Limited extension after linked total elbow arthroplasty in patients with rheumatoid arthritis

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Abstract

Objective: Total elbow arthroplasty (TEA) has become an established procedure to relieve pain and to increase the range of motion of the destructed elbow in patients with rheumatoid arthritis (RA). However, some patients still have limited extension after TEA, and the causes of limited extension after TEA have yet to be elucidated.

Methods: To examine whether widening of the joint space can cause such limited extension, we retrospectively analyzed 35 cases of linked TEA in patients with RA. There were seven male and 40 female with a mean age of 63.8 years (range, 30–80 years) and a mean follow-up of 7.5 ± 4.2 years (range, 2.5–15.6 years). The Mayo Elbow Performance Score (MEPS) and radiological measurements were recorded. Widening of the joint space was calculated by subtracting the length measured on postoperative radiograph from preoperative radiograph.

Results: MEPS and range of motion were significantly improved after surgery except for extension. The degree of extension was significantly correlated with radiological widening of the joint space in the limited extension group. Correlation analyses showed that postoperative limited extension was correlated with lower MEPS daily function.

Conclusions: Limited extension after linked TEA is partly derived from perioperative widening of the joint space and potentially limits daily function in patients with RA.

Introduction

Total elbow arthroplasty (TEA) has become an established procedure in the treatment of irreversible structural damages of the elbow joint and/or severe impairment of the activities of daily living (ADL) in patients with a variety of disorders, including rheumatoid arthritis (RA). Numerous reports have shown reliable mid- or long-term outcomes of TEA, as shown by several systematic reviews of the literature and registry reports [1–5].

One crucial aspect of the postoperative outcomes of TEA is undoubtedly the range of motion (ROM). There is universal agreement that flexion is far more important than extension in the elbow joint, and severe extension contracture alone is a strong indication of TEA [6,7]. Naturally, a great deal of attention is paid to postoperative flexion, and physiotherapists focus mainly on the improvement of any flexion loss after the operation. On the other hand, patients and physicians are well aware of a tendency toward limited extension after TEA, although in most cases, it is not severe [8–10]. Unfortunately, the causes of limited extension of the elbow and the degree to which such limitation affects clinical scores after TEA have not been fully investigated.

Radiographs are an established, simple modality for identifying any postoperative changes associated with TEA. Its main role in total arthroplasty is to identify periprosthetic osteolysis as a predictor of future loosening of the implant [11,12]. Immediately after surgery, a check of the anteroposterior (AP) and lateral radiographic views would ideally show a well-positioned implant with no disturbance of the crucial elements of the bone, thus avoiding subsequent mechanical failures. On the other hand, TEA can extensively change the biomechanical behavior of the joint, and simple measurements on radiographs can conceivably demonstrate the perioperative changes that are crucial for a successful postoperative outcome. In a previous study, Blewitt et al. [13] reported widening (lengthening) of the joint space, measured by lateral radiographs after TEA. However, they used only a single method to measure the widening and did not observe significant differences in postoperative outcomes between widened and not-widened cases. Mibe et al. [14] reported that the limited extension was correlated with widening of the joint when assessing the Kudo and GSB III prostheses, but they also used only a single method of measurement and did not examine association of the limited extension with the clinical outcomes. Few studies elucidated the perioperative changes of TEA observed on plain radiographs.

We hypothesized that widening of the joint space can cause the limited extension after linked TEA and may lead to an inability to perform daily activities. The aims of the present study were to examine whether radiological measurements can detect widening...
We defined a group of patients with limited extension of more than 27 ± 7, as preoperative stiffness group, and others as control group. To analyze possible factors that affected the extension loss, the patients were divided into two groups according to the classification of Larsen [17]. Operation-related complications were recorded as follows: fracture around the implant, wound-healing disturbance, nerve palsy, infection, triceps failure, and thromboembolism.

Materials and methods

Participants

Institutional review board approval was obtained prior to the study. This retrospective, cohort study included a consecutive series of patients with RA who underwent primary TEA with a Coonrad–Morrey (Zimmer, Warsaw, IN) or a Discovery (Biomet, Warsaw, IN) linked total elbow prosthesis, depending on the individual surgeon’s preference. Between June 1998 and May 2012, a total of 51 Coonrad–Morrey and 24 Discovery TEA procedures were carried out. Two patients died within 5 months after the operation from unrelated causes and were excluded from this evaluation. The exclusion criteria for this study were non-RA disorders (seven), immeasurable radiographs (two), substantial muscle weakness due to other disorders (one), and a secondary major operation within one year (two). Patients with incomplete records were also excluded (six), resulting in a total of 55 cases analyzed. Five patients died, and three were lost to follow-up, but their evaluations at the time last seen were included. The demographic data are shown in Table 1. All patients fulfilled the 1987 or 2010 version of the revised criteria of the American College of Rheumatology (ACR). To analyze possible factors that affected the extension loss, the patients were divided into two groups according to the data at 1 year after arthroplasty: those whose postoperative elbow extension was 10° more than the postoperative average (≥40°, limited extension group), and <40° (control group); the cutoff point of 40° was determined by a previous study, which indicated that positional tasks require a minimum of 27 ± 7° of flexion [15,16].

We also analyzed relationship between preoperative stiffness (limited extension of more than 30°) and activity of daily living. We defined a group of patients with limited extension of more than 30° as preoperative stiffness group, and others as control group.

Operative procedures and postoperative rehabilitation

TEA was performed with the patient under general anesthesia. The Campbell posterior V–Y approach was used in all cases. Soft tissues were sufficiently released with both the collateral ligaments cut, and any bony impingements were resolved. For the patients with preoperative elbow stiffness who have severe deformity and poor extension during operation, we cut the anterior capsule with preoperative position of the rotation center of the elbow was defined as the midpoint between the center of the articular surface of the trochlea of the humerus and that of the ulna. In case of elbow dislocation, the point was defined as the center of the articular surface of the trochlea of the humerus. Radiographs were independently evaluated by two experienced orthopedic surgeons. We assessed if magnification percentage was constant. For each

| Demographic data               | Values are given as the mean and the standard deviation with the range in parentheses or the number with the ratio in parentheses. |
|------------------------------|-----------------------------------------------------------------------------------------------------------------|
| Age at operation (years.)     | 63.8 ± 9.7 (30 to 80)                                                                                              |
| Larsen grade, number of patients (percent) | I 0 (0%), II 0 (%), III 14 (25.5%), IV 30 (54.5%), V 11 (20%)                                                                 |
| ACR Class*, number of patients (percent) | I 1 (2%), II 27 (49%), III 24 (44%) IV 3 (6%)                                                                 |
| Follow- up in yrs.             | 7.5 ± 4.2 (2.5 to 15.6)                                                                                             |
| Disease duration               | 20.0 ± 9.7 (3.0 to 47.0)                                                                                            |
| Gender (M/F)                  | 12/43                                                                                                              |
| Implant (C/D)                 | 38/17                                                                                                               |

ACR = American College of Rheumatology, M/F = male versus female, C/D = Coonrad/Morrey versus Discovery prostheses.
considered as significant when were evaluated with Spearman’s rank correlation. Results were correlated with postoperative extension, we made calculation using Student’s t-test. The inter- and intraobserver reliabilities of the radiological measures were examined by two separate methods: first by using the intraclass correlation coefficient (ICC). The ICCs for intraobserver agreement were calculated as 0.8667 for humerus and 0.7996 for ulna, respectively, indicating that the magnification differences were negligible.

Statistical analysis

Data are presented as the mean ± standard deviation. The differences between pre- and postoperative variables were evaluated using Student’s t-test. The inter- and intraobserver reliabilities of the radiological measures were examined by two separate methods: first by using the intraclass correlation coefficient and then by calculating the absolute value of differences between individual measures against the frequency of occurrence. Correlations between degrees of extension and other variables were evaluated with Spearman’s rank correlation. Results were considered as significant when \( p < 0.05 \). To identify variables that were correlated with postoperative extension, we made calculation using Spearman’s rank correlation coefficient. The tested variables included all datasets mentioned earlier. Subsequently, the significant variables identified in this univariate correlation were tested in multivariate analyses for between-subject effects and were tested further by linear regression modeling. In these models, variables were selected using a cutoff point of \( p < 0.01 \) for entry into the regression models.

Results

We analyzed clinical outcomes from the latest follow-up compared with the preoperative evaluations. MEPS values improved significantly from \( 51.6 \pm 14.3 \) preoperatively to \( 90.6 \pm 9.6 \) after the surgery, and the improvement was maintained throughout the follow-up period (Supplementary Table 1). ROM also improved significantly after surgery and was maintained thereafter, but extension remained unchanged from \( 30.1 \pm 16.9^\circ \) preoperatively to \( 29.5 \pm 19.4^\circ \) postoperatively (Supplementary Table 1).

In the limited extension group, the mean values of A, B, and C were \( 23.7 \pm 5.5 \text{ mm}, \ 29.2 \pm 10.1 \text{ mm}, \) and \( 16.6 \pm 6.7 \text{ mm}, \) respectively, while those of A’, B’, and C’ were \( 31.9 \pm 5.0 \text{ mm}, \ 39.9 \pm 8.8 \text{ mm}, \) and \( 22.8 \pm 4.1 \text{ mm}, \) respectively. Also those of \( \Delta A, \Delta B, \) and \( \Delta C \) were \( 8.2 \pm 4.4 \text{ mm}, \ 10.8 \pm 7.5 \text{ mm}, \) and \( 6.3 \pm 6.6 \text{ mm}, \) respectively. In the control group, the mean values of A, B, and C were \( 27.5 \pm 5.2 \text{ mm}, \ 30.8 \pm 7.2 \text{ mm}, \) and \( 19.2 \pm 5.9 \text{ mm}, \) respectively. In the control group, the mean values of A, B, and C were \( 33.2 \pm 5.3 \text{ mm}, \ 39.2 \pm 8.4 \text{ mm}, \) and \( 26.1 \pm 3.9 \text{ mm}, \) respectively. Also those of \( \Delta A, \Delta B, \) and \( \Delta C \) were \( 5.7 \pm 6.0 \text{ mm}, \ 8.4 \pm 6.7 \text{ mm}, \) and \( 6.9 \pm 3.8 \text{ mm}, \) respectively.

Reliability of radiological measurements

First, we tested whether the measurement methods had sufficient reliability. Intraclass correlation coefficients (ICCs) were calculated for 10 consecutive measurements of six values (A to C and A’ to C’), first for intraobserver reliabilities at two different times and then for interobserver reliabilities of two different observers. The ICCs for intraobserver agreement were calculated as 0.9823, 0.9644, 0.9910, and 0.9791 for A to C, and 0.9937, 0.9811, 0.9814, and 0.9394 for A’ to C’, respectively. The ICCs for interobserver agreement were calculated as 0.9677, 0.9465, 0.8984, and 0.8754 for A to C, and 0.9941, 0.9186, 0.7893, and 0.8821 for A’ to C’, respectively. To quantify the reliability further, we tabulated the absolute difference of measurements and found a difference of \( \leq 1.0 \text{ mm} \) for 71 of 80 (88.8%) measurements repeated by the same observer and for 57 of 80 (71.3%) measurements by different observers.

Radiological evaluations and postoperative extension

We examined correlations between the radiographic measurements and postoperative extension and found that in the limited extension group (\( N = 18 \)), the postoperative extension was significantly correlated with \( \Delta B \) and \( C’ \) (Table 2), indicating that limited extension after linked TEA was, at least partly, derived from perioperative widening of the joint space. We made a calculation using a receiver operating characteristic (ROC) curve analysis. In the ROC curve, \( AUC = 0.580 \), while the sensitivity and specificity were 41.2% and 81.5%, respectively, and the optimal cutoff value for widening of \( \Delta B \) was considered as 14 mm (data not shown).

Subsequently, subanalyses of two prostheses showed the results similar to that of the total group. In addition, subanalysis of the

![Figure 1. Widening of the elbow joint space is measured in lateral plain radiographs. Values A, B, and C in a lateral view of radiograph at 90° of flexion of the elbow. A and A’ are from pre- and postoperative radiographs, respectively.](image-url)
The significance was set at \( p < 0.05 \). Each value was described in Methods section.

Clinical outcomes and postoperative extension

To evaluate whether limited extension of the elbow joint affected the MEPS, we examined correlations between postoperative limited extension and several variables, and we found that reduced postoperative extension was significantly correlated with pre- and postoperative lower MEPS (Table 3), indicating that limited extension may lead to impaired daily function. Reduced postoperative extension was also correlated with worse preoperative limited extension and worse Larsen grade.

The size of implant distribution in the humerus and ulnar was not significantly different between control group and limited extension group (Supplementary Table 2). The results of intraoperative extension, extension at the time of discharge, extension at 1 year after arthroplasty, and supination at the time of discharge were significantly improved in control group (Supplementary Table 2). Postoperative extension was correlated with intraoperative extension and extension at the time of discharge (Table 3, Supplementary Table 3).

Preoperative extension and extension at 1 year after arthroplasty showed significantly good results in no contracture group. Preoperative supination and pronation in no-contracture group were significantly better than that of preoperative stiffness group and pre- and postoperative MEPS daily function scores were significantly good in control group (Supplementary Table 4).

Discussion

TEA is a widely established procedure in the treatment of a variety of elbow-related disorders. However, the number of procedures carried out is much less than the numbers of total knee and hip arthroplasties worldwide [18], and partly because of this fact, several crucial questions remain to be answered. One of the major issues to be addressed is that of improving postoperative ROM, while perioperative improvement of flexion is usually satisfactory that of extension may be not. Indeed, average values of postoperative extension are typically between 20° and 30°, as shown in this study as well as others [8–10,15]. The postoperative limited extension may be dependent on the preoperative extension (as shown in this study), the degree of joint destruction, and biomechanics, but it is expected that some causes of this limitation could be prevented by taking deliberate precautions during the operation and using careful surgical techniques. In this study, we showed a significant correlation between widening of the joint space and limited extension in linked TEA. The present results can provide a clue in searching for possible countermeasures against this issue that can be implemented surgically.

To date, there has not been a full of literature on the topic of postoperative extension and clinical outcomes after TEA. Szyłuk et al. [19], reported that the ROM domain score of preoperative MEPS was significantly associated with that of the postoperative score and negatively associated with the difference between the total scores of pre- and postoperative MEPS, but they did not mention any direct association or correlation with the domain scores, especially daily function. Koh et al. [20] reported in their heterotopic ossification case series that the final ROM was not significantly associated with clinical variables, but they did not show any specific results for daily function. However, limited extension of the elbow joint can undoubtedly lead to a functional disability, and this issue should be addressed, wherever possible, by surgical procedures, especially TEA.

Several descriptions of surgical techniques for TEA mention how extension can be obtained during the operation. The importance of releasing the anterior aspect of the capsule has been reported [21,22]. Mansat et al. [22] further suggested that the attachment of the flexors and extensors should be released if they are contracted. These techniques are clearly reasonable and useful, but we also place confidence in the usefulness of restraining widening of the joint space as a technique to avoid limited extension after TEA. Indeed, Peden et al. [7] suggested that in some cases, shortening of the humerus may be needed to enhance elbow extension.

In theory, each measurement parameter described previously provides a different effect that results in widening of the joint space. For example, the value B can be changed by the proximal–distal depth of the humeral implant and also by the AP placement of the ulnar implant. Furthermore, the differences between pre- and postoperative distances showed significant correlations with postoperative extension in B, while the postoperative distance showed the significance of C, indicating the diversity of subtle changes made during the operation. This study suggests that widening of the elbow joint after TEA may cause functional impairment of the elbow. As indicated in this study, if \( AB \) is found to be over 14 mm intraoperatively, we insert the component more deeply to avoid the functional disorder due to flexion contracture after TEA. We believe that values A and B, C are useful indicators of elbow widening after TEA. How each measurement can affect the daily function and biomechanics of the joint should be explored in the future.

The report by Blewitt et al. [13] described that lengthening (widening) of the joint space will result in tensile forces passing across the elbow through the adjacent soft tissues and a
corresponding compressive force across the components. This may be beneficial when using unlinked implants such as the Kudo prosthesis to gain appropriate stability but may not be necessary when using linked implants. We used two types of linked prostheses and found a similar tendency in the correlation between widening of the joint space and the postoperative extension. Indeed, Mibe et al. [14] also reported that the correlation between the widening of the joint space, and the postoperative extension was found with both the Kudo prosthesis (an unlinked prosthesis), and the GSB III prosthesis (a linked prosthesis). Other designs of prosthesis remain to be tested and should be investigated in the future.

This study has several limitations. One inherent limitation was the use of radiographs to measure distance parameters. This method may sometimes cause ambiguity in the measurements, although the intra- and interobserver reliabilities of the measurements used in this study were considered sufficient for our analysis. Another issue was that widening of the joint space was only found in the radiographs of the limited extension group. This suggests the potential for multifactorial reasons that affected the degree of extension. This study suggests that extension at the time of discharge is a predictive factor of postoperative extension at 1 year after arthroplasty, indicating importance of achieving the maximum extension ROM intraoperatively and during hospitalization.

In conclusion, the degree of postoperative extension was correlated with radiological widening of the joint space in the limited extension group after linked TEA. Postoperative limited extension was also correlated with worse daily function, as assessed by MEPS. Taken together, we conclude that limited extension after linked TEA is partly derived from perioperative widening of the joint space and possibly limits daily function in patients with RA.

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Ethical Approval
Ethical approval for this study was granted by the committee of Kyoto University Graduate School and Faculty of Medicine (E1785).

Conflict of interest
Moritoshi Furu and Masahiro Ishikawa are affiliated with a department that is supported financially by four pharmaceutical companies (Mitsubishi-Tanabe, Bristol-Myers, Chugai, Eisai). Hiroyuki Yoshitomi is affiliated with a department that is supported financially by Astellas. Hiromu Ito has received grant and research support from Mitsubishi-Tanabe, Chugai, Pfizer, Astellas, and Daiichi Sankyo. Hiroko Ogino and Shuichi Matsuda declared no conflict of interest exists; The sponsors were not involved in the study design, in the collection, analysis, interpretation of data, in the writing of this manuscript, or in the decision to submit the article for publication. The authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

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