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Linked Elbow Replacement: A Salvage Procedure for Distal Humeral Nonunion

By Akin Cil, MD, Christian J.H. Veillette, MD, Joaquin Sanchez-Sotelo, MD, and Bernard F. Morrey, MD

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Background: Nonunion is a challenging and not uncommon complication of distal humeral fractures. Our long-term experience with linked semiconstrained total elbow arthroplasty as a salvage procedure for patients with distal humeral nonunion not amenable to internal fixation was investigated.

Methods: Ninety-one consecutive patients (ninety-two elbows) underwent total elbow arthroplasty for the treatment of a distal humeral nonunion, and the results were reviewed at a mean of 6.5 years postoperatively. Patients' charts and anteroposterior and lateral radiographs made prior to and immediately after the joint replacement and at the time of the latest follow-up were reviewed to identify intraoperative and postoperative complications, and radiographic evidence of loosening or bushing wear. The outcome measures consisted of prosthetic survival, with implant removal as the end point for failure, and the Mayo Elbow Performance Score (MEPS).

Results: At the time of the most recent follow-up, joint stability had been initially restored in all patients, including nine who had a grossly flailed elbow. Sixty-seven (74%) of the patients had no pain or mild pain at the time of the latest follow-up, whereas seventy-nine patients (87%) had had moderate or severe pain prior to the surgery. While 85% (seventy-seven) of the ninety-one patients rated the outcome as better or much better, twenty patients (22%) had a fair or poor MEPS. A total of forty-four complications occurred in forty elbows, and there were thirty-two reoperations, twenty-three of which involved implant revision or removal. Factors that increased the risk of implant failure were a patient age of less than sixty-five years, two or more prior surgical procedures, and a history of infection. The rate of prosthetic survival without removal or revision for any reason was 96% at two years, 82% at five years, and 65% at both ten and fifteen years.

Conclusions: Linked semiconstrained total elbow arthroplasty is a salvage procedure that can provide pain relief and restore motion and function in patients with a distal humeral nonunion that is not amenable to internal fixation. Substantial risk factors for failure include an age of less than sixty-five years, multiple previous surgical procedures, and any history of infection.

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

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functional range of motion is predictable, and pain and limited motion secondary to persistent nonunion, malunion, or post-traumatic osteoarthritis are avoided. The main disadvantages are the risk of implant-related complications and the need to limit use of the upper extremity postoperatively to minimize the risk of loosening and wear.

We previously reported our initial experience, between 1982 and 1990, with the treatment of distal humeral nonunions with linked implants in thirty-nine patients. The current series is an extension of our previous series, with the addition of new patients and with all patients followed for a longer period of time. The purpose of the current study was to evaluate the clinical and radiographic outcomes of non-custom linked semiconstrained total elbow arthroplasty done as a salvage procedure for patients with distal humeral nonunion not amenable to internal fixation.

Materials and Methods

We performed a retrospective review of the results in ninety-one consecutive patients (ninety-two elbows) in whom a distal humeral nonunion had been treated with a non-custon semiconstrained total elbow arthroplasty between 1982 and 2003. Elbow arthroplasty was selected for symptomatic patients who had a radiographically documented nonunion of the distal part of the humerus that, at the time of surgery, was not considered suitable for secondary osteosynthesis because of poor bone quality or extensive articular comminution. During the same period, 116 distal humeral nonunions were treated with open reduction and internal fixation at our institution. The Coonrad-Morrey total elbow prosthesis (Zimmer, Warsaw, Indiana) was used for all of the elbow arthroplasties; modifications of the design of this prosthesis during the study period have been previously described in detail. The operative technique and our experience from 1982 to 1990 have also been previously described. The triceps was left intact in sixty-five elbows, subperiosteally reflected in twenty, partially reflected in four, and split in three. The ulnar nerve was routinely identified and, unless its path was known with absolute certainty and the patient was asymptomatic, it was dissected free and transposed anteriorly in a subcutaneous pocket. The so-called shuck test was used to determine the correct depth of insertion of the humeral component in the presence of bone loss. The trial implant was inserted, the elbow was placed in 90° of flexion, and the forearm was pulled away from the humerus to determine the soft-tissue tension and balance. The relationship between the remaining humeral condyles and the implant was noted and was reproduced at the time of the final fixation of the implant with cement. A 6-in (15.2-cm) humeral component was used in seventy-three (79%) of the elbows, and a 4-in (10.2-cm) component was used in the remainder.

Patients

Ninety-one patients (ninety-two elbows) were available for follow-up at an average of 6.5 years (median, 5.2 years; range, 0.5 to 20.3 years). All patients were followed for a minimum of two years or until death or implant removal. Three patients were followed for less than twenty-four months: one required a re-operation because of infection at six months, one required revision of the humeral component because of aseptic loosening at thirteen months, and one required revision of the ulnar component because of aseptic loosening at eighteen months. There were twenty-two men and sixty-nine women with an average age of sixty-five years (range, twenty-two to eighty-four years) at the time of elbow replacement. Three patients were less than forty years of age, seven were between forty and forty-nine, fifteen were between fifty and fifty-eight, twenty-seven were between sixty and sixty-nine, thirty-one were between seventy and seventy-nine, and eight were eighty or older. Thirteen fractures were originally open.

The nonunions were classified according to the system described by Mitsunaga et al. Fifty-one nonunions (55%) were intercondylar, thirty-two (35%) were supracondylar, seven (8%) were transcondylar, and two (2%) were condylar. The mean time from the original fracture to the elbow replacement...
was forty-five months (range, four to 672 months). Seventy-six (83%) of the ninety-two elbows had undergone prior surgery, with an average of two procedures (range, one to ten) having been performed. Eight (9%) of the elbows had a history suggestive of infection during the course of treatment, but none had clinical or laboratory evidence of an active infection at the time of the index procedure. The patients had multiple presenting symptoms, with pain in seventy-nine patients, instability in fifty-eight (including nine flail elbows), loss of motion in thirty-eight, and gross deformity in eight. The most common indications for replacement were pain with instability (thirty-five patients) and pain with loss of motion (twenty-six patients). Forty-two (46%) of the patients (forty-three of the elbows) had preoperative ulnar-nerve-related problems. Isolated sensory symptoms were present in nineteen elbows; sensory and motor symptoms, in thirteen; sensory symptoms and ulnar nerve tenderness at the elbow, in nine; and isolated ulnar nerve tenderness, in two.

Coexistent pathological conditions were present in seventy-six patients (84%), with fifty-one of them having multiple comorbidities. Major comorbidities included rheumatoid arthritis in fifteen patients, diabetes mellitus in ten, coronary artery disease in seven, chronic obstructive pulmonary disease in six, asthma in nine, hypertension in forty-eight, cancer in thirteen, and smoking in five patients.

**Clinical and Radiographic Assessment**

A comprehensive evaluation of the preoperative medical history of each patient was performed, and each had a physical examination. We reviewed anteroposterior and lateral radiographs made prior to and immediately after the joint replacement, and at the time of the latest follow-up. Outcome measures included the Mayo Elbow Performance Score (MEPS), radiographic evidence of loosening or bushing wear, adverse events, and prosthetic survival with implant removal as the end point for failure. Five patients were excluded from the radiographic assessment because of deep infection, as two of the infections were clinically apparent despite minimal radiographic changes, and all five were considered to have a failure of treatment. Two patients were excluded from the clinical assessment because of component or periprosthetic fracture requiring immobilization at the time of follow-up, which precluded assessment of the range of motion and function.

None of the patients were lost to follow-up. However, at the time of the review, thirty-eight patients (thirty-nine elbows; 42%) had died of unrelated causes. Thirty-six of the thirty-eight patients (thirty-seven of the thirty-nine elbows) had a well-functioning prosthesis at the time of the last follow-up. The average duration of follow-up for these thirty-eight patients was 5.5 years (range, two to 20.3 years). The follow-up data for these patients had been collected either by the treating surgeon when the patient returned for a routine assessment (nine patients) or by the total joint database surveillance program at our institution when the patient failed to return for a follow-up assessment by the treating surgeon (twenty-nine patients). The total joint database program initially sent a questionnaire to the patients biennially after the operation, and twenty-three returned it by mail. Six patients failed to respond to the questionnaire, and they were interviewed over the telephone by database person-
nel. In either instance, the patients were asked to send radiographs to our institution for review. The average duration of follow-up for the fifty-three living patients was 7.2 years (range, 0.5 to 16.6 years). Of these patients, twenty-six returned for a clinical and radiographic assessment, five were assessed by local physicians, and twenty-two responded to a questionnaire and had radiographs sent to our institution.

The cement technique was assessed on the immediate postoperative radiographs of both the ulnar and the humeral components and was categorized into one of three types, as previously described. Type 1 indicates adequate cementation with a <1-mm-wide radiolucent zone at the bone-cement interface and cement extending past the tip of the prosthesis; type 2, marginal cementation with a 2-mm-wide radiolucency at the interface and cement not extending past the tip of the prosthesis or a <2-mm-wide radiolucency and cement not extending past the tip of the prosthesis; and type 3, inadequate cementation with >2 mm of radiolucency and cement not extending past the tip of the prosthesis.

Implant loosening was assessed on radiographs and was graded on a scale of 0 to 4, as previously described. Type 0 indicates a radiolucent line that is <1 mm thick and involves <50% of the interface; type 1 is a radiolucent line that is 1 mm thick and involves <50% of the interface; type 2 is a radiolucent line that is >1 mm thick and involves >50% of the interface; type 3 is a radiolucent line that is >2 mm thick and involves the whole interface; and type 4 is gross loosening.

Bushing wear was assessed on anteroposterior radiographs made at the time of the latest follow-up and was graded as type 1, 2, or 3, as previously described. Type 1 indicates normal bushings with <3.5° of ulnohumeral angulation in

![Fig. 1-C](image1.png)

Anteroposterior (Fig. 1-C) and lateral (Fig. 1-D) radiographs of the left elbow, made at the time of the sixteen-year follow-up evaluation. The patient had no pain and a MEPS of 95 points (compared with 45 points preoperatively). There was partial bushing wear (between 3.5° and 5° of bushing angulation) without any signs of osteolysis or progressive radiolucency.
the coronal plane (bushing angulation); type 2, partial bushing wear with between 3.5° and 5° of bushing angulation; and type 3, complete bushing wear with >5° of bushing angulation.

The Mayo Elbow Performance Score (MEPS), a performance index based on subjective, objective, and functional characteristics, was calculated preoperatively and at the time of the final assessment. The MEPS assigns a maximum score of 45 points for pain, 25 points for daily functional activities, 20 points for motion, and 10 points for stability. An outcome was considered to be excellent if the score was ≥90 points, good if it was between 75 and 89 points, fair if it was between 60 and 74 points, and poor if it was <60 points.

**Statistical Methods**

The Student t test was used for the comparison of means for scale variables in independent groups (ages of patients with and without aseptic loosening, preoperative and follow-up MEPS, and preoperative and follow-up ranges of motion). Nominal variables were analyzed with the chi-square test or Fisher exact test. A Kaplan-Meier survivorship analysis was performed with implant removal as the end point. Comparison of Kaplan-Meier curves for stratified factors was performed with the log-rank test (Mantel-Cox). Multivariate analysis was performed with use of the Cox proportional hazards model with censoring to identify the independent prognostic factors associated with clinical and radiographic failure. All tests were two-sided. A p value of <0.05 was considered significant.

### Results

**Complications and Reoperations**

Fifty-two (57%) of the ninety-two elbows had no surgical complication or any additional surgery between the time of the index arthroplasty and the follow-up review (Figs. 1-A through 1-D). Thirty-six (39%) of the ninety-two elbows had one complication, and four (4%) had two complications. Overall, forty-four complications occurred in forty (43%) of the ninety-two elbows (Table I).

Five patients had a deep infection. Three of these five patients had a history consistent with infection during the initial management of the distal humeral fracture. Overall, an infection developed after the total elbow arthroplasty in three of the eight elbows with a history of infection compared with two (2%) of the eighty-four elbows with no history of infection (p = 0.004). One patient in whom an infection developed was initially managed with oral suppressive antibiotics for twenty-six months but eventually required a resection arthroplasty. Another patient had an unsuccessful staged revision arthroplasty after aggressive débridement and component removal and required a resection arthroplasty. Two patients initially had débridement with retention of the components, placement of antibiotic beads, and administration of intravenous antibiotics and subsequently were treated with chronic suppressive antibiotics. One of these implants remained in place until the patient died 106 months after the initial replacement; the other required a resection arthroplasty six months after débridement. The fifth patient with an infection had positive intraoperative cultures after a humeral revision done because of loosening and had a successful débridement with chronic suppressive antibiotic therapy for twenty-four months.

There was aseptic loosening of twelve implants, with revision of the humeral component required in four elbows, revision of the ulnar component required in five, and revision of both components required in three (Table I; Figs. 2-A through 2-D). A precoated ulnar component was used in four of the eight elbows in which the ulnar component was revised, and an uncemented humeral implant was used in one. Failure of the c-ring locking mechanism in one implant resulted in progressive bushing wear and osteolysis. One patient had a perforation of the ulna at the time of surgery, and the ulnar component subsequently loosened, requiring revision at sixty-five months. One patient returned to strenuous labor against medical advice; rapid bushing wear and ulnar loosening developed, requiring ulnar revision and humeral bushing exchange at twenty-eight months. The mean age of the patients with aseptic loosening was fifty-six years (range, twenty-eight to seventy-three years) compared with sixty-nine years (range, twenty-two to eighty-four years) for the patients without evidence of aseptic loosening (p = 0.01). Ten of the twelve implants revised because of aseptic loosening were in patients who were less than sixty-five years of age, and the average time to loosening was fifty-four months (range, thirteen to ninety-eight months).

There was a fracture of two humeral and three ulnar components. The average time to component fracture was 107
months (range, forty-six to 195 months), and the mean age of these patients at the time of surgery was sixty years (range, forty-nine to seventy-one years). The ulnar implants included an extra-small precoated Coonrad-Morrey component that showed loosening with partial bushing wear and fractured at forty-six months, a small ulnar component in a forty-nine-year-old woman that loosened and fractured at sixty-nine months, and a small ulnar component in a fifty-nine-year-old man with three previous surgical procedures that showed complete bushing wear and fractured at 181 months. One of the humeral implants was a small component in a patient who did not have graft incorporation under the humeral flange and who had type-4 loosening of the humeral component, which fractured at forty-six months. The other was a small humeral component in a fifty-two-year-old man with ten previous surgical procedures; the implant showed complete bushing wear and fractured at 195 months. The component fractures occurred at the junction between the better-fixed part of the stem within bone and the less-well-supported portion of either the humeral or the ulnar component adjacent to the linkage, where the implant was unprotected by host bone.

Four patients with a mean age of sixty-nine years (range, sixty-four to seventy-six years) had a periprosthetic fracture resulting from minor trauma at an average of seventy-nine months (range, thirty-one to 186 months) following the index arthroplasty. We believe that two of these four fractures resulted from osteolysis around the distal tip of the precoated Coonrad-Morrey ulnar component. Both fractures were treated with strut-allograft reconstruction of the proximal part of the ulna with revision of the ulnar component; these procedures were done at thirty-one and forty-one months after the index surgery. The remaining two patients, one with an ulnar fracture and the other with a humeral fracture, were treated effectively with a brace.

Soft-tissue and wound complications occurred in twelve elbows, with five requiring a reoperation. One patient had skin necrosis on the distal horizontal part of a previous z-shaped incision and required a local flap for definitive management. Two patients underwent irrigation and débridement because of a subcutaneous hematoma, one patient underwent irrigation and débridement because of a stitch abscess, and one patient had an anconeus tricepsplasty because of triceps insufficiency and excision of heterotopic ossification. The seven elbows

Fig. 2-A
Preoperative anteroposterior (Fig. 2-A) and lateral (Fig. 2-B) radiographs of the left elbow of a sixty-two-year-old woman with a supracondylar distal humeral nonunion.

Fig. 2-B
with soft-tissue complications that did not require a reoperation included two with wound-edge necrosis, four with prolonged drainage and/or blisters, and one with a subcutaneous hematoma.

New nerve complications arising from the surgical intervention included one transient ulnar nerve palsy, which resolved by three months; one case of persistent ulnar nerve sensory symptoms, which were evident before the index arthroplasty and subsequently required decompression; and one case of temporarily decreased sensation in the radial nerve distribution after a triceps-splitting approach. Twenty-one (51%) of forty-one patients who had had preoperative ulnar-nerve-related problems continued to have problems after the total elbow arthroplasty. Isolated sensory symptoms were present in sixteen elbows; mixed sensory and motor symptoms, in four; and isolated ulnar nerve tenderness, in one.

Additional complications included a loose c-ring with no evidence of progressive loosening at sixty-two months after the operation in one patient, isolated bushing exchange with retention of the components at 186 months after the replacement.
in another, and a painful proximal radioulnar articulation that required radial head excision in a third.

**Implant Survival**

The rate of mechanical implant failure was 25%; these failures included twelve cases of aseptic loosening, four periprosthetic fractures, five component fractures, one loose c-ring, and one case of isolated bushing wear. Overall, twenty-three implants (25%) required removal or major revision of a component because of complications, including four deep infections (4%) and nineteen cases of mechanical failure (21%) (Table I). The Kaplan-Meier survivorship analysis of all elbow implants (Fig. 3) showed that the probability of not requiring removal or revision for any cause was 96% (95% confidence interval, 94% to 98%) at two years, 82% (95% confidence interval, 78% to 87%) at five years, and 65% (95% confidence interval, 59% to 72%) at ten and fifteen years. Eighty-nine implants remained at two years; fifty, at five years; twenty-one, at ten years; and twelve, at fifteen years. Censored implants (no reoperation or revision at the time of the most recent follow-up) are shown by the cross symbol.

There was a mechanical failure of seven (27%) of the twenty-six implants with a precoated ulnar component and sixteen (26%) of the sixty-one implants without a precoated ulnar component ($p = 0.5$). The rate of mechanical failure in the elbows with one or no previous surgical procedures was 16% (five of thirty-two) compared with 33% (eighteen of fifty-five) in the elbows with two or more previous operations ($p = 0.06$). There was mechanical failure of 44% (sixteen) of the thirty-six implants in patients under the age of sixty-five years but only 14% (seven) of the fifty-one implants in patients who were sixty-five years of age or older. Implants in patients less than sixty-five years of age were three times more likely to require revision for mechanical failure than were implants in patients sixty-five years of age or older ($p < 0.01$). Comparison of Kaplan-Meier curves showed the survival rate of elbow implants in patients sixty-five years of age or older to be higher than that in patients younger than sixty-five years of age.

**Assessment According to Mayo Elbow Performance Score (MEPS)**

All ninety-one patients had a MEPS recorded by the treating surgeon preoperatively. At the time of the latest follow-up,
forty patients had individual components of the MEPS documented by a physician: thirty-five of them returned to our institution for a follow-up examination, and the other five were evaluated by their local physicians. The data regarding the individual components of the MEPS were obtained from mailed questionnaires for forty-five patients and from telephone interviews for six. The average MEPS (and standard deviation) for all ninety-two elbows (ninety-one patients) before the initial arthroplasty was 29 ± 9 points (range, 15 to 75 points) compared with 81 ± 19 points (range, 15 to 100 points) at the time of the latest follow-up (p < 0.01). On the basis of the MEPS, thirty-five elbows (38%) had an excellent result and thirty-seven elbows (40%) had a good result; thus, the result was satisfactory for 78% of the elbows. The distribution of the MEPS is shown in Table II. Of the twenty elbows with a fair or poor MEPS, five had an infection, two had a component fracture, one had a periprosthetic fracture, and six had aseptic loosening. The findings of an analysis of the components of the MEPS are presented below.

### Pain

Before the initial arthroplasty, seventy-nine (87%) of the ninety-one patients had moderate or severe pain. At the most recent follow-up, sixty-seven (74%) had no or only mild discomfort.

### Range of Motion

The average arc of motion prior to the arthroplasty was 37° (range, −5° to 90°) of extension to 106° (range, 30° to 155°) of flexion. After elbow replacement, the mean arc of extension was 22° (range, 0° to 90°) and the mean arc of flexion was 135° (range, 60° to 170°). The mean arcs of pronation and supination before the elbow replacement were 59° (range, 0° to 90°) and 71° (range, 10° to 90°), respectively. At the time of follow-up, the average arc of pronation was 79° (range, 0° to 90°) and the average arc of supination was 77° (range, 30° to 90°). Paired assessment showed a mean improvement of 15° of extension (p < 0.01), 29° of flexion (p < 0.01), 19° of pronation (p < 0.01), and 6° of supination (p < 0.01). Seventy-two (78%) of the ninety-two elbows had less than a 100° flexion-extension arc prior to the replacement compared with only twenty-six elbows (28%) at the time of follow-up (p < 0.001)

**Table II** Distribution of Preoperative and Latest Follow-up Mayo Elbow Performance Scores (MEPS)

<table>
<thead>
<tr>
<th>MEPS</th>
<th>Preoperative</th>
<th>Postoperative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent (90 to 100 points)</td>
<td>0</td>
<td>35</td>
</tr>
<tr>
<td>Good (75-89 points)</td>
<td>4</td>
<td>37</td>
</tr>
<tr>
<td>Fair (60-74 points)</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>Poor (&lt;60 points)</td>
<td>80</td>
<td>8</td>
</tr>
</tbody>
</table>

**Stability**

Moderate or severe instability was present in eighty-one elbows (88%) prior to elbow replacement. Nine of these elbows were flail and were unable to support the upper extremity against gravity during activities of daily living. At the time of follow-up, sixteen elbow implants (17%) had moderate and two had severe instability. Eight of these implants (44%) underwent a reoperation for implant-related complications as discussed previously. One implant with severe postoperative instability had an ulnar component fracture which made the elbow unstable, and the other implant with severe instability had complete bushing wear. Stability was restored in all nine flail elbows. However, subsequent follow-up in the flail group revealed one humeral component fracture and one case of ulnar component loosening that affected stability.

**Activities of Daily Living**

The ability to perform activities of daily living was restored. The patients were able to perform an average of 0.7 of the five basic activities of daily living before the elbow replacement and 4.5 after it. Seventy-three elbows (79%) could not be used to perform a single activity prior to replacement, whereas seventy-six elbows (83%) could be used to perform four or more activities at the time of follow-up.

**Subjective Assessment**

Subjectively, sixty-three elbows (68%) were rated as much better; fifteen (16%), as better; ten (11%), as the same; and four (4%), as worse compared with their status before the operation. As a result, seventy-eight (85%) of the elbows had a satisfactory subjective result.

**Radiographic Outcome**

Five elbows with a deep infection were excluded from the radiographic assessment as they were considered to be overall failures. The mean duration of radiographic follow-up of the remaining eighty-seven elbows was 5.5 years (range, 1.1 to 16.6 years). The cement technique used for the humeral components was graded as inadequate (type 3) in one case and marginal (type 2) in seventeen. Three ulnar components had been fixed with a marginal (type-2) cement technique. Progressive radiolucent lines developed around nine humeral components, with seven having type-4 loosening. Progressive radiolucent lines developed around ten ulnar components, including five with type-4 loosening. There was new or progressive radiolucency of ten (37%) of the twenty-six precoated ulnar components compared with ten (17%) of the sixty-one non precoated ulnar components (p = 0.04). Overall, fifteen (17%) of the eighty-seven elbows had radiographic evidence of loosening (type-3 or 4 radiolucency) of the humeral and/or ulnar components. Thirteen of these elbows had undergone revision arthroplasty at the time of the most recent follow-up.

Thirty-two elbows (37%) showed evidence of bushing wear at the time of follow-up, with type-2 wear in seventeen implants and type-3 wear in fifteen. Incarceration of the...
bone graft between the anterior prosthetic flange and the distal humeral cortex was seen radiographically in sixty-four of the seventy-one elbows in which a bone graft had been placed.

**Discussion**

Newer internal fixation principles and techniques have improved our ability to achieve stable fixation of complex distal humeral fractures. However, some fractures fail to unite, leaving the patient with an unstable, dysfunctional, and often painful upper extremity. Salvage in this situation is complicated, as progressive bone resorption at the nonunion site may lead to severely compromised bone stock, especially in the presence of loose hardware, creating a windshield-wiper effect in an elderly patient with osteopenia and multiple small articular fragments. Treatment options for a patient with a distal humeral nonunion include allograft replacement, distraction arthroplasty, open reduction and internal fixation, and total elbow arthroplasty. However, the reports on allograft replacement for the treatment of distal humeral nonunion have shown high complication rates with instability, resorption, and allograft-host nonunion limiting the routine use of this treatment option. Although distraction arthroplasty is another salvage procedure for patients with posttraumatic arthritis after distal humeral fracture, it is technically demanding and associated with a high rate of complications and inconsistent outcomes. Consequently, on the basis of the results in the literature, the two viable options for the treatment of distal humeral nonunion are open reduction and internal fixation and total elbow arthroplasty.

In previous studies of open reduction and internal fixation of distal humeral nonunions, residual elbow stiffness and pain were reported to be the major reason for long-term disability despite the successful achievement of a union. Subsequent improvements in fixation methods in addition to routine performance of an elbow capsulectomy to restore motion and limit the stress on fracture fixation have been associated with improved outcomes. Helfet et al. reported a 98% union rate, with an average time to union of six months, and an average range of elbow motion of 94° following treatment of fifty-two delayed unions or nonunions with open reduction and internal fixation. Fifteen patients (29%) required a reoperation, with the vast majority of the procedures performed because of prominent hardware. However, no additional outcome data, other than the range of motion of the elbow, were obtained in that study, and there was limited long-term follow-up regarding the development of posttraumatic arthritis. Therefore, it is not possible to compare the results of our current series with those in that study.

Our initial experience, between 1982 and 1990, with thirty-nine of the patients in the present study showed that use of a linked implant to treat a distal humeral nonunion resulted in a 91% rate of pain relief and an average arc of motion of 111° at a mean of four years. The mean MEPS for these patients improved from 51 points preoperatively to 92 points at the time of the latest review, and the objective result was satisfactory for 86% of the patients. The current series of ninety-one patients (including the thirty-nine patients in the previous study, with an extension of their follow-up), treated over a twenty-one-year period and followed for an average of 6.5 years, demonstrated less favorable results. Pain relief was achieved in 79% of the patients, and the objective result was satisfactory for 78% of the elbows. In the current series, the mean MEPS improved from 29 points preoperatively to 81 points at the time of the most recent follow-up. The average arc of motion of 113° is comparable with that in our previous study and is definitely better than the arc of motion obtained after open reduction and internal fixation. The patients in the current series had a higher frequency of complications, reoperations, and mechanical failure compared with the patients in our previously reported series, observations that are consistent with the longer follow-up. The overall complication rate in the previous series was 18% with a 13% reoperation rate. Implant-related problems led to a reoperation in only 8% of the cases, and none of those reoperations were done because of mechanical loosening. In the current series, the complication rate was found to be 43% and the reoperation rate was 35%. Implant-related problems resulted in a reoperation in 21% of the cases. Although the reoperation rate is higher than that in our previous study, it is still comparable with the published reoperation rates for distal humeral nonunions treated with open reduction and internal fixation.

As expected, at the time of the long-term follow-up, aseptic loosening had become the major reason for implant failure (Figs. 2-A through 2-D). There was aseptic loosening of twelve of the ninety-two implants, and four were associated with some form of osteolysis and/or progressive radioluency resulting in a periprosthetic fracture. Component fracture (in five cases) was the second most common reason for a reoperation related to implant failure. Mechanical component failure was associated with several factors, by themselves or collectively, including the use of a precoated ulnar component, the lack of cement fixation of the implants, accelerated bushing wear, and the patient’s inability to comply with the weight-lifting restrictions during activities of daily living and work. However, because of the small number of patients, none of these factors were identified as being significant. The prevalence of new radioluencies or progression of perioperative radioluencies around the precoated ulnar components was significantly higher than the rate of such radioluencies around the non precoated ulnar components (p = 0.04).

Our most striking finding was the effect of the age of the patient on the survival of the implant. Elbow implants in patients less than sixty-five years of age were three times more likely to require revision because of mechanical failure than were those in patients sixty-five years of age or older, and ten of the twelve implants that had aseptic loosening were in patients who were less than sixty-five years of age (p < 0.01).

The relatively high rate of component fracture deserves special attention in the context of a distal humeral nonunion.
The prevalences of humeral and ulnar component fracture following primary total elbow arthroplasty have been reported to be 0.65% and 1.2%, respectively. However, these numbers more than double when elbow arthroplasty is performed for the sequelae of trauma or for revision. In our series, the fracture rate was 2% for the humeral components and 3% for the ulnar components, rates that are higher than those reported in the literature. All fractured implants were small or extra-small in diameter, made of titanium, and beaded or precoated to enhance cement fixation. When these inherent implant-related risks were added to the probably inadequate osseous support due to the nature of the problem, the risk of fatigue failure was increased. As a result, we recommend the use of the largest-diameter implant possible, with a 6-in (15.2-cm) humeral stem, and we encourage strong patient compliance with the restrictions required by total elbow arthroplasty, even with improved contemporary implant designs.

Four patients had a periprosthetic fracture; three of these fractures were at the distal tip of a precoated ulnar component, and one was around a loose humeral component. The pre-coating of polymethylmethacrylate on the surface of the ulnar component is vulnerable to micromotion and has been demonstrated to be associated with an increased rate of osteolysis. If this osteolysis occurs around the proximal part of the ulnar component in the face of a well-fixed distal part of the stem, cantilever loading of the well-fixed part from the unsupported periarticular portion of the stem is inevitable, leading to excessive stress at the junction of these two parts and resulting in implant fracture. However, if this osteolysis occurs around the distal part of the stem and weakens the ulnar cortex, a periprosthetic ulnar fracture may occur. For this reason, the precoated Coonrad-Morrey ulnar component was replaced with a plasma-sprayed ulnar component in 2000. None of the patients in this series who were treated with this modification have had a periprosthetic fracture or a fracture of the ulnar component to date.

Isolated exchange of the articular bushings as a result of polyethylene wear was performed in only one patient, a finding consistent with the reported prevalence of 1.3%. The established risk factors for bushing wear, such as posttraumatic deformity of the elbow, loss of at least one humeral condyle, higher physical demand, and a younger age at the time of the elbow replacement, were inherent characteristics of this patient population. As a result, the higher rate of bushing wear in our study (seen in approximately one-third of our patients) as compared with the rate seen in patients without these risk factors is in accordance with findings in previous studies. However, since stress radiographs were not routinely made, the absolute wear rate could have been higher. The need for activity restrictions must be emphasized to these patients, and bushing wear should be monitored.

Weaknesses of the study include the heterogeneity of the follow-up methods and the retrospective nature of the analysis. Overall, only 44% of the patients had a clinical evaluation by either the treating surgeon or a local physician while the remaining patients were followed with only a questionnaire and a radiographic assessment. Although 38% of the patients were able to return to the treating institution for a follow-up assessment, the end points selected in this study allowed determination of implant survival with use of a questionnaire and telephone contact and are thus independent of the clinical examination. Radiographs were performed at different institutions with different techniques, which may have affected the assessment of the radiographic parameters that were evaluated. In addition, the death rate was 42%, which decreased the average duration of follow-up considerably.

References


