the humerus, radius and ulna to track the relative motions of the bones.

Total Elbow Implantation

The Sorbie-Questor total elbow arthroplasty was implanted using the special instrumentation system for the precise orientation of components on the anatomic axes of motion. A 7-degree-valgus humeral component and six millimeter thick ulnar component were used in this study. The epicondyle was reattached with a titanium screw into a hole that had been augmented with polymethylmethacrylate in order to restore integrity of the lateral ligamentous supports. The prosthesis has three (small, medium, large) component sizes. Standard implantation techniques were used with special care to ensure correct positioning of the component. After placement of the components and reattachment of the lateral epicondyle, the remaining soft tissue envelope was closed in layers (TEA with radial head). The motion patterns and laxity were then measured. In the last step, the radial head component was removed (TEA without radial head), and the motion patterns and laxity of the elbow prosthesis were then recorded.

Results

Functional kinematics

The kinematics of the elbow before and after the surgical approach (control) were very similar and without significant differences. After TEA, the motion patterns were similar to those of the intact elbows. Both tended to be in valgus in extension, slight varus at mid-flexion, and valgus towards full flexion.

Laxity

The maximum varus-valgus laxities, under varus-valgus stresses respectively, throughout the arc of elbow flexion-extension were not different for the intact elbows and controls after the surgical approach. Under conditions of simulated muscle loading, there were significant increases in maximum laxity for TEA's with (8.6±4.0 degrees) or without radial heads (13.3±5.5 degrees). The presence of a radial head reduced laxity by 4.2 degrees. The maximum valgus-varus laxity of the TEA remained, on the average, 6.9±3.6 degrees greater than normal under medium muscle loads. Without a radial head component, the TEA laxity further increased by 2.2 degrees (13.3 ± 2.9).

In the presence of a radial head component, increasing the muscle loading progressively decreased the varus-valgus laxity for the TEA, especially towards full extension. However, such was not the case if the radial head was left out. After TEA with radial head, both the varus and valgus stress curves in the extension half of motion were close to the neutral curve under high muscle loads. Under high loads, the laxity at 30 degrees was significantly smaller for the TEA with radial head (4.4 ± 2.2) than for the TEA without radial head (7.4 ± 3.3). Under medium and high loads, the total valgus-varus laxity of the TEA with a radial head was always less than that for the TEA without the radial head throughout the arc of motion. This was a significant effect of the radial head replacement.

The effect of the radial head on stabililty after TEA was evident grossly as none dislocated during testing with a radial head component in place, but one elbow dislocated after TEA without the radial head component.

Discussion

This study specifically addresses the importance of the radial head component in an unlinked TEA, demonstrating the role of radial head replacement on elbow kinematics and stability of an anatomic design total elbow prosthesis. In the present study, under conditions of medium and high joint compressive force and muscle-loading, the motion patterns of the TEA resembled those of the intact elbow. This indicates that the design of the prosthesis make it possible to replicate physiologic joint tracking, presumably due to replication of the native anatomy. This is the first unlinked TEA whose motion pattern so closely resembles the normal kinematics of the elbow. semiconstrained TEA.

To achieve kinematics close to the normal required implantation of the radial head component supplied with the prosthesis. Clinically, one of the unsolved problems with TEA is the question of whether or not a radial head replacement should be used. This study suggests that replacement should be carefully weighed. The stability and kinematic patterns were further improved with increasing joint compressive loading by simulated musle contraction, but this benefit only occurred when the radial head had been implanted. This dynamic stabilization mechanism is very important for clinical performance, and likely will have an effect on the functional long-term survival of the prosthesis.

The humeral component in this design has a valgus inclination of 7 degrees, which is the same as the normal elbow (6.8 degrees). The humeral stem of two popular TEA's, the Capitellocondylar and Kudo are set in valgus angulation of 5 degrees. Increasing the valgus angulation will increase the valgus torque. The radial head component is therefore important both for stress distribution and for transfer of joint reactive force. It can normalize the stress distribution at the joint interface, and can also decrease the extent of eccentric joint loading. For these reasons, the radiocapitellar articulation is important in this type of design. Unbalanced or eccentric force vectors may lead to polyethylene wear and osteolysis with prosthetic loosening.

Another potential advantage of the radial head component might be to decrease the incidence of dislocation. In our series, one elbow dislocated by a posterolateral rotatory mechanism after TEA without a radial head component, while under valgus stress, but was quite stable after replacement of the radial head. This suggests that etiologies of dislocation after unlinked TEA include not only soft tissue imbalance or implant malalignment but the absence of the radial head itself. The importance of the radial head as an articular stabilizer against valgus stress forces as well as a transmitter of vertical loading across the elbow is significant.

In conclusion, this study demonstrates that the motion patterns of the Sorbie-Questor unlinked TEA replicated the kinematics of the normal elbow, confirming the achievement of an anatomic surface replacement. However, the radial head component was necessary for stability and proper tracking under varus-valgus loads. The radial head component enhances the dynamic contribution of muscle loading to stability in the extension half of the arc of motion. The use of radial head implant will be an important factor enhancing stability in unlinked resurfacing TEA. The inclusion of a radial head component can also balance load distribution which would reduce stress on the ulno-humeral articulation and possibly reduce polyethylene wear, osteolysis and loosening.