REVIEW

The History and Future of Unlinked Total Elbow Arthroplasty

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Unlinked total elbow arthroplasty (TEA), which has no mechanical connection between the humeral and ulnar components, has theoretical advantages based on its near-normal elbow kinematics and the preservation of bone stock. Unlinked TEA is appropriate only for patients who have limited bone loss or limited deformity and good ligamentous function. This is because postoperative instability has been a major complication of unlinked prostheses. The concept and goal of unlinked TEA is to share the loading stress on the bone implant interface with the surrounding tissues. Although the loosening rate of unlinked prostheses theoretically should be lower than that of linked prostheses (which have a mechanical connection between the humeral and ulnar components), there is no clear evidence that unlinked TEAs are superior to linked TEAs in this respect. However, we believe that primary TEA should be performed using an unlinked TEA, especially for younger patients, because revision surgery for unlinked TEA results in longer prosthesis survival than revision surgery for linked TEA. Improvement of the design of unlinked prostheses and the introduction of less invasive surgical techniques are required to reduce postoperative instability. (DOI: 10.2302/kjm.2017-0007-IR; Keio J Med 67 (2) : 19–25, June 2018)

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Introduction

Total elbow arthroplasty (TEA) is indicated for rheumatoid arthritis, osteoarthritis, post-traumatic arthritis, and distal humeral fractures. In the past, TEA prostheses were categorized as constrained, semi-constrained, or unconstrained according to the prosthesis design. Because various linkage mechanisms have recently been developed and because even so-called “surface replacement” prostheses are known to possess some element of intrinsic constraint (as a result of the shape and interaction of their articular surfaces),¹ the terms “linked type” (with a mechanical connection between the humeral and ulnar components) and “unlinked type” (with no connection between the humeral and ulnar components) are now widely used.² Unlinked TEA has theoretical advantages based on its near-normal elbow kinematics and the pres-

ervation of bone stock. However, unlinked TEA is appropriate only for patients who have limited bone loss and good ligamentous function because postoperative instability is a major complication.³ The presence of functioning elbow flexor and extensor muscles is also important to maintain the stability of unlinked implants. Elbows with severe joint destruction and unstable elbows should be treated with linked TEA. This article focuses on the history, surgical techniques, surgical results, and problems associated with unlinked TEA.

History

Aseptic loosening of linked total elbow arthroplasties is a significant problem seen in long-term follow-up, particularly in young and active patients.⁴ The concept and goal of unlinked TEA is to share the loading stress on the

joint surface/bone implant interface with the surrounding tissues such as the capsule, ligaments, and muscles. Although the loosening rate of unlinked prostheses should theoretically be lower than that of linked prostheses, there has been no definite evidence of this in clinical studies.⁵⁻⁷

A number of designs of unlinked TEA prostheses have been developed and employed. The capitellocondylar implant is one of the most studied and widely used unlinked elbow prostheses.⁸ The initial non-stemmed designs were superseded by stemmed prostheses to prevent subsidence of the humeral component. The Souter-Strathclyde total elbow arthroplasty has components that are similar to the anatomy of the ulnotrochlear joint. The prosthesis is unlinked but has a relatively constrained design.⁹ Instability of this implant has been less frequent than that of other unlinked designs; however, loosening of the short-stemmed humeral component has a 3.6- to 5.6-fold risk of revision for aseptic loosening compared to the long-stemmed humeral components.¹⁰ The Kudo total elbow arthroplasty was introduced in 1972.^{11,12} Initially, both the Type 1 and Type 2 prostheses had non-stemmed humeral components with a cylindrical articulation; however, the humeral component was redesigned to a stemmed component because of a high incidence of early loosening.¹² The humeral articulation has a saddle design that allows for medial-lateral translation of the ulnar component. The reported results with the current design are favorable, although instability has been problematic because of the low intrinsic stability compared with other designs.¹³⁻¹⁵

The majority of unlinked TEAs lack a radial head prosthesis; indeed, only a few designs have a radial head prosthesis.^{8,16} Although, in theory, the radial head component improves soft tissue balance and has been shown to improve stability in *in vitro* biomechanical studies,¹⁷ the *in vivo* results for TEAs using prostheses with radial head components have not been favorable. The radial head prosthesis in the original capitellocondylar total elbow prosthesis was abandoned because it was considered to contribute to the loosening of the humeral component.⁸ The results for the Pritchard ERS prosthesis, which has a radial head component, showed a high failure rate of 70% after an average of 83 months. Correct positioning and orientation of the radial component was difficult to achieve during surgery. If congruous radiocapitellar articulation was not achieved, severe polyethylene wear of the radial head component or dissociation of the polyethylene was observed. If unlinked TEAs that incorporate radial head components are to achieve future success, precise instrumentation and methodology will be required.¹⁸

In our opinion, the majority of patients can be managed with an unlinked TEA for their primary arthroplasty; however, some patients do require a linked prosthesis because of a lack of adequate bone stock or functional collateral ligaments. Although a patient's suitability for an unlinked TEA can be predicted preoperatively in most cases, it is always desirable to make a linked implant

available in the operating room when a surgeon is planning to perform an unlinked TEA. Postoperative instability is a problem common to all unlinked TEA prostheses, and such instability is often difficult to manage.^{19,20} The K-NOW total elbow system (Teijin Nakashima Medical Co., Ltd., Okayama, Japan), which has been in clinical use since 2005, is a convertible design that provides the option to change an unlinked TEA to a linked type without removing the humeral stem (**Fig. 1**). Conversion can be performed at the time of the initial arthroplasty or at a subsequent revision procedure (**Fig. 2**). The removal of a well-fixed humeral stem, either cemented or uncemented, is usually difficult and entails a significant risk of complications.¹⁹

Surgical Techniques

The surgical techniques involved in TEA with an unlinked prosthesis depend on the design of the selected prosthesis and the surgeon's preferences. We describe our preferred technique using the K-NOW prosthesis.

The patient is positioned in a lateral position with the affected elbow resting on an arm support. A tourniquet is placed on the upper arm, and a posterior, slightly laterally curved skin incision is made to the elbow. The ulnar nerve is isolated and transposed anteriorly.

The management of the triceps is based on the surgeon's preferences. A distally based triceps flap is commonly used, but recently we have tried to preserve the insertion of the triceps tendon into the olecranon by using the triceps-on approach.^{21,22} Then, the medial collateral ligament is divided and the elbow is dislocated. The radial head is excised, but the lateral collateral ligament is preserved. It is important to preserve the anterior capsule to prevent postoperative dislocation. The resection of the joint surface and the preparation of the stem is performed according to the manufacturer's instruction. The bone resection required to fit the K-NOW prosthesis is minimal, which may facilitate later revision (**Fig. 3**).

It is important to evaluate the soft tissue balance and articular tracking by suturing the triceps tendon at the trial reduction (**Fig. 4**). Intraoperatively, if there is some concern about possible instability, conversion to the K-NOW SNAP IN prosthesis (linked type) is easily achieved with additional bone resection.

After placement of the prosthesis and reduction of the elbow, the triceps is meticulously repaired. The medial collateral ligament is repaired if possible without excessive tension. A removable splint is applied at 90° of flexion for 2 weeks postoperatively. Active and assisted range-of-motion exercises are started 1 week after surgery. Patients are allowed to return to daily living activities 4 weeks after surgery, but are restricted to lifting no more than 2 kg.

Fig. 1 Component design of the K-NOW total elbow system.

This system uses a modular and convertible design that allows the surgeon to decide during surgery whether or not to use cement and whether to use the unlinked type or linked type. The photos of the prosthesis were provided by Teijin Nakashima Medical Co., Ltd.

Outcomes for Unlinked TEAs

In 1980, Kudo et al. reported the clinical results for Type 1 and Type 2 Kudo prostheses, which are stemless resurfacing prostheses.¹¹ Long-term follow-up revealed that subsidence or loosening of the humeral component was more frequent than had been previously reported. As a result, the Kudo prosthesis was modified to Type 3, which has an intramedullary stem.¹² In 2001, Tanaka et al. reported successful long-term outcomes, with a 90% survival rate at 16 years using the Type 3 prosthesis.¹⁵ Tanaka et al. also mentioned that no great differences in results were found with or without preservation of the anterior oblique component of the ulnar collateral ligament.

The short-term results of the unlinked K-NOW prosthesis in 42 patients with an average follow-up of 24 months were mostly satisfactory. Average elbow flexion improved from 105° before surgery to 128° at the final follow-up. Average elbow extension also improved from -35° to -25°; however, postoperative flexion contracture persisted.²³

There are few studies comparing the outcomes of different unlinked TEA prostheses. Little et al.⁶ compared the outcome of the Souter, Kudo, and Coonrad-Morrey designs in a prospective cohort study based on the year

of surgery. At an average follow-up time of 5 years, all three implants relieved pain, and the improvements in the range of motion were comparable among the three groups. The survival rate of the Souter-Strathclyde prosthesis appeared to be worse than those of the other two implants, with 5-year survival rates of 93% for the Kudo, 90% for the Coonrad-Morrey, and 85% for the Souter-Strathclyde. Park et al. reported the long-term results of different types of TEA with an average of 13 years of follow-up. They compared complications and revision rates according to the type of implant and found that the complications and revision rates were significantly higher in the unlinked group (62.9%, 34.3%) than in the linked group (30.6%, 22.4%).²⁴

Levy et al.⁷ evaluated the survival of unlinked and linked designs in primary and revision surgeries. The initial survival rate was lower for unlinked prostheses (56% at 367 months) than for the linked prosthesis (84% at 371 months). However, revision surgery in the linked cohort had a lower survival rate (66% at 288 months) than that of revision surgery in the unlinked cohort (72% at 284 months). Unlinked devices revised to linked devices (84% at 271 months) were more reliable than unlinked devices revised to another unlinked device (47% at 284 months). Although the long-term survival of linked TEA prosthe-

Fig. 2 Conversion from the unlinked type to the linked type is not difficult even as a subsequent revision procedure. (A) An unlinked K-NOW TEA was dislocated 1 week after surgery. Left, antero-posterior view; right, lateral view. (B) The prostheses were revised to the linked K-NOW SNAP IN TEA without any significant complications such as periprosthetic fracture. Left, antero-posterior view; right, lateral view.

Fig. 3 Photo taken after excision of the joint surface for the K-NOW TEA.

The amount of bone resection is minimal and the triceps tendon (white arrow) was left attached to the olecranon in this patient. H, humerus; U, ulna.

ses is quite acceptable for the primary surgery, unlinked TEA prostheses should be selected especially for younger and more active patients because of the poorer outcome of revision surgery for primary linked TEA prostheses.

Treatment of Postoperative Instability

Postoperative instability is a major problem common to all unlinked elbow arthroplasties. If instability occurs shortly after surgery, a closed reduction and cast immobilization may maintain reduction. However, conservative treatment often fails and revision surgery is required in most cases.²⁵

Ring et al.¹⁹ reported the operative treatment of unstable capitellocondylar TEAs in 12 patients. Three elbows underwent conversion to linked prostheses. In the other nine elbows, an attempt was made to continue with an unlinked prosthesis: three had reconstruction of one or both collateral ligaments, four had component revision, and two had both ligament reconstruction and component revision. At an average follow-up of 6 years, only three elbows had retained a functioning unlinked prosthesis and four elbows had been converted to a linked prosthe-

sis. Thus, 7 of 12 elbows eventually were converted to a linked prosthesis. The authors concluded that the revision of an unlinked total elbow prosthesis to a linked total elbow prosthesis restores elbow function but is technically difficult and there is a high risk of perforation of the humerus and ulna. We always try to stabilize unlinked prosthesis by soft tissue repair before converting to a linked prosthesis. The rotation of the components should be checked carefully because component malposition has been demonstrated to alter the in vitro kinematics and stability of unlinked TEAs.²⁶ In our opinion, surgeons who use unlinked TEAs should always take account of the possibility of future revision surgery to a linked prosthesis. We have successfully treated three patients by converting from an unlinked K-NOW prosthesis to a linked K-NOW SNAP IN prosthesis. The conversion was performed during the initial surgery in one case, and the other two were performed at 2 weeks and at 2 months after initial surgery. For this reason, we usually use a convertible design such as the K-NOW TEA.

Previous radial head resection and synovectomy is reported to increase the risk of instability after unlinked TEA.²⁷ In the study by Schemitsch et al. that compared

Fig. 4 (A) After trial components are positioned (left), it is important to evaluate the soft tissue balance and articular tracking by suturing the triceps tendon (right, white arrow). (B) Postoperative radiograph.

primary capitellocondylar TEA with capitellocondylar TEA after failed radial head resection and synovectomy, none of the primary capitellocondylar TEAs dislocated postoperatively, whereas TEAs in 6 of 23 patients with failed synovectomy and radial head resection dislocated postoperatively. The reason for this difference is unclear, but it is important to prepare a linked prosthesis or a convertible design for surgery in these patients.

Summary

There is no clear evidence that unlinked TEAs are superior to linked TEAs. However, we believe that unlinked TEAs should be considered for primary TEA, especially for younger patients, because of the poor outcome of revision surgery for primary linked TEA. Improvement of the design of unlinked prostheses and the introduction of less invasive surgical techniques are required to reduce postoperative instability. Further clinical trials are also needed to compare the long-term outcomes between unlinked and linked TEAs.

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