

POLYETHYLENE WEAR AFTER TOTAL ELBOW ARTHROPLASTY

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Background: Articular wear is considered to be a possible long-term complication of the use of stemmed, coupled elbow replacements with the capacity to correct deformity and restore function. There have been no reports on this topic, to our knowledge.

Methods: A review of the results of 919 replacements with the semiconstrained linked Coonrad-Morrey total elbow implant, performed between 1981 and 2000, revealed that twelve patients (1.3%) had undergone an isolated exchange of the articular bushings as a result of polyethylene wear. The status of these patients was assessed clinically and radiographically.

Results: The mean age of the twelve patients at the time of the initial total elbow replacement was forty-four years compared with a mean age of sixty-two years in the overall group ($p < 0.001$). Seven of the twelve patients had post-traumatic arthritis, and five had rheumatoid arthritis. Nine patients had extensive deformity. The group consisted of seven women and five men, and ten patients had involvement of the right dominant elbow. The mean age at the bushing revision was fifty-two years, and the bushings were revised at an average of 7.9 years after implantation. All twelve patients reported pain, and five reported crepitus or a squeaking sound. None had extensive osteolysis. The mean duration of follow-up after the bushing exchange was sixty-five months. The mean arc of motion improved from 89° before the surgery to 109° after it. Three of the twelve patients underwent an additional articular revision at fifty-three, fifty-four, and 136 months after the initial bushing exchange. At the time of final follow-up, all twelve patients had functioning elbows.

Conclusions: Isolated bushing exchange can be a successful revision procedure in patients with a semiconstrained linked total elbow prosthesis. Younger patients with a posttraumatic condition and/or severe pre-existing deformity are at greater risk for the development of excessive bushing wear. Patients should be cautioned against exceeding the recommended activity and lifting restrictions.

Level of Evidence: Therapeutic Level IV. See Instructions to Authors for a complete description of levels of evidence.

The success of total elbow arthroplasty has become more established and accepted in the last decade¹. Indications have also expanded to include the full spectrum of traumatic conditions, including distal humeral nonunion, instability², ankylosis³, established arthritis⁴, and acute intra-articular, comminuted fracture in selected older patients⁵⁻⁷. To our knowledge, wear of the polyethylene articulating surface has not been previously described as a mode of failure of total elbow arthroplasty since loosening and implant dislocation have tended to occur before articular wear. With improved longevity of the total elbow replacement and better function resulting in increased use of the limb, polyethylene wear and its consequences now occur and should be studied. We are not aware of any specific reports on this topic, which is not typically con-

sidered when complications are being discussed⁸.

To address this issue, we reviewed our experience with operations to exchange worn bushings in the semiconstrained linked Coonrad-Morrey total elbow replacement (Zimmer, Warsaw, Indiana). Our aim was to document the prevalence of isolated bushing exchange due to wear problems, factors predisposing to bushing wear, diagnostic features, and results of the revision surgery.

Materials and Methods

Database

Through a search of the Mayo Clinic total joint database, we identified 919 Coonrad-Morrey semiconstrained total elbow arthroplasties that had been done at our institution from October 1981 through December 2000. The majority of the procedures were performed because of rheumatoid arthritis (377; 41%) or trauma-related conditions (310; 34%). The latter category included posttraumatic elbow arthritis, distal



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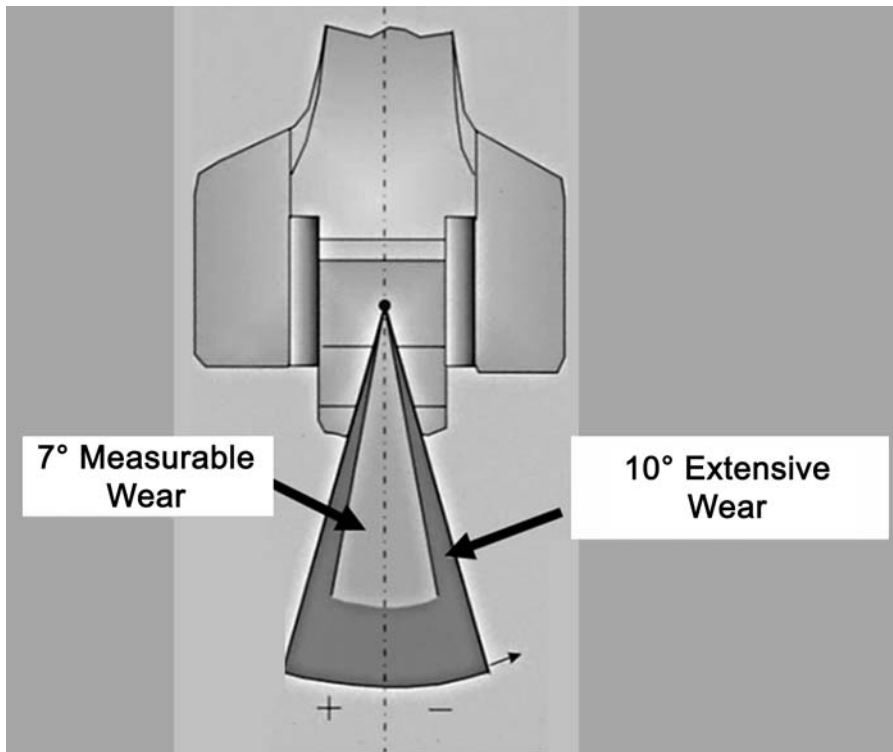


Fig. 1

Wear of the polyethylene bushing is measured according to the angle formed by the articulating portion of the ulnar component and the medial or lateral aspect of the humeral articular yoke. Angles in excess of 7° indicate displacement greater than allowed by the design tolerances. When this angle is 10° , mild-to-moderate wear is considered to be present and the patient is considered to be a candidate for surgery.

humeral nonunion, acute distal humeral intra-articular fracture, chronic instability, and ankylosis^{6,7,9}. The remaining 232 procedures were revision total elbow arthroplasties: sixty were revisions of Coonrad-Morrey prostheses that had been implanted at our institution, forty-eight were revisions of other designs that had been inserted at our institution, and 124 were revisions of various designs that had been implanted elsewhere. Of the 919 elbows, ten (1%) were lost to follow-up and sixty-two were followed for less than one year. Thus, data obtained after at least one year of follow-up were available for 847 elbows (92%).

Study Group

Of the 919 elbows, twelve (1.3%) in twelve patients underwent exchange of the articular bushings between 1989 and 2000 (see Appendix). Patients who underwent revision because of loosening were excluded from the study regardless of the status of the bushings. An additional six patients were diagnosed as having bushing wear on the basis of an asymmetric anterior-posterior orientation of the ulnar component within the humeral yoke, but these patients did not have a revision.

Demographic data were obtained through a review of the patients' charts. Predisposing factors such as hand dominance, body weight, occupation, and amount of deformity seen radiographically were specifically assessed to identify potential influences on bushing wear.

The presence of pain, the range of motion, and the functional assessment were recorded to determine elbow function. This information allowed calculation of the Mayo Elbow Performance Score (MEPS) both before and after bushing ex-

change (see Appendix). The results were graded as excellent, good, fair, or poor according to this system¹⁰.

Radiographic assessment was conducted before the total elbow replacement to identify deformity and after replacement to identify signs of bushing wear, osteolysis, and the status of the implant. Anteroposterior plain radiographs of each elbow in full extension that were made following the index total elbow arthroplasty and at the time of the bushing exchange were compared to measure the extent of the bushing wear. The prosthesis was designed with 7° to 10° of varus-valgus laxity. The criteria for the assessment of wear were previously described by Ramsey et al.². A line is drawn parallel to the yoke of the humeral component, and another line is drawn parallel to the medial or lateral surface of the articular surface of the ulnar component. An angle of intersection of $>7^\circ$ between these two lines indicates alteration of the bushing due to wear or plastic deformation (Fig. 1). An angle of $\geq 10^\circ$ is considered to indicate mild-to-moderate bushing wear. In addition, the presence of humeral or ulnar implant-bone lucency and osteolysis were recorded at the time of the bushing exchange.

Surgical Technique

The previous skin incision is used to explore the elbow, and the ulnar nerve is palpated. If the patient has ulnar nerve symptoms, the nerve is explored and decompressed. If the nerve is not symptomatic, it is identified proximally at the medial aspect of the triceps and is protected throughout the procedure. If the distal part of the humerus has been resected or is absent, the triceps is left attached to the ulna, the pseudocap-

sule is entered medially and laterally, the articulation is disengaged, and the humerus and ulna are separated. If the condyles are intact, the triceps is again reflected from the ulna according to a previously described technique¹¹. At this juncture, the anterior aspects of the medial and lateral epicondyles are removed to an extent sufficient to allow the implant locking pin to be removed both medially and laterally (Fig. 2). The posterior aspects of the condyles are left intact. The medial and lateral bushings are removed from the humerus, and the bushing is removed from the ulna. The soft tissue is assessed, and a thorough débridement is carried out. If the wear is sufficient to have resulted in impingement of the metallic ulnar component on the metallic humeral component, then black synovitis is the predominant feature.

After débridement, the implant is inspected for the integrity of the fixation and orientation. In this series, no patient was thought to have sufficient malorientation to justify revision of either implant. If there has been resorption or osteolysis at the distal aspect of the humerus or the proximal aspect of the ulna, the interface is thoroughly cleaned and is filled with methylmethacrylate. Fresh bushings are then inserted in the ulnar and humeral components, and the implant is coupled with use of the pin-within-pin snap-fit articulation. If the preoperative assessment and intraoperative evaluation indicated a fixed angular deformity that cannot be corrected passively, then the soft tissue is released to allow correction of the deformity. Thus, an extensive flexor release from the humerus is carried out for the treatment of varus deformity. Similarly, an aggressive extensor tendon release, including the distal fibers of the brachioradialis, is performed to treat a fixed valgus deformity. The triceps is reattached with use of a cruciate and transverse drill pattern as previously described¹¹.

Statistical Analysis

A chi-square test was used to determine significant differences between two sets of discrete data. Differences that had less than 0.05 probability of occurring from chance were considered significant.

Results

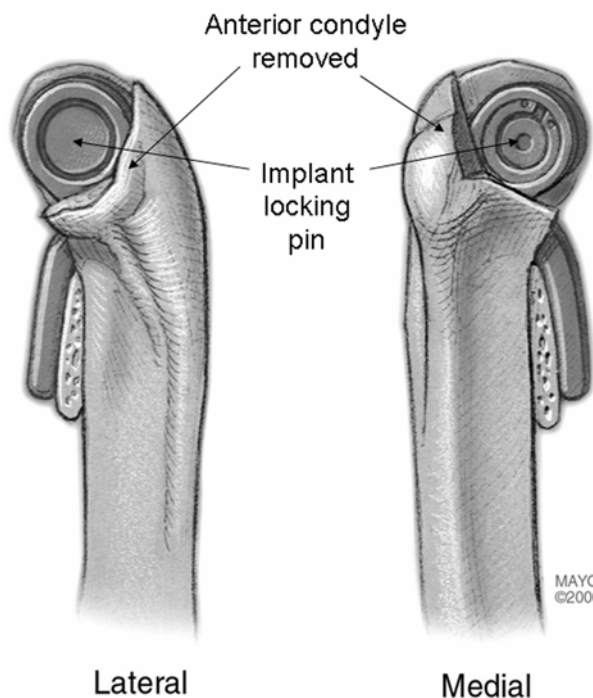
Initial Clinical Characteristics

Seven female and five male patients (twelve elbows) underwent bushing exchange. Five had rheumatoid arthritis and seven had posttraumatic arthritis. Ten patients had involvement of the right, dominant elbow. In the overall sample, the patients with posttraumatic arthritis had a higher prevalence of bushing wear (seven of 294; 2.4%) than did those with rheumatoid arthritis (five of 377; 1.4%) ($p = 0.14$, chi-square test). There were no isolated bushing exchanges following any of the 232 index revision total elbow replacements. The index primary total elbow arthroplasties in the twelve patients who subsequently had a bushing exchange were performed between 1982 and 1994, when the patients were an average of forty-four years old (range, thirty to fifty-nine years). This compares with a mean age of sixty-two years in the 907 patients who did not have isolated bushing exchange in the overall sample of 919 patients ($p < 0.001$). Of the twelve patients who underwent bushing exchange, six had a sedentary occupation (homemaker or a desk job), four had a moderately active occupation (nurse and sales agent), and two had a strenuous occupation (contractor and lumberjack). The mean body weight of the twelve patients was 77 kg (range, 54 to 96 kg).

Prior to the arthroplasty, radiographic assessment revealed a markedly distorted joint in nine patients, with severe rheumatoid arthritis in four, marked varus or valgus defor-

Fig. 2

The condyles are preserved by removing sufficient anterior condylar bone to expose and reveal the pin. Bushing exchange is carried out by unlinking the coupled articulation. (By permission of the Mayo Foundation.)



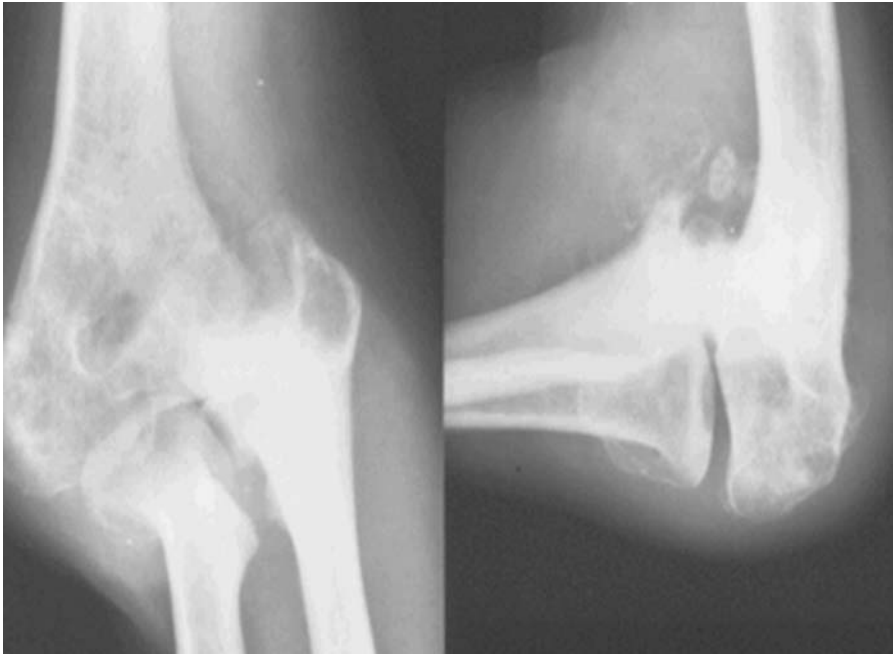


Fig. 3-A
Radiographs showing severe elbow deformity of thirty-five years' duration secondary to a fracture of the humeral condyle sustained when the patient was a child.

mity of $\geq 10^\circ$ in nine, and gross dissociation of the ulna from the humerus (a flail elbow with complete loss of the distal humeral condyles) in four (Figs. 3-A and 3-B). Nine of the elbows had absence of one or both distal humeral condyles.

Initial Outcome

All twelve patients had had an excellent or good result immediately following the index elbow arthroplasty. Postoperative anteroposterior radiographs revealed that the articulation was at the limits of the designed angular tolerance in nine of the twelve patients. One patient had a fracture of the medial condyle during the index surgery, which was fixed with a screw.

Failure of the index total elbow arthroplasty occurred at a mean age of fifty-two years (range, thirty-seven to sixty-eight years). The period between the index arthroplasty and the bushing exchange averaged 7.9 years (range, forty-eight to 156 months).

Prior to the bushing exchange, all twelve patients had pain and five had crepitus or squeaking sounds with any movement of the affected elbow. Pain was graded as mild in two patients, moderate in seven, and severe in three. The mean total arc of motion was 89° (range, 60° to 130°). The average extension loss was 32° (range, 0° to 55°), and the average flexion was 121° (range, 105° to 140°). The mean amount of pronation and supination were 64° (range, 30° to 90°) and 59° (range, 20° to 90°), respectively. No patient had any symptoms of functional instability. The Mayo Elbow Performance Score (MEPS) averaged 48 points (30 to 65 points), with two elbows graded as fair and ten graded as poor.

Radiographic Assessment

Plain anteroposterior radiographs of the elbow in full extension made just prior to bushing exchange all showed obvious

asymmetry of $\geq 10^\circ$ at the yoke as described above. Osteolysis, defined as localized osseous resorption, was assessed immediately after the primary total elbow arthroplasty and at the time of the bushing revision. It was identified in the distal part of the humerus in four patients, and some resorption of the proximal part of the ulna was recorded in three.



Fig. 3-B
Worn bushing noted four years after the surgery. The patient worked as a lumberjack against medical advice.



Fig. 4-A
A moderate preoperative valgus deformity of 25° in a patient with rheumatoid arthritis and a prior radial head excision.

Bushing Exchange

Marked synovial discoloration due to titanium particulate debris was found at the time of surgery in four patients. Two patients had a moderate amount of discoloration, four had a small amount, and two had no appreciable synovial discoloration. In no instance did the osteolytic process appear to compromise fixation or function. The humeral and ulnar bushings were replaced in all patients.

Clinical Outcome

Initially, the isolated bushing exchange was technically successful in all twelve patients (Figs. 4-A through 4-E). There were no wound complications or deep infections. Clinically, eight patients had no pain, one had mild pain, one had moderate pain, and two had severe pain following the revision surgery. None had instability symptoms. The mean MEPS was 86 points (range, 50 to 100 points), with eight elbows graded as excellent; one, as good; one, as fair; and two, as poor. The mean arc of flexion after the bushing exchange improved to 109° (range, 70° to 130°) with a mean extension loss of 21°

(range, 0° to 50°) and a mean flexion of 130° (100° to 145°). Pronation and supination, which were essentially unchanged from the preoperative values, averaged 69° (range, 50° to 90°) and 63° (range, 20° to 90°), respectively.

All patients were assessed at an average of sixty-five months (range, twenty-four to 136 months) after the revision. At this time, three patients were examined by us, five were in-



Fig. 4-B
Alignment at six months.



Fig. 4-C
Excessive wear of the articulation at five years.

interviewed by telephone, and four returned a questionnaire. The final radiographs for eight patients were made at our institution, and four patients sent radiographs that had been made locally. The time of the final contact with the patient or the time of subsequent revision surgery was defined as the time of the last follow-up.

Three patients underwent a second bushing exchange procedure because of clinical and radiographic evidence of wear of the previously exchanged bushings at fifty-three, fifty-four, and 136 months after the initial bushing exchange. Of the three patients, two had a sedentary occupation and one, a

moderately strenuous occupation. All had had a marked initial deformity. All three patients had a successful second bushing exchange, with a "good" MEPS at fifteen, eighteen, and fifty-one months. Hence, at the time of final follow-up, all twelve patients had a functioning elbow replacement.

Two patients had a poor result, due to persistent pain from ulnar nerve neuropathy, following the bushing exchange. In one of these patients, the symptoms had been present before the revision procedure and did not resolve or change after the nerve was decompressed at the time of the bushing replacement. In the other patient, ulnar neuritis developed after the revision surgery. In both cases, clinically adequate ulnar nerve transposition had been performed at the time of the primary total elbow arthroplasty and the nerve had been reexplored at the revision operation and noted to have been decompressed. These residual symptoms substantially compromised the overall functional outcome for these two individuals.

Discussion

Despite the increased longevity of semiconstrained linked total elbow prostheses and the use of these implants to treat an increasingly complex array of pathological conditions, only twelve (1.3%) of 919 such implants inserted at our institution over a twenty-year period required a reoperation specifically for replacement of worn articular bushings. A higher bushing revision rate was associated with a younger patient age and showed a trend toward an association with traumatic conditions.

While the low prevalence of clinically relevant wear requiring revision is encouraging, the small numbers in this study make analysis difficult. This experience does not docu-



Fig. 4-D
Note the absence of osteolysis.



Fig. 4-E

At twelve years after the initial procedure and seven years after the bushing exchange, the implant had not loosened and the bushing showed little evidence of wear.

ment the overall wear rate of this device during the study period because six additional patients with radiographically documented worn bushings were found in the database. Furthermore, since stress radiographs were not routinely made, the absolute wear rate cannot be determined from this study. On the basis of the data available, neither increased patient weight nor hand dominance in relation to the involved elbow was found to predispose the bushings to wear. We do not have

sufficiently accurate data to definitely correlate strenuous or very active lifestyles or occupations with bushing wear.

It is possible that the feature with the greatest prognostic importance is severe preoperative deformity at the time of the index total elbow arthroplasty. Nine of the twelve patients had extensive or high-grade deformity or loss of at least one humeral condyle at the time of the primary total elbow arthroplasty. In addition, all three elbows that required a second bushing exchange procedure had had marked initial deformity with both angular and translatory loss of the humeral relationship to the ulna.

In all patients, the angular deformity exceeded the tolerance of the articular design. Yet, it is these very problems that



Fig. 5

Extensive osteolysis from loosening without radiographic evidence of bushing wear.

can be addressed only with this type of coupled implant. Substantial malrotation of components at the time of insertion, even without deformity, can also contribute to increased bushing wear¹² although this problem was not specifically recognized in any of the patients in the present series. The insight documented herein is that correcting deformity comes at a price of a potential increased rate of bushing wear. Our current practice, therefore, is to extensively release soft-tissue contractures to eliminate preoperative deformity. We are more willing to resect bone in order to lessen soft-tissue tension that can result in an imbalance that differentially loads the polyethylene.

When a patient has radiographic evidence of wear but no symptoms following the arthroplasty, the process is discussed with the patient. Typically, we simply follow the patient radiographically since, in our experience, the wear debris does not cause fixation-compromising osteolysis. Instability was not a symptom in this group of patients. If a patient has pain or mechanical squeaking, then revision is offered.


Osteolysis that presumably developed in reaction to debris from the worn bushing was not extensive in any of these patients. This finding is in contrast to the situation with hip and knee replacements, in which polyethylene wear causes periarticular osteolysis that can lead to fixation failure. This difference is presumably due to the much smaller absolute volume of wear debris generated by the smaller articular surfaces at the elbow. However, osteolysis can develop and progress in the presence of loose cemented total elbow implants. This has been attributed to small-fragment debris, generated from micromotion, that accelerates osteolysis as a result of third-body abrasion (Fig. 5). A reaction of this type and extent is specifically associated with a loose cemented stem, and it is very important to recognize that polyethylene wear is not its principal cause. Although the reaction has been attributed to bushing wear, its extent and location readily distinguish it as one primarily due to loosening and not directly related to a worn bushing.

Isolated bushing exchange is a successful procedure in the particular situation of isolated bushing wear. The procedure is not extensive, and morbidity is minimal when compared with that associated with the index total elbow arthroplasty. Yet, the issue of articular wear is likely to receive more attention with the rapid increase in the number of total elbow arthroplasties performed worldwide, improved longevity of the implant, ex-

panded indications, and increased patient activity. Attempts to mitigate the problem of bushing wear, such as by increasing the thickness of the polyethylene bushings and using cross-linked polyethylene, are being investigated. Most importantly, the results of our study emphasize the need to perform soft-tissue release and to attempt to balance elbow alignment at the time of total elbow arthroplasties. This is especially the case in patients with severe long-standing deformity.

In summary, the prevalence of isolated wear of polyethylene bushings as a complication and an isolated cause of revision of total elbow arthroplasty was low in our practice, although wear was associated with severe pre-existing deformity in younger patients. Our data revealed that osteolysis is not extensive in patients with worn bushings and well-fixed implants. Isolated bushing exchange is a reliable and effective revision procedure in the majority of instances.

Appendix

 Tables presenting details on all twelve patients and the Mayo Elbow Performance Score are available with the electronic versions of this article, on our web site at jbjs.org (go to the article citation and click on "Supplementary Material") and on our quarterly CD-ROM (call our subscription department, at 781-449-9780, to order the CD-ROM). ■

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