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ORIGINAL ARTICLE

Computed tomography–based 3-dimensional preoperative planning for unlinked total elbow arthroplasty

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Hypothesis: Three-dimensional (3D) surgical planning for unlinked total elbow arthroplasty (TEA) would be helpful for estimation of the implant size and accurate placement of implants.
Methods: We included 28 patients who underwent TEA with an unlinked total elbow implant in this study. All patients underwent computed tomography scans of the elbow before surgery, and a 3D digital model of the elbow was reconstructed. After the appropriate size and position of the prosthesis were determined, 10 points around the bone tunnel (4 on the humerus and 6 on the ulna) were measured to plan the insertion of the humeral and ulnar stems. Two-dimensional planning was also performed using anteroposterior and lateral radiographs. Intraoperatively, the surgeon measured the planned parameters using a slide gauge to reproduce the 3D planned position of the stem insertion.
Results: The stem sizes were accurately estimated in 57% of patients for the humerus and 68% for the ulna with 2-dimensional planning and in 86% for the humerus and 96% for the ulna with 3D planning. The mean differences between the positions of the prostheses after surgery with reference to the planned positions were 0.8° of varus and 1.5° of flexion for the humeral component and 0.7° of varus and 2.9° of flexion for the ulnar component. We did not evaluate rotational positioning in this study.
Conclusions: The 3D surgical planning allowed accurate estimation of the implant size and appropriate placement of implants. This method may contribute to a reduced incidence of complications and improved long-term outcomes from TEA.
Level of evidence: Basic Science Study; Computer Modeling

Keywords: Computed tomography; K-NOW; surgical planning; three-dimensional planning; total elbow arthroplasty; unlinked type

For treatment of painful and unstable elbow joints caused by conditions such as rheumatoid arthritis (RA), osteoarthritis, and post-traumatic arthropathy, total elbow arthroplasty (TEA) is a useful therapeutic strategy that restores elbow joint function through successful pain relief and stabilization. TEA is performed less frequently than total hip and knee

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arthroplasties; however, according to data from an American database, the number of patients undergoing TEA increases annually because the indications for this procedure have expanded to include trauma and osteoarthritis.[5] Implants that are used for TEA are classified into 2 types: linked type, which has a structure linking the humeral and ulnar components, and unlinked type, which consists of separate humeral and ulnar components. For both types, favorable long-term outcomes, such as a 10-year survival rate of 80%-90%, have been reported.[3,14] A recent study from the Danish National Patient Register showed an overall 10-year survival rate of 81%; however, the results were different between the linked design (88%) and unlinked design (77%).[10] On the other hand, TEA has been reported to be associated with a high incidence of complications. A systematic review showed that the overall incidence of complications reached 24.3%.[15] In a study using California's Discharge Database, 132 of 1625 patients (8%) who underwent TEA subsequently underwent another operation within 90 days, with 88 patients (5%) requiring revision of the implants.[8] On the basis of these reports, prevention of early postoperative complications from TEA is an extremely important issue.

In prosthetic arthroplasty, the placement of implants in appropriate positions is essential for reducing the incidence of complications.[9] Postoperative instability and excessive polyethylene wear are important issues that occur as a consequence of implant malpositioning. For preoperative planning for prosthetic arthroplasty, 2-dimensional (2D) templates using anteroposterior and lateral plain radiographs have been commonly used. In contrast, with recent advances in image processing technology, there have been many reports on the usefulness of 3-dimensional (3D) templates using computed tomography (CT) for total knee and hip arthroplasties.[1,11-13] However, CT-based 3D templates for prosthetic arthroplasty of the upper limbs have been described in only a few reports, with sporadic reports on total shoulder arthroplasty.[4,6]

The objective of this study was to assess the usefulness of CT-based 3D templates for unlinked TEA. We hypothesized that 3D preoperative planning would be helpful for the estimation of implant size and improve the accuracy of implant placement.

Materials and methods

Between April 2012 and June 2015, 1 senior surgeon (T.I.) performed 39 consecutive TEA procedures. Among them, data from 28 patients who were treated with the unlinked-type K-NOW implant (Teijin-Nakashima Medical, Okayama, Japan) were retrospectively reviewed and included in this study (Fig. 1, *A*). The stem was available in 3 sizes (small, medium, and large) for each humeral and ulnar component. The humeral components were fixed without cement in all patients, and the ulnar components were fixed with cement in 7 patients and without cement in 21. There were 25 female and 3 male patients, with a mean age of 66 years (range, 42-83 years) at the time of surgery. Of the patients, 3 had primary osteoarthritis and 25 had RA. Preoperative radiographs of the 25 patients with RA showed grade 3 in 5 patients, grade 4 in 18, and grade 5 in 2, according to the Larsen grading system. Among the 28 patients, the affected arm was the right arm in 20 patients and the left arm in the remaining 8 patients. The average follow-up period was 24 months (range, 12-48 months). Informed consent for the surgical procedure and the retrospective chart review was obtained from all patients.

CT scans of the elbow were obtained before surgery in all patients to perform 3D surgical planning. Axial CT scans of the affected arm (including the entire humerus and forearm) were taken with low-dose radiation for bone analysis with a 2-mm slice thickness. The image data were extracted from the database in Digital Imaging and Communications in Medicine (DICOM) format, and a 3D digital model of the elbows was reconstructed using preoperative planning software (ZedView; LEXI, Tokyo, Japan). ZedView provides the desired reconstructed images in 3 orthogonal planes and facilitates the measurement of the angles and distances between any 2 points in each reconstructed plane. The computer-aided design models of each of the 3 implant sizes provided by the manufacturer were uploaded to the software to facilitate the 3D planning (Fig. 1, *B*).

Preoperative 3D planning using ZedView

The stem size was determined to fit the humeral and ulnar canals using the superimposition of the selected components' sizes on the

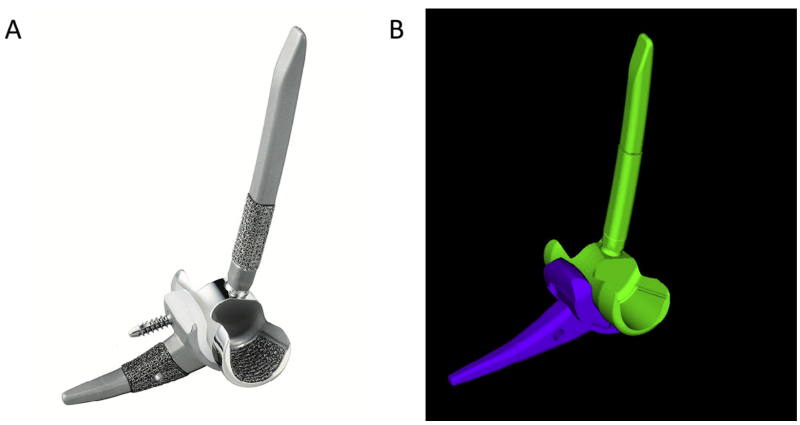

Figure 1 (**A**) Unlinked-type K-NOW implant. This implant is used for cementless fixation on both the humerus and ulna, and porous coating is applied on its stems. This image was provided by Teijin-Nakashima Medical. (**B**) Computer-aided design model of implant.