Implant survival after total elbow arthroplasty: a retrospective study of 324 procedures performed from 1980 to 2008

Hans Christian Plaschke, MD\textsuperscript{a,*}, Theis M. Thillemann, MD, PhD\textsuperscript{b}, Stig Brorson, MD, PhD\textsuperscript{a}, Bo S. Olsen, MD, PhD\textsuperscript{a}

\textsuperscript{a}Shoulder and Elbow Clinic, Department of Orthopedic Surgery, Copenhagen University Hospital, Herlev, Denmark
\textsuperscript{b}Department of Orthopedic Surgery, Horsens Regional Hospital and Aarhus University Hospital, Horsens, Denmark

Background: Total elbow arthroplasty (TEA) is an established treatment for late-stage arthritis of the elbow. Indications have expanded to osteoarthritis and nonunion in distal humeral fractures. Information on implant survival and risk factors for revision is still sparse. The aim of this study was to evaluate implant survival and risk factors for revision of TEAs inserted in patients in the eastern part of Denmark in the period from 1980 until 2008.

Material and methods: The Danish National Patient Register provided personal identification numbers for patients who underwent TEA procedures from 1980 until 2008. On the basis of a review of medical reports and linkage to the National Patient Register, we calculated revision rates and evaluated potential risk factors for revision, including, age, sex, period, indication for TEA, and implant design.

Results: We evaluated 324 primary TEA procedures in 234 patients at a mean follow-up of 8.7 years (range, 0-27 years). The overall 5-year survival was 90\% (95\% confidence interval [CI], 88\%-94\%), and 10-year survival was 81\% (95\% CI, 76\%-86\%). TEAs performed with the unlinked design had a relative risk of revision of 1.9 (95\% CI, 1.1-3.2) compared with the linked design. Fracture sequelae was associated with a relative risk of revision of 1.9 (95\% CI, 1.05-3.45).

Conclusions: We found acceptable implant survival rates after 5 and 10 years, with a higher revision rate for the unlinked design and primary TEA due to fracture sequelae. Patient-related outcome measures should be included in future studies for further elaboration of the outcomes after TEA.

Level of evidence: Level III, Retrospective Cohort Design, Treatment Study.

Keywords: Total elbow arthroplasty; elbow; arthroplasty; prosthesis; elbow release; rheumatoid arthritis; elbow fracture; joint replacement

The Scientific Ethics Committee for the Hovedstaden Region approved this study.

*Reprint requests: Hans Christian Plaschke, MD, Copenhagen University Hospital, Department of Orthopedic Surgery, Aavej 34, Haareskov, DK-3500 Vaerloese, Denmark.
E-mail address: hcplaschke@dadlnet.dk (H.C. Plaschke).

The elbow is a complex joint with a critical role in upper extremity function. Mobility and stability of the elbow joint are important for daily, leisure, and professional activities. Even minor trauma or transient disease involvement can result in limited and painful elbow motion. The biomechanical function and the complex articular anatomy...
of the elbow are important to understand when performing reconstructive surgery to this joint.

Since the first commercial total elbow arthroplasty (TEA) was introduced by Dee in 1972, different implant designs have been introduced. The TEA implants are grouped by linked and unlinked design. The linked design consists of a humeral and an ulnar component that are physically connected. In the early linked design, the connection between the components was a fixed hinge that did not allow any varus-valgus motion between the humeral and ulnar components. This design was associated with high failure rates secondary to transmission of high stresses toward the implant cement–bone interface and mechanical failure. In contrast to the earlier design, today’s linked design has a sloppy hinge that allows varus-valgus motion between the components.

The unlinked design consists of a humeral and an ulnar component that are not mechanically linked. This design relies on matching shapes of the bearing surfaces, adequate bone stock, and soft tissue support for stability. The unlinked design, with the possibility of subluxation and dislocation of the joint, is less favorable when elbow destruction is more severe.

Surgical techniques have improved, and indications for TEA have expanded from severe rheumatoid arthritis (RA) to include osteoarthritis, post-traumatic arthritis, and post-traumatic conditions, such as nonunion after distal humeral fracture, and more recently, as the initial treatment for comminuted distal humeral fractures in the elderly. This places higher demands on implants and may lead to higher failure rates.
Literature on TEA is increasing but is still sparse concerning the indication for surgery and on survival and revision rates for different designs. Recent studies from the Finnish, Norwegian, and Scottish registers show no difference in survival or revision rates by implant. However, the indication for TEA seems to influence the survival, with primary TEA inserted due to fracture sequelae of the distal humerus having the highest risk for revision. The purpose of this study was to analyze the survival rates after primary and revision TEA in eastern part of Denmark in the period 1980 to 2008, to compare the revision rate of the different TEA designs used, and to analyze the difference in survival by choice of design, implant, and indications for primary TEA.

Material and methods

This study was based on data provided by the Danish National Patient Register (NPR) for patients who underwent TEA procedures in eastern part of Denmark between 1980 and 2008.

Danish NPR

The NPR holds data on all discharges from public and private hospitals in Denmark since 1977, including dates of all admissions and discharges, up to 20 diagnoses for every discharge, and the surgical procedures performed. The diagnoses are classified according to the Danish version of the International Classification of Diseases (ICD). The physician who discharges the patient assigns all discharge diagnoses. With use of the NPR, it is possible to construct the complete hospitalization history for each patient. The NPR was used to identify all primary and revision TEAs performed in Sealand (eastern part of Denmark) from 1980 to 2008.

The Civil Registration System

A unique personal identification number is given to all Danish citizens at birth or according to their date of birth. The Civil Registration System (CRS) records information on changes in vital status of all Danish citizens, including changes of address, date of emigration, and (since 1968) the date of death. Accurate linkage between the public Danish registers is possible at the level of individual patients by using the personal identification number. Thus, we used the personal identification number to merge data from the NPR and the CRS.

Study population

Retrieval of data was based on the ICD-8 criteria from 1980 to the end of 1993 and the ICD-10 criteria from 1994 to 2008. The criteria included all types of primary and revision prosthesis for the elbow; caput radii prosthesis, isolated ulnar component or humeral component, hemiarthroplasty, and TEAs, as well as choice of cemented or uncemented technique. Given these criteria (ICD-9: 70010, 70011, 70012, 70013, 70014, 70015, 70016, 70019, 70110, 70111, 70112, 70113, 70114, 70115, 70116, and 70117; and ICD10: KNCB0, KNCB1, KNCB20, KNCB30, KNCB40, KNCB59, KNCB69, KNCB99, KNCC0, KNCC1, KNCC2, KNCC3, KNCC4, KNCC59, and KNCC99), 1664 personal identification number were provided covering all of Denmark. Of these, 526 patients underwent operations in the eastern part of Denmark at 12 different hospitals. To verify data, we studied the patients’ medical reports at the different hospitals.

Medical report data

From the medical reports we obtained demographic data, age, and sex, indication for surgery, brand of implant used, complications, revision surgery, and reason for revision. Any revision performed outside the eastern part of Denmark was identified in the data provided by the NPR. By going through the medical reports, 324 procedures were verified as being primary TEA procedures performed on 234 patients in the period 1981 until 2008 (Fig. 1). In 68 cases of the 324 primary TEAs, revision TEA procedures were
performed. An isolated survival analysis of these revision TEAs was also performed. None of the procedures performed in 1980 could be confirmed.

Statistics

The end point for survival was defined as revision involving 1 component or the entire implant (removal or exchange). All patients were followed up from surgery to revision, death, emigration, or January 1, 2013. Kaplan-Meier survival analyses were used to calculate implant survival rates at 1, 5, 10, and 15 years. Survival data obtained in the Kaplan-Meier analysis were compared by the log-rank test (Mantel-Cox). The TEA was bilateral in 45 patients, and each replacement procedure was considered a separate case.20

The Cox multiple-regression model was used to calculate relative risk (RR) estimates adjusting for confounding factors of age, sex, period of procedure, and indication for TEA. The factors studied with the Cox regression model were sex, age at surgery, period where primary TEA was performed, indications for TEA, implant design, and implant brand. When calculating RR by brand of implant, we only included implants that had been used in more than 40 procedures. Differences between groups were considered statistically significant if the P values were <.05 in a two-tailed test. SPSS 20.0 software (IBM Corp, Armonk, NY, USA) was used for statistical analysis.

Results

Patient characteristics

Of the 324 TEA operations, 264 (81.5%) were performed in women. At the time of primary TEA, the mean age was 62 years (range, 25-91 years), and 160 (49.4%) of the TEAs were performed on the right elbow. Rheumatoid arthritis (RA) was the most frequent indication for the TEA operation, with 237 (73.1%) procedures performed. Other indications for primary TEA were fracture sequelae with 61 procedures, including 7 acute fractures (18.8%), osteoarthritis (OA) in 18 (5.6%), and other indications, including septic and psoriasis arthritis, in 8 (2.5%). Development in distribution of indication for TEA surgery and TEA design over time are shown in Figure 2. Mean overall follow-up was 105 months for primary TEA and 89 months for revision TEA.

Implants

Seven different brands of TEA implants were used, counting 152 linked and 172 unlinked designs: Souter Strathclyde (Stryker, Rutherford, NJ, USA), Capitellocondylar (CC) TEA (Johnson & Johnson Orthopaedics Inc, Raynham, MA, USA), Pritchard ERS (DePuy, DePuy Mitek, Raynham, MA, USA), Kudo type 3 (Biomet Inc, Warsaw, IN, USA), Coonrad-Morrey (Zimmer Inc, Warsaw,
IN, USA), GSB III (Zimmer), and Discovery (Biomet; Table I). From 1981 to 2000 the most commonly used implant was the unlinked Souter Strathclyde. Since 2003, the tendency has gone from the unlinked toward the linked design, and since 2008, only 1 TEA implant, the linked Coonrad-Morrey implant, has been used in eastern part of Denmark. Since 2008, total elbow replacement procedures have been centralized to a single unit in the eastern part of Denmark.

Revision procedures

During the period 1981 to 2008, 68 revisions and 2 cases of permanent implant removal were performed. The most common reason for revision was aseptic loosening in 39 (57.4%), followed by periprosthetic fracture in 11 (16.2%), prosthesis dislocation in 8 (11.8%), infection in 5 (7.4%), fracture of the prosthesis in 3 (4.4%), and loose hinge pin in 2 (2.9%). The difference in the reason for revision between linked and unlinked design is summarized in Table II. The 66 revision TEAs used were Coonrad Morrey in 30 (45.5%), GSB III in 15 (22.7%), Souter Strathclyde in 14 (21.2%), the CC TEA in 3 (4.5%), Kudo in 3 (4.5%), and Pritchard ERS in 1 (1.5%).

Survival of TEA

The overall survival rates for primary TEA were 90% (95% confidence interval [CI], 88%-94%) at 5 years and 81% (95% CI, 75%-86%) at 10 years, and varied for the different types of implants, as reported in Table III. The Kaplan-Meier survival curves related to Table III are shown in Figure 3. The cumulative survival rates for linked prostheses were 90% (95% CI, 84%-95%) at 5 years and 88% (95% CI, 83%-94%) at 10 years. These results were comparable with the unlinked design at 5 years (90%; 95% CI, 87%-96%) and at 10 years (77%; 95% CI, 70%-84%). This result was not significantly different from the linked designs but indicated a tendency of better long-term survival for the linked design.

The implant-specific 10-year cumulative survival rate for the 4 most commonly used implant brands were 88% (95% CI, 81%-95%) for Coonrad-Morrey, 89% (95% CI, 80%-97%) for GSB III, 88% (95% CI, 78%-97%) for the CC TEA, and 72% (95% CI, 62%-82%) for the Souter Strathclyde.

Revision rates

We found that the unlinked design was associated with a higher RR of revision of 1.88 (95% CI, 1.1-3.2; P = .049) compared with the linked design. The adjusted RR for revision was calculated between the 4 most used implants: Coonrad-Morrey (RR, 0.49; 95% CI, 0.2-1.22; P = .12), GSB III (RR, 0.42; 95% CI, 0.19-0.94; P = .039), and the CC TEA (RR, 0.50; 95% CI, 0.23-1.1; P = .09), with Souter Strathclyde set as the indicator because it has been used the longest and with a high frequency (n = 90; Table IV).

Compared with RA, primary TEAs performed due to fracture had an increased adjusted RR for revision of 1.9 (95% CI, 1.1-3.4; P = .035). The adjusted RR for revision was 0.88 (95% CI, 0.54-1.42; P = .85) for patients older than 60 years and was 1.75 (95% CI, 1.02-3.01; P = .043) for men compared with women.

Discussion

In this retrospective study we found acceptable 5-, 10-, and 15-year implant survival rates after primary TEA. Patients receiving TEAs over time have increased, and

<table>
<thead>
<tr>
<th>TEA</th>
<th>No.</th>
<th>S1, % (95% CI)</th>
<th>nR1</th>
<th>S5, % (95% CI)</th>
<th>nR5</th>
<th>S10, % (95% CI)</th>
<th>nR10</th>
<th>S15, % (95% CI)</th>
<th>nR15</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>324</td>
<td>97 (96-100)</td>
<td>314</td>
<td>90 (88-94)</td>
<td>245</td>
<td>81 (75-86)</td>
<td>120</td>
<td>67 (59-72)</td>
<td>46</td>
</tr>
<tr>
<td>Design</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linked</td>
<td>152</td>
<td>97 (95-100)</td>
<td>146</td>
<td>90 (84-95)</td>
<td>102</td>
<td>88 (83-94)</td>
<td>30</td>
<td>81 (70-92)</td>
<td>12</td>
</tr>
<tr>
<td>Unlinked</td>
<td>172</td>
<td>97 (94-99)</td>
<td>164</td>
<td>90 (86-95)</td>
<td>143</td>
<td>77 (70-84)</td>
<td>90</td>
<td>62 (52-72)</td>
<td>34</td>
</tr>
<tr>
<td>Implant</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coonrad-Morrey</td>
<td>91</td>
<td>97 (93-100)</td>
<td>87</td>
<td>88 (81-95)</td>
<td>54</td>
<td>88 (81-95)</td>
<td>6</td>
<td>88 (81-95)</td>
<td>1</td>
</tr>
<tr>
<td>GSB III</td>
<td>60</td>
<td>98 (95-100)</td>
<td>58</td>
<td>91 (84-98)</td>
<td>46</td>
<td>89 (80-97)</td>
<td>22</td>
<td>80 (66-94)</td>
<td></td>
</tr>
<tr>
<td>Capitellocondylar</td>
<td>54</td>
<td>100</td>
<td>54</td>
<td>92 (85-100)</td>
<td>45</td>
<td>88 (78-97)</td>
<td>36</td>
<td>84 (70-97)</td>
<td></td>
</tr>
<tr>
<td>Souter Strathclyde</td>
<td>90</td>
<td>93 (88-98)</td>
<td>84</td>
<td>91 (85-97)</td>
<td>78</td>
<td>72 (62-82)</td>
<td>42</td>
<td>60 (47-73)</td>
<td></td>
</tr>
<tr>
<td>Revision TEA</td>
<td>66</td>
<td>100</td>
<td>64</td>
<td>96 (90-100)</td>
<td>43</td>
<td>89 (79-100)</td>
<td>18</td>
<td>89 (79-100)</td>
<td>4</td>
</tr>
</tbody>
</table>

CI, confidence interval; n, number; nR, numbers at risk; S, survival in %; TEA, total elbow arthroplasty.
since 2003, the choice of implant has been dominated by the linked design. Revision rates and RR estimates were higher for the unlinked design. The most common reason for revision for both the linked and unlinked design was aseptic loosening. TEA procedures performed due to fracture and fracture sequelae were associated with 1.8-times increased risk for revision compared with RA. The unlinked Souter Strathclyde TEA was associated with increased risk for revision compared with the linked GSB III. Male patients were associated with a 1.8-times increase risk for revision.

The overall 5-year and 10-year survival rates of 90% and 81% are comparable to previous studies from the Scottish Arthroplasty Project and the Norwegian and Finnish Arthroplasty Registers, with 8% to 10% and 10% to 18% revision rates, respectively.7,10,22 The Scottish Arthroplasty project lacks data related to implant types. Fevang et al included 30 linked TEAs compared with 475 unlinked, and there was no 10-year follow-up on linked implants. In the study by Skyttä et al,22 all of the TEAs were unlinked and the indication was restricted to RA.

In this study, the 5-year and 10-year survival rates for the linked design were 90% and 88% compared with 90% and 77% for the unlinked design. The survival results after revision TEA are excellent, with 5-year and 10-year survival of 96% and 89%. It is uncertain though whether this high percentage of survival is due to good functional TEAs and a low level of pain or the unwillingness among surgeons to perform further revision surgery on already revised TEAs.

We found the same association between a TEA procedure performed due to fracture sequelae and an increased risk for revision as Fevang et al.7 The RR in their study was 5.8 and also significant, but they counted only 12 procedures of unknown design.7 Our higher level of power could explain the difference in the RR estimates. The linked design was used in 67% of the TEA procedures performed due to fracture sequelae in this study.

The present data cover 172 unlinked and 152 linked TEAs. Since 2006, only the linked design has been used in TEA procedures. The tendency of increasing use of the linked design was recently described by Giannicola et al8 in a review. Studies have indicated lower complication rates and revisions in the linked design compared with the unlinked design, but no studies have included survival analysis.12,18 The use of the linked design has increased as has the increase in TEA procedures due to fracture and fracture sequelae. The TEA procedures due to fracture sequelae are associated with a higher revision rate, and due to lack of sufficient bone stock and potential ligamentous insufficiency, literature advocates for the linked design.12,18 Patients with RA are known to generally have lower demands than patients who undergo TEA procedures due to fractures and fracture sequelae. A lower level of activity provides less strain on the prostheses, thus decreasing the risk for revision. Younger and more active patients have higher demands. Surgeons must keep this in mind when considering TEA when the indication is fracture sequelae and acute fracture in the distal humerus.

Because TEA procedures remain a challenge, the literature advocates centralization to ensure that surgeons with adequate expertise perform the procedures.10,14,22,24 Since 2008, the TEA procedures in the eastern part of Denmark have been centralized to a single clinic.

The number of TEA procedures, the long-term follow-up, inclusion of revision TEAs, as well as the equal number of linked and unlinked implants provides strength to this study. The weaknesses are the lack of radiographic follow-up, identification of other complications that could require revision, uncertainty of the numbers lost to follow-up, the retrospective design of the study, and the lack of functional and patient-related outcome measures.
**Conclusions**

Survival analysis on TEA is sparse as are studies comparing TEA designs. RA continues to be the most common indication, but TEA procedures due to fracture and fracture sequelae are increasing, with a higher risk for revision. The survival rates of revision TEAs are promising, which is of interest when performing primary TEA surgery on younger patients, who are more likely than older patients to live past the survival of their primary TEA. The tendency goes toward the linked design, which in this study is supported by the significantly higher RR for revision for the unlinked design. A centralization of the procedures should ensure adequate expertise and volume to conduct further studies. Prospective studies that include survival analysis, functional, and patient-related outcomes would benefit to the studies on TEA surgery, and further studies on revision TEAs should be conducted. National registers and databases could contribute to the knowledge about TEA as well.

**Disclaimer**

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.

**References**


