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Management of rheumatoid arthritis of the elbow with a convertible total elbow arthroplasty

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Background: Total elbow arthroplasty (TEA) is commonly performed in patients with rheumatoid arthritis (RA). The purpose of this study was to compare outcomes and complications of unlinked and linked TEA using a convertible system in patients with RA.

Methods: All patients with RA who underwent TEA at a single center with a minimum of 2 years' follow-up were reviewed. Demographic information, patient-reported outcome scores, functional outcome assessments, and radiographic parameters were evaluated at most recent follow-up.

Results: We evaluated 82 patients (27 with unlinked TEA and 55 with linked TEA) with RA. The mean age at surgery was 61 ± 10 years, with a mean follow-up period of 6 ± 4 years. Demographic characteristics were similar between groups, with the exception of longer follow-up in the unlinked group (8 years vs. 5 years, $P = .001$). No differences in range of motion were noted. Elbow strength was similar other than pronation strength (74% ± 8% for unlinked vs. 100% ± 8% for linked, $P = .03$). The mean Mayo Elbow Performance Index was 83 ± 16; Patient Rated Elbow Evaluation score, 15 ± 18; and QuickDASH (short version of the Disabilities of the Arm, Shoulder and Hand questionnaire) score, 34 ± 20. No differences in the rates of reoperation (17% vs. 24%, $P = .4$), complications (32% vs. 31%, $P = .4$), or revisions (13% vs. 17%, $P = .3$) were found between unlinked and linked devices. Four patients with instability, all with unlinked designs, underwent revision to a linked design. Four patients, all with linked designs, underwent revision for aseptic loosening of smooth short-stem ulnar components.

Conclusion: TEA using a convertible implant design provides good patient-reported outcomes at mid-term follow-up in patients with RA. Our study was unable to detect a difference in the use of either unlinked or linked implant designs; further large comparison trials are needed.

Ethics committee approval was obtained (study no. 107300) from the Western University Health Science Research Ethics Board. Institutional review board approval was granted prior to patient chart review and radiographic analysis.

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Total elbow arthroplasty (TEA) is frequently used in patients with symptomatic end-stage inflammatory arthropathy, osteoarthritis, acute unreconstructible distal humeral fractures, post-traumatic arthritis, complex elbow instability, and other forms of end-stage articular elbow pathology. Although the incidence of TEA for rheumatoid arthritis (RA) is declining because of advances in medical management, arthroplasty remains an important procedure to restore function and relieve pain in patients with end-stage disease.[5] A recent literature review found a paucity of patient-reported outcome scores reported in the literature for total elbow replacement.[13,16,24]

Modern TEA designs have been developed to address the specifics of elbow anatomy.[3,4,11,19] Three broad categories of TEA exist: unlinked, linked, and convertible systems. Current linked designs use a ''sloppy'' hinge providing more freedom of motion and reduced mechanical bearing wear or interface stress. In contrast, unlinked designs rely on the inherent constraints based on implant design as well as the soft-tissue envelope for stability. Theoretically, this reduced constraint decreases forces at the implant interfaces; however, this biomechanical advantage has yet to be confirmed in clinical studies.[10-12,18,20] The selection of an unlinked vs. linked design remains an important decision that each surgeon must make considering each patient's diagnosis, activity level, and bony and soft-tissue profile. In an effort to provide the surgeon increased flexibility intraoperatively, convertible implants have been developed. These designs allow for the interchangeable conversion of an unlinked system to a linked system intraoperatively as the patient's pathoanatomy dictates. This may provide a theoretical advantage by optimizing the available options specific for each patient and case and thereby maximize patient outcomes. Only limited reports on the outcomes of convertible implants have been published to date.[2,17,22]

The purpose of this study was to compare unlinked vs. linked outcomes of TEA using a convertible design (Latitude; Wright Medical Group, Bloomington, MN, USA) in patients with RA. We used patient-reported outcome scores, impairment measurements, and range-of-motion and strength assessment tools to validate outcomes.

Methods

All patients enrolled in our prospectively collected TEA database and hospital surgical operative database were available for review. Patients identified with a primary diagnosis of RA were included. A cohort of 84 consecutively performed TEAs for RA using a convertible implant (Latitude or Latitude EV convertible total elbow system; Wright Medical Group) were available between 2003 and 2016. The Latitude implant was used until the device was updated to the Latitude EV in 2012. The main design change was the addition of a titanium plasma coating to the component stems, as well as simplification of the surgical instruments and technique. Patients were contacted to return for follow-up and to complete outcome measurements. A minimum of 2 years of follow-up was required for inclusion. The exclusion criteria included patients undergoing TEA for another indication, those who refused follow-up, and those who were unable to consent or provide clinical outcome data.

Patient enrollment

Standardized data collection was performed based on the most recent clinical visit including demographic characteristics, comorbidities, and indications for TEA. Mortality data were also collected. A research assistant performed functional outcome assessments including elbow range of motion, grip strength, pinch strength, isometric elbow flexion, extension, pronation, and supination strength. Patient-reported outcome scores were collected, including the Mayo Elbow Performance Index (MEPI); Patient Rated Elbow Evaluation (PREE); and short version of the Disabilities of the Arm, Shoulder and Hand questionnaire (Quick-DASH). All patients underwent review of standardized anteroposterior and lateral radiographs by 3 fellowship-trained upper-extremity surgeons. Radiographs were reviewed for signs of bearing wear, osteolysis, loosening, periprosthetic fracture, and implant subsidence. Heterotopic ossification was evaluated by the Hastings classification,[9] and radiographic loosening was evaluated using the technique described by Wagener et al[22] (Fig. 1). The widest point of lucency as measured between either the cement-bone interface or implant-cement interface was recorded. Systematic measurements using modified Gruen zones permitted comparison of locations.

Surgical technique

All surgical procedures were performed at a dedicated tertiary referral upper-extremity teaching facility by 3 fellowship-trained upper-extremity surgeons and their trainees under direct supervision. Standard antibiotic prophylaxis was administered to all patients preoperatively.[7,21] The Latitude or Latitude EV convertible TEA was used in all cases. The surgical approach was at the discretion of the surgeon. A triceps-splitting approach was used initially; however, the lateral para-olecranon approach was used more recently.[1,7,21] The decision to link the implant or have the implant remain unlinked was left to the treating

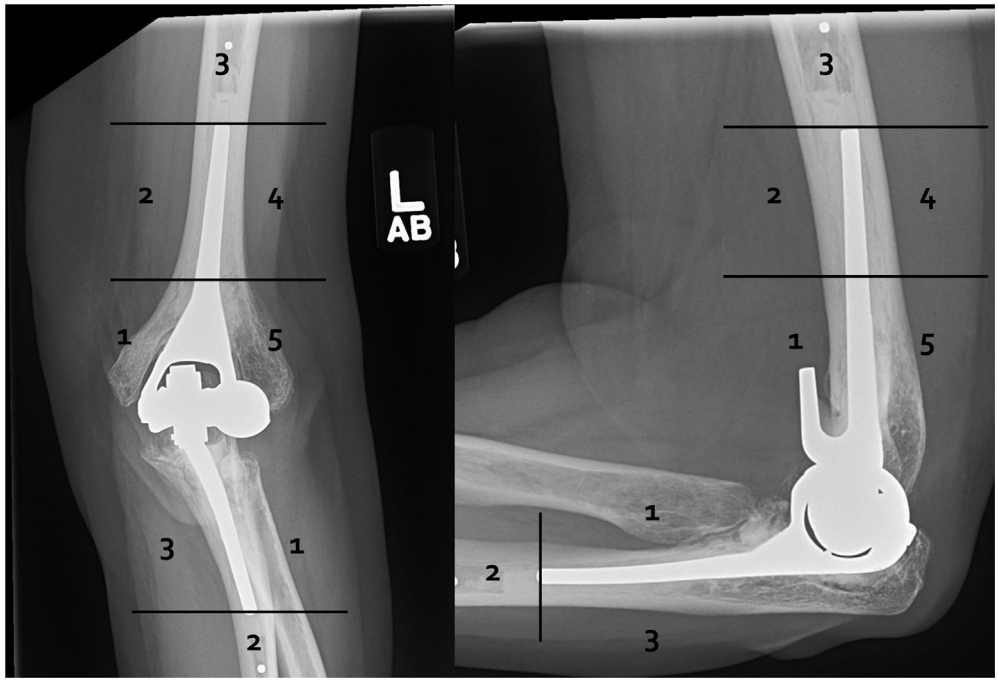

Figure 1 Radiolucent zones (modified Gruen zones) around total elbow arthroplasty. Adapted from Wagener et al.[22]

physician based on preoperative and intraoperative circumstances. Contraindications for unlinked designs included instability (bony or ligamentous), bone loss, or periarticular muscular dysfunction. The collateral ligaments were repaired if an unlinked device was used. Careful implant placement and soft-tissue repair optimized elbow stability. The mechanical flexion-extension axis of the elbow was restored based on preoperative planning, intraoperative landmarks, and surgical instrumentation. The collateral ligaments were repaired using nonabsorbable sutures placed in a locking fashion through the common muscular origins and collateral ligaments. The sutures were then passed through a central axis hole in the prosthesis and tied to the other collateral ligament. The ''tails'' of collateral ligament sutures were tied to each other through an ulnar drill hole to offload the collateral repair during healing. Stability was then assessed through the range of motion and by varus-valgus testing to ensure the elbow tracking was concentric. If maltracking or instability was present, the implants were linked. Intraoperative stability was achieved in all cases.

Postoperative rehabilitation was left to the discretion of the surgeon; however, all patients were immobilized for 1 to 2 weeks prior to initiating range of motion. A physiotherapy program with a progressive recovery focused on regaining motion while protecting elbow stability and the triceps repair, if indicated, followed by gradual strengthening, was used. All patients had access to a dedicated upper-extremity therapy team; however, the rehabilitation was focused as a home program.

Follow-up was performed at standard intervals including at 2 weeks, 6 weeks, 6 months, and 12 months for the first year. Active implant surveillance was performed thereafter on an annual basis. Statistical analysis was performed using multivariate analysis of variance, χ^2 tests for nonparametric variables, and quantitative statistics.

Results

Eighty-two patients met the inclusion criteria; however, 10 patients were deceased at final follow-up and 15 did not complete outcome questionnaires during their last clinical follow-up. The mean patient age at the index procedure was 61 ± 10 years. The average follow-up period was 6 ± 4 years (range, 2-13 years). Fifteen patients had bilateral total elbow replacements performed and were excluded from comparative strength analysis. Table I reports patient demographic characteristics.

Overall, all patients after TEA obtained a functional arc of elbow motion. Mean range-of-motion values for the entire cohort were as follows: flexion, 133° ± 12° (range, 95°-145°); extension, 24° ± 16° (range, 5°-72°); supination, 71° ± 16° (range, 25°-90°); and pronation, 81° ± 10° (range, 45°-90°). Mean patient-reported outcome measures were good to excellent, with the mean MEPI being 83 ± 16; PREE score, 15 ± 18; and QuickDASH score, 34 ± 20. Postoperatively, 72% of patients reported no pain and 28% reported mild pain. No patients reported moderate or severe pain postoperatively.

Unlinked vs. linked

No significant demographic differences were found between the patients receiving an unlinked arthroplasty and those receiving an linked arthroplasty (Table II). In addition, no statistical differences were found between groups

Table I Patient demographic characteristics

	Data
Age, yr	61 ± 10
Sex (female/male)	64 (78)/18 (22)
Dominant side	40 (49)
Bilateral total elbows	15 (18)
Length of follow-up, yr	6 ± 4
Linked vs. unlinked	55 (67) vs. 27 (33)
Latitude vs. Latitude EV	56 (68) vs. 26 (32)
Associated radial head replacement	39 total (48) 26 unlinked 13 linked
Deceased at time of final study recruitment	10 (12)

Data are presented as mean ± standard deviation or number (percentage).

Table II Comparison of linked vs. unlinked implant cohorts

	Linked	Unlinked	*P* value
Age, yr	68 ± 2	69 ± 2	.658
Sex (male/female)	12/43	6/21	.867
Follow-up, yr	8 ± 4	5 ± 3	.001*
Complications	17 (32)	9 (31)	.355
Revision rate	7 (13)	5 (17)	.319
Reoperation rate	9 (17)	7 (24)	.434

Data are presented as mean ± standard deviation or number (percentage).
* Statistically significant ($P < .05$).

in patient-reported outcomes (MEPI, PREE score, and QuickDASH score), radiographic signs of loosening, revisions, or complications. The follow-up period was greater in the unlinked arthroplasty group than in the linked arthroplasty group ($P = .001$). Range of motion and strength were similar between the linked and unlinked cohorts with the exception of pronation strength ($P = .03$) (Fig. 2). Patients with linked implants demonstrated an overall strength increase of 16%, returning to nearly 100% of their contralateral pronation strength postoperatively compared with only 74% for the unlinked cohort. We noted no differences in absolute strength between the cohorts with the exception of elbow extension, which was lower in the operative elbows in the unlinked group only ($P = .01$).

Implant survivorship

Survivorship analysis was carried out using Kaplan-Meier curves to assess the overall survivorship of the Latitude and Latitude EV components (Fig. 3). No significant difference was noted; however, longer-term comparison could not be made as no data were available beyond 6 years ($P = .18$). We found that the overall survivorship of the unlinked and linked components was similar ($P = .57$) (Fig. 4). The main divergence in survival appears to be early revision in the unlinked cohort potentially related to early instability revision (Fig. 5). The presence of a radial head component did not affect outcomes.

Radiographic outcomes

Radiographically, humeral zone (HZ) 1 and HZ 5 and dorsal ulnar zone 3 were found to be the most frequent areas of lucency. The mean lucency width was 0.4 ± 0.2 mm in HZ 1 and 0.3 ± 0.1 mm in zone 5. The mean radiographic lucency in lateral ulnar zone 3 measured 0.1 ± 0.8 mm. All other zones contained less than 0.1 mm of loosening. Although the mean lucency around linked implants was greater in HZ 1, HZ 5, and ulnar zone 3, this did not reach statistical significance (HZ 1, 0.3 ± 0.2 mm for unlinked vs. 0.5 ± 0.2 mm for linked [$P = .5$]; HZ 5, 0.2 ± 0.17 mm for unlinked vs. 0.3 ± 0.2 mm for linked [$P = .6$]; and lateral ulnar zone 3, 0.9 ± 0.1 mm for unlinked vs. 0.1 ± 0.1 mm for linked [$P = .7$]). Radiologic lucent lines were compared between the Latitude and Latitude EV implants, demonstrating no differences in incidence or size except in HZ 1 ($P = .02$).

Complications

A total of 26 patients (32%) experienced complications. No statistical difference was observed in the complication rate between unlinked and linked implants (32% vs. 31%, $P = .92$.) A complete breakdown of complications is shown in Table III.

At least 1 reoperation was performed in 16 patients (7 with unlinked and 9 with linked implants, $P = .434$). Twenty-one reoperations were performed overall. Twelve revisions were required in our cohort (5 with unlinked and 7 with linked implants, $P = .62$). Four revisions for ulnar loosening occurred, with 1 patient undergoing ulnar revision after a previous revision for instability. All had smooth short-stem Latitude ulnar components and had linked designs.

One linked implant with ulnar loosening requiring revision had an associated radial head component dissociation. Wound dehiscence was seen in 3 patients and treated with local wound care and antibiotics in 2. One patient underwent isolated wound exploration, débridement, and irrigation with antibiotics for a wound dehiscence. Neurologic complications including transient neuropathy of either the radial or ulnar nerve occurred in 6 patients (7%). Among those with complete ulnar nerve injuries, their recovery was incomplete, as would be expected in patients with ulnar nerve injuries requiring microsurgical repair. The triceps was grossly deficient at follow-up in 3 patients, all of whom underwent a triceps-splitting approach.

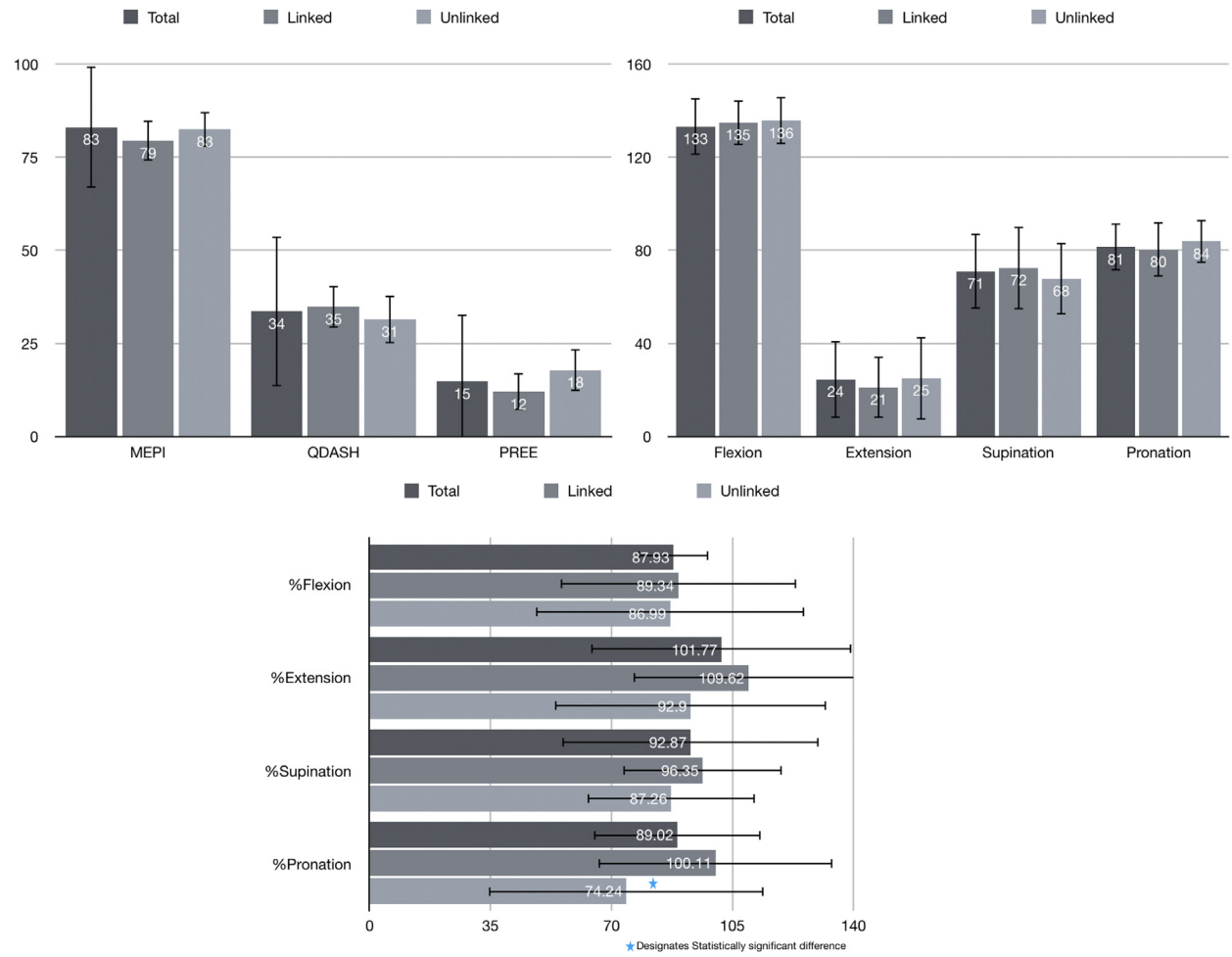

Figure 2 Measured outcomes of linked and unlinked implants including patient-reported outcome measures. *MEPI*, Mayo Elbow Performance Index; *QDASH*, short version of Disabilities of the Arm, Shoulder and Hand questionnaire; *PREE*, Patient Rated Elbow Evaluation.

Discussion

The advent of modern disease-modifying drugs and an improved understanding of the pathology of RA have reduced the overall incidence of symptomatic end-stage RA and the incidence of TEA for this condition. Historically, TEA for RA has demonstrated successful outcomes comparable to hip and knee arthroplasty in some series but inferior outcomes in others.[6,14,15] Limited evidence exists on the outcomes of convertible TEA implants in patients with RA. Our study demonstrates that a rheumatoid elbow can be successfully managed with a convertible TEA implant. Similarly to the reported literature, our patients had nearly complete resolution of pain (100% with no pain or with mild residual pain).[6,8,15] In addition, all of our patients reported excellent restoration of their elbow motion consistent with the literature. The incidence of complications, as in all series of TEA, remains frustratingly high, although most complications did not influence the final results as reflected in the favorable functional outcome scores.

Wagener et al[22] (2015) and Mehta et al[17] (2017) have both specifically evaluated the use of a convertible implant in a mixed patient population with all indications. We chose to focus on RA as the indication for TEA, noting a slightly older population in our cohort than in those previous studies. In addition, the percentage of unlinked implants in our cohort was greater than that in the study by Wagener et al (27% vs. 17%). The rate of complications was slightly higher in our cohort (33%); however, this is in line with a recent literature review and meta-analysis of TEA with a median complication rate of 33%.[14] Our reoperation rate is notable for an RA population but may reflect the early use of short-stem ulnar components for linked implants, which represented all the cases of ulnar loosening. Our need to link 4 unstable unlinked designs likely reflects our learning curve with this device and the early use of a triceps-splitting surgical approach. As we have gained experience with

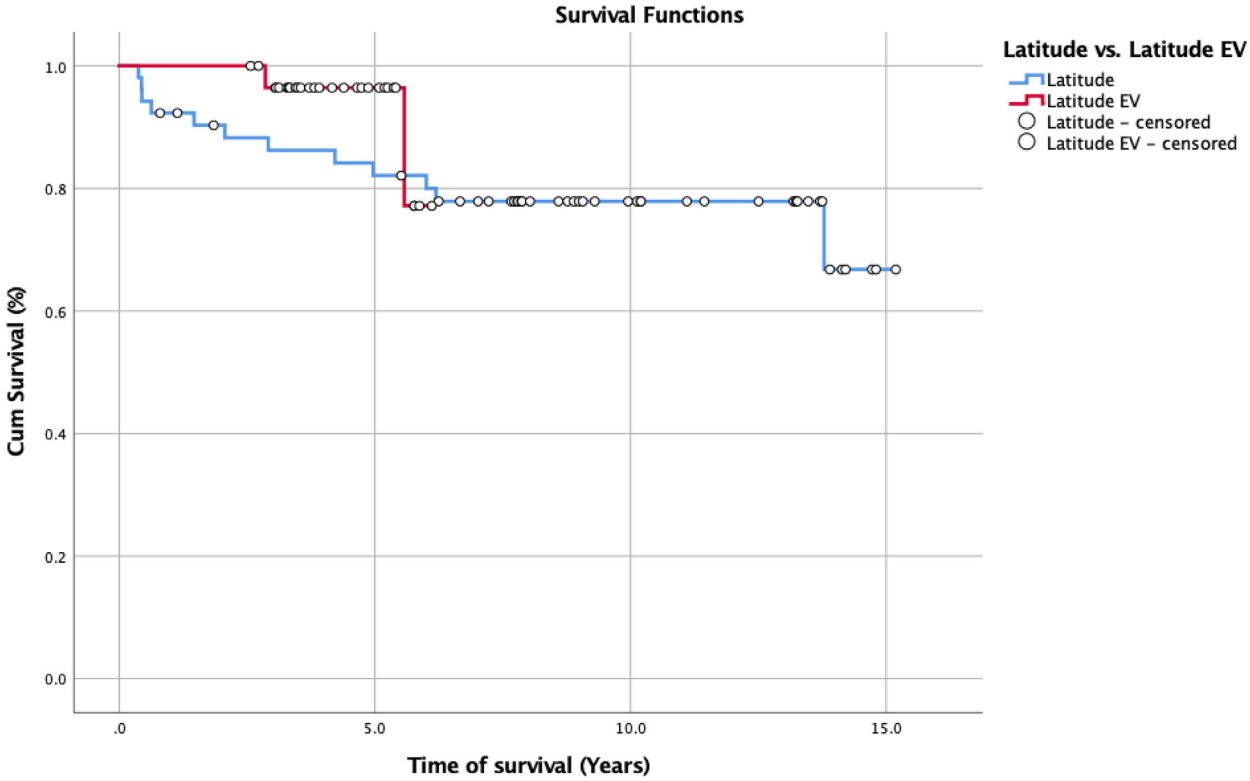

Figure 3 Kaplan-Meier curve comparing Latitude and Latitude EV components. It should be noted that the Latitude EV was used after 2012; therefore, no survival data are available beyond 6 years. *Cum*, cumulative.

this system and changed to a lateral para-olecranon surgical approach, our incidence of instability of the unlinked system has become lower. Dissociation of the radial head component will likely be reduced with the recent release of an improved coupling mechanism. Our rate of infection, although high, is consistent with other reports in this immunocompromised patient population and requires further efforts to mitigate. We have included all possible complications including superficial infection and stiffness to ensure a complete capture of the complications of this procedure.

The implant revision rate matched that of previously reported studies (14%). It is interesting to note that our rate of conversion to a linked arthroplasty for instability of an unlinked implant was substantially lower than previously reported (13% vs. 25%).[22] It is difficult to explain this finding based solely on the patient population; however, given that the previous studies included a mixed pool of diagnoses, it may be that rheumatoid patients are at lower risk of experiencing postsurgical implant instability than post-traumatic or fracture TEA. Additional comparative studies are required to delineate whether this is the case. The revision rate in our series was comparable to other studies evaluating mid-term TEA outcomes.[12,13,21] The ulnar component was the main source of loosening and revision with the Latitude system. All were linked devices with short-stem components without the plasma spray now used on the Latitude EV stems. The use of a standard-length ulnar component may be wise in patients undergoing a linked TEA. Although the survivorship of the Latitude EV stems seems more promising than the Latitude stems, their surveillance is shorter, suggesting further longer-term follow-up is needed. In addition, we documented a lower rate of radial head dissociation than that reported by Wagener et al[22] (8% vs. 31%). It is difficult to speculate as to why this was the case. Our radial head dissociation rate was more in keeping with that reported by Mehta et al.[17] Improvements in the coupling mechanism of the radial head implant are needed to reduce the incidence of this complication. No patient experienced clinically evident bearing wear, suggesting the larger bearing design of this system may provide durable outcomes.[23]

A small but significant rate of ulnar nerve injury was noted, with 3 patients experiencing either a partial or complete transection of the nerve. The remainder of these were neurapraxia-type injuries that recovered postoperatively. A similar incidence of transient and persistent nerve injuries (8.3%) was noted in a series of convertible TEAs from the Wrightington Hospital group (Acclaim implant, DePuy Orthopaedics Inc., Warsaw, Indiana, USA).[2] We believe the design of the original Latitude instrumentation, whereby the bone resection of the proximal ulna was performed from lateral to medial, may

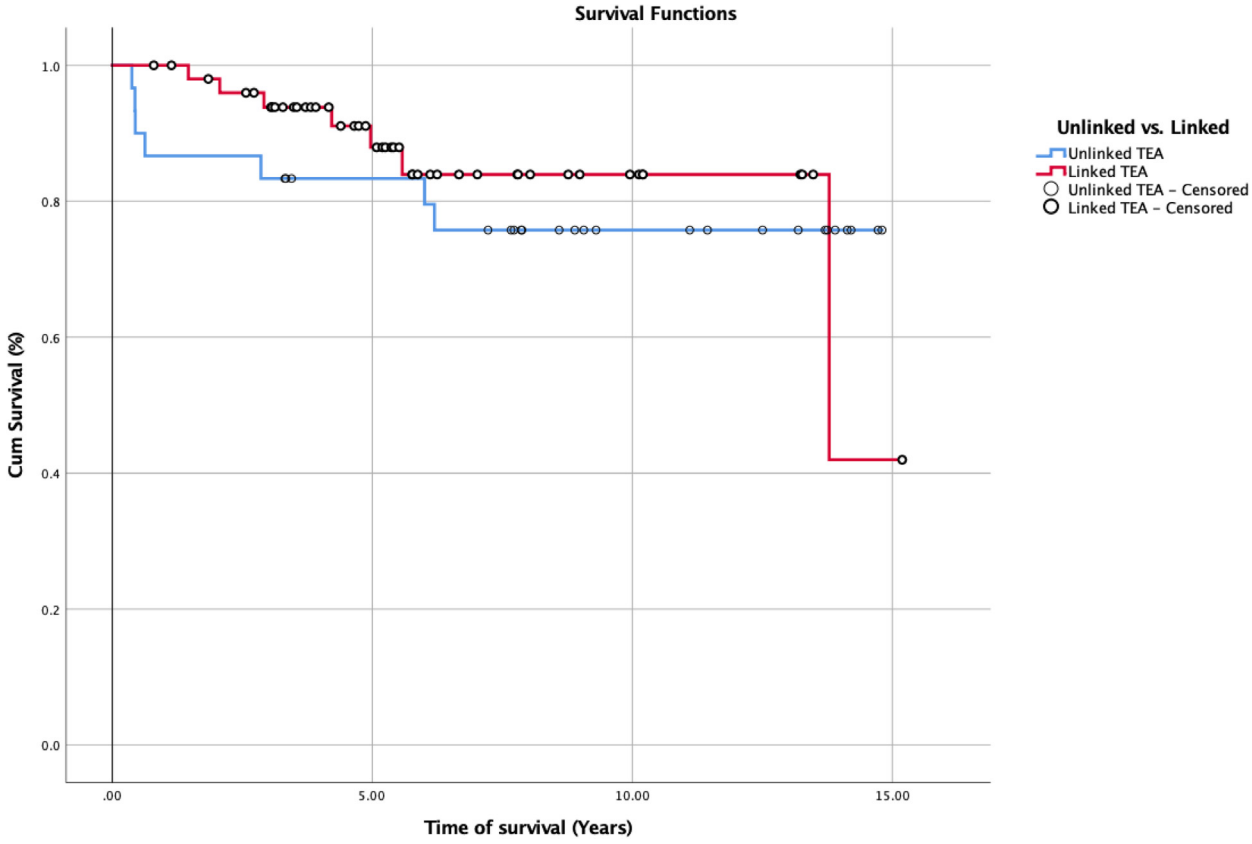

Figure 4 Kaplan-Meier survival analysis of unlinked vs. linked total elbow arthroplasty *(TEA)*. *Cum*, cumulative.

have increased the potential for ulnar nerve laceration. Injury to the ulnar nerve has not occurred since the introduction of the Latitude EV instrumentation, which removes bone in a medial-to-lateral direction, allowing the surgeon and assistants to better protect the ulnar nerve from the saw.

One of the most surprising findings of our study remains the failure of the unlinked implant group to regain pronation strength postoperatively. We noted a roughly 16% difference between the linked and unlinked implant groups. This value was calculated using the percentage difference in contralateral elbow strength. This metric was used in an effort to standardize the quantification of strength for each individual. Given the difference in pronation noted, we also examined absolute strength differences between the cohorts in an attempt to ensure the noted difference was not a result of the extent or severity of RA disease between the linked and unlinked cohorts. The lack of absolute strength differences in pronation strength would suggest that the improvement in the linked group is likely a true difference. We speculate that this may occur as a result of an inherent stability difference in the implant designs that renders the patient with the unlinked design either unable or unwilling to place this type of rotatory force through the loose coupling interface of the implant. Alternatively, this could be a result of patient selection; a larger randomized clinical trial between linked and unlinked implants is required to further explore this observation.

A number of limitations limit the broad applicability of our results. Our center is an upper-extremity tertiary referral center with a dedicated team with extensive experience in all aspects of TEA care. That said, many of the procedures were performed by trainees under the supervision of the consultants, which may have influenced the outcomes and rate of complications. Previous literature has demonstrated that complications and outcomes after TEA are linked to surgeon experience, and therefore, surgeons with less experience may experience higher complications or different outcomes that those seen in this study.[16] Although our study had a high proportion of unlinked arthroplasties, our study population has a higher number of linked implants. This is likely because of the higher incidence of patients with advanced joint destruction in this cohort and the propensity to link a TEA if there is any question regarding possible instability intraoperatively. In our study, the decision to link TEA implants was at the surgeon's discretion. Factors influencing the decision to consider performing an unlinked arthroplasty preoperatively included the presence of sufficient

Figure 5 Preoperative (**A, B, E, F**) and postoperative (**C, D, G, H**) anteroposterior and lateral radiographs of 2 patients receiving Latitude EV for advanced rheumatoid arthritis. A linked implant (**C, D**) is shown at 5 years after the index procedure. An unlinked implant (**G, H**) is shown at 3 years after the index procedure.

bone stock and collateral ligaments, the absence of severe deformity, and younger patients with higher expected demands or pauciarticular disease. The decision to link the implants intraoperatively was made because of a failure to achieve intraoperative implant stability after implant insertion and ligament repair. Although this inherently introduces a factor that cannot be controlled in data analysis when comparing the linked and unlinked groups, it does provide a pragmatic assessment of the implants and the effect of linked or unlinked TEA. A more robust comparison of unlinked and linked implants would require a randomized clinical trial in patients whose ligaments and osseous structures would be candidates for both options. Our study population largely comprised female patients, and we had a high number of bilateral replacements, which reduced the available assessment of strength as there was no baseline contralateral comparison. This likely had a limited effect on the results as our findings suggest that patients return to or near their baseline contralateral strength following TEA. That said, because the contralateral elbows were usually also afflicted with RA, it seems clear that TEA in patients with RA likely does not return strength to values expected in a normal population. Finally, the retrospective nature of our study introduces inherent limitations. Although the data in the study were collected prospectively, the study design and analysis do potentially introduce recall bias.

Conclusion

TEA using a convertible implant design provides good patient-reported outcomes at an average of 6 years' follow-up in patients with RA. The lack of differences in outcomes and complication rates demonstrated in this study may be a result of the relatively small sample size

Table III List of complications

	Data	Reoperation
Complication, n (%)		
Neurologic	6 (7)	One partial ulnar nerve transection occurred during dissection of extensive scar and elbow deformity. One partial and one complete ulnar nerve injury occurred from the rotating saw used to perform the ulnar bone preparation, which in the Latitude device occurred from lateral to medial. (The direction of the cut for the ulnar instrumentation was changed in the Latitude EV, facilitating a medial-to-lateral cut, allowing for better protection of the ulnar nerve.) The 3 aforementioned nerve injuries underwent primary microsurgical repair with variable recovery. All remaining neurologic complications, comprising ulnar neurapraxia in 2 cases and radial neurapraxia in 1, spontaneously recovered.
Instability	4 (5)	All patients underwent revision to a linked implant (all patients had radial head prostheses).
Periprosthetic fracture	2 (2)	Ulnar revision for ulnar periprosthetic fractures was performed at 3 and 5 yr postoperatively owing to a fall and osteolysis, respectively.
Infection		
Deep	8 (10)	Five patients were treated with 2-stage revision. Two patients were treated with I&D. One patient is being managed with lifelong suppression.
Superficial	3 (4)	
HO	5 (6)	One patient underwent contracture and HO excision for stiffness.
Radial head disengagement	6 (7)	
Implant loosening	4 (5)	
Triceps insufficiency	3 (4)	
Total, %	50	

HO, heterotopic ossification; *I&D*, débridement and irrigation.

and the lack of randomization between the 2 cohorts. However, the results suggest that when cases are carefully selected in experienced surgical hands, similar early- and mid-term outcomes can be achieved with the convertible implant design whether it is linked or unlinked. Preoperative osseous and ligamentous integrity, patient demands, and intraoperative findings will likely dictate implant choice. The surgeon and patient should be aware, however, that there is a non-negligible risk that an unlinked implant will require revision to a linked implant (13%) and that pronation strength may not as predictably return to baseline compared with the linked implant. Stem loosening requiring revision was not seen in patients with an unlinked TEA, whereas 4 patients with a linked TEA required revision of short-stem ulnar components. The use of a standard-length ulnar component may be wise in patients undergoing a linked TEA. Although bearing wear was not observed in this series, it remains unclear if the survivorship of the unlinked implants will be superior in the longer term, justifying the choice to use an unlinked device. Our current data suggest that early revision for instability appears to level off and the overall survivorship with the available data is similar. The survivorship of the newer Latitude EV system with titanium plasma-coated stems is promising; however, longer-term follow-up is required.

Disclaimer

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