Long-term Effectiveness of Sorbie-QUESTOR Elbow Arthroplasty: Single Surgeon’s Series of 15 Years

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abstract

Full article available online at ORTHOSuperSite.com. Search: 20110714-08

With increasing usage of many types of total elbow replacements, there is a continuing need for clinical series that report survivorship, complications and revisions, and performance of single types of implants over extended time periods. The purpose of this study was to assess the long-term effectiveness of all implants of the Sorbie-QUESTOR (SQ) unlinked surface arthroplasty conducted by a single surgeon (C.S.) over 15 years at a single site, and to determine whether there were diagnostic group differences. Between 1995 and 2002, 51 S-Q prosthetic elbows were implanted into 44 patients. The patient groups were hemophilia, rheumatoid arthritis, and “other,” which included osteoarthritis, traumatic arthritis, psoriatic arthritis, and reactive arthritis. Annual evaluations included scores of pain, range of motion, and function. The most recent annual evaluation was included in the data set. Details of complications and revisions were recorded. The hemophiliac group had the best survival outcomes at 87.5%. Eighteen prostheses required revision or removal with all but 3 retained or replaced. Postoperatively, 73% rated their pain as ‘slight’ or ‘none’. The hemophilia and rheumatoid arthritis groups made very large total flexion/extension gains. The rheumatoid arthritis group made significant forearm motion gains. Average functional assessment gains were nearly 2 grades of 5 functional levels and were significant for all groups. The S-Q surface arthroplasty has demonstrated long-term effectiveness in patients with a variety of elbow joint pathologies showing reduction in pain, large gains in joint range and function, and good long-term survival.

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Canada; Died March 29, 2010.

The authors thank Carolyn Heymans for her extensive technical assistance, Dr Derek Cooke for editorial assistance, and the many patients who contributed to this study.

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doi: 10.3928/01477447-20110714-08
Arthritis of the elbow joint may cause chronic, often unremitting, pain, joint instability, or stiffness, and results in serious functional loss. A good elbow is essential for placing the hand in space, for personal care, and for the use of canes and crutches. Before the development of replacement arthroplasty, synovectomy of the elbow joint, ressection arthroplasty, cheilectomy, radial head resection, and arthrodesis were the surgical techniques available for the treatment of elbow arthritis. With modern technology and improved implant design, it is now possible to achieve a stable joint and a pain-free range of movement. The complexity of the surface geometry and the kinematics of the joint have challenged surgeons and engineers in the design of elbow implant prostheses for successful arthroplasty. The evolution of design has progressed from a rough approximation metal hinge, to linked or semi-constrained hinges and finally to unlinked prostheses, including one mirroring normal surface geometry, and the kinematics of the joint have challenged the joint being stabilized by surface shape and soft tissues. This is the basis of the design of the Sorbie-QUESTOR (S-Q) (Wright Medical Technology, Mississauga, ON, Canada) surface arthroplasty reported in this study.

Clinical and survivorship performance of an implant are important in device selection. Findings to date are by no means uniform or conclusive. Survivorship reporting has rarely involved the use of a survival analysis, making the data unreliable. Complication rates have varied from 14% to 80% with little insight into differences. With respect to function, constrained implants have shown a better range of movement than unlinked, although overall outcomes have been marginally better with semi-constrained than either unlinked or constrained devices. Unlinked devices have been reported to have higher rates of loosening, instability, and dislocation than other types. The average reporting time for follow-up has been 60 months, making reports of >5 years of considerable value.

The provision of systematic information on a 15-year clinical series of 1 type of unlinked implant would complement current information and assist in clinical decision-making.

Between 1995 and 2002, fifty-one S-Q prosthetic elbows were implanted into 44 patients by a single surgeon (C.S.). The purpose of this study was to assess the long-term effectiveness, including pain relief, range of motion, stability, and function of total elbow arthroplasty using the unlinked S-Q surface arthroplasty in the treatment of a variety of arthritic conditions. A secondary purpose was to determine if there were any apparent differences between major diagnostic groups that might affect clinical decision-making.

Materials and Methods
This research was approved by the Queen’s University Health Sciences and Affiliated Teaching Hospitals Research Ethics Board. The protocol, consisting of questions about pain and function, as well as direct observations and measurements made by the surgeon, was administered to each patient returning for annual follow-up visits. For the purpose of this analysis, the most recent complete data set available for each patient was included in the data set. Patients who retained the prosthesis but were unable to attend clinic due to distance or health constraints were interviewed by the Research Associate (P.C.), over the telephone.

The outcome protocol, based on the Mayo Elbow Performance Score with modification was completed prior to surgery and at follow-up. The assessment of pain (0 = complete disability, 5 = none) included elbow, shoulder, and wrist joints. Measurements included elbow range of motion (flexion and extension), forearm movement (supination, pronation), shoulder movement (flexion, extension, abduction, adduction, internal rotation, external rotation), and wrist movement (flexion and extension). Only data for the elbow and forearm is presented in this article. Functional assessment was based on 11 items (cup to mouth, eating with spoon, cutting with knife, lifting 1-liter kettle, pouring kettle to glass, telephone to ear, grasp opposite earlobe, wash opposite axilla, rise from chair with arms, turn door knob and push door open, pull door open), with each item scored from 0 (impossible) to 4 (no difficulty); total scores ranged from 0 to 44. Additional information including age, gender, diagnosis, dominant side, and time since symptoms started, was also collected.

Statistical Analysis
Data was entered into an Excel spreadsheet and imported into SPSS 18.0 for Windows for statistical analysis. Following descriptive analyses (frequencies for the categorical variables, means, standard deviations, and medians for the linear variables), improvements in range of motion and functional activity were assessed by calculating change scores; the 95% confidence intervals of the change scores indicate whether the changes within the groups were statistically significant. Chi-square tests were used to compare the 3 diagnostic groups on categorical data such as sex, and 1-way analysis of variance was used to compare continuous data such as the change within each of the 3 diagnostic groups. A Kaplan-Meier curve was generated to assess the survival time of the prosthesis; cases were censored at the last known time that they had a functional S-Q prosthesis. If the patient died with a functional prosthesis, the date of death was used as the last time of known functional prosthesis.

Implant Design
The design philosophy for the S-Q unlinked arthroplasty had the objective of transferring load more naturally from the forearm to the arm through synthetic joint surfaces and the soft tissues around the joint. It was assumed that surface arthroplasty implants using soft tissue to transfer a significant amount of load, would be less likely to wear or loosen with the passage of time. For successful function and survival of unlinked forms of arthroplasty, there would have to be sufficient ligament and capsule integrity for joint stability. An arthroplasty faithfully...
reproducing the natural surface geometry of the 3 elbow joint bones, correctly placed, would allow the forearm to move along normal kinematic axes and allow muscles to restore normal strength. Such an arthroplasty would require instruments to ensure precise bone preparation and firm fixation of implants to host bone in the correct original axes of motion.

In 1980, the morphometry of the elbow joint was determined. Overall dimensions were obtained by statistical analysis of distances between 11 identifiable bony points in the distal humerus and upper ulna obtained on radiographs of 60 normal left/right, male/female adult elbow joints.16 Cartilage thickness was added to bone surface measurements using cadaveric data. A biostatistical analysis17 determined ideal dimensions for 1 to 6 sizes for humeral and ulnar components. Using 3 average sizes, small, medium, and large, the maximum dimensions are within 2 mm of correct fit tolerance in the greatest dimension (mediolateral width) for normal patients.

The kinematics of the elbow joint were studied to determine axes of motion, carrying angle, and the distribution of forces across the trochlea, olecranon, and capitello-radial head surfaces described in full in previous publications.10 To determine the surface geometry, cadaver elbow bones fixed on standard, definable axes were sliced on a milling machine in the sagittal plane. Slices of .76 mm thickness were shaved from each distal humerus and upper ulna specimen. The cut surfaces, cartilage stained red, were photographed and digitized, yielding 5000 coordinates, which described the outer limits of the slices. A software program was written for analysis of the data using Cartesian mathematical assumptions. Reproduction of the virtual slices by computer graphics visually displayed their amassed coordinates, their joint surface geometry, and the location of their centers. The centroidal axis of flexion/extension of the humerus was determined by joining the centers of the humeral slices. The axes of rotation of the olecranon and coronoid facets were similarly determined.

The data showed that the elbow does not move in flexion and extension on a single, single axis of motion, but one described as a “sloppy hinge.” Instant centers of motion are defined when major contact is between the posterior surface of the trochlea and the olecranon facet (force applied with the joint in extension) and between the anterior surface of the trochlea and the coronoid facet (force applied with the joint in flexion). The data was also used to create software that allowed computer numeric contouring in steel of implant prototypes for the humerus, radius, and ulna. Instruments were developed that, when attached to bone, guide precision cutting tools to remove damaged joint surfaces. The ulnar implant was made to hold modular polyethylene inserts of 2 thicknesses, which reproduce the ulnar surfaces. The contact surface of the radial head component is polyethylene covered. Stabilizing stems are present on all components.

Surgical Technique

The S-Q elbow arthroplasty is inserted with the patient supine, elevated on the affected side so that the weight of the arm across the front of the chest maintains its position. While a posterior midline incision is possible, a modification of the Kocher18 approach has been used in this series. Before lifting the anconeus and triceps insertion, Methylene Blue or a colored pen is used to mark its area of insertion on the triceps posterior surface. This facilitates the tendon’s accurate repositioning and fixation at the end of the procedure. Steel templates are used on the sides of the trochlea and capitellum to locate the centroidal axis of flexion/extension, which extends between the center points of their surface contours (Figure 1). One-eighth inch (3.175 mm) drills are inserted to a depth of 1 cm at these points to accept pins protruding from the first cutting guide, which directs the saw at the correct angle to remove the central part of the trochlea and open the distal medullary canal of the humerus. The elbow is dislocated to allow this. The canal is broached and a second block-cutting guide attached with side bars and pins that use the same drill holes in the centroidal axis of flexion/extension to fix the block in place. An attached rod engages the medullary canal at the correct angle for the humeral implant stem. Five osteotomy cuts are made in the subchondral bone of the distal humerus, excluding the non-cartilage covered area on the posterior surface of the capitellum, which is the origin of the anconeus (Figure 2). These cuts shape the end of the humerus to accept the implant. A trial humeral implant is inserted and then removed.

Using an oscillating saw, a minimum amount of radial joint surface is removed at 90° to the long axis of the neck, making sure that the cut is below the cartilage boundary. The neck is broached with a trifin instrument to take the radial implant stem. A jig is attached to the ulna, and a side-cutting router, directed by a cam, is used to remove the surface of the sigmoid fossa of the ulna in a precise curve, retaining the maximum amount of subchondral bone. The upper part of the ulna is broached to take a trial implant. When all 3 trial implants are in po-

![Sizing Humerus](image)

Figure 1: Sizing of the humerus. (Reprinted with permission from Wright Medical.)
position, the elbow is reduced, and depending on the laxity of the joint space when flexed, a decision is made on the thickness of the polyethylene modular bearing surface on the ulnar component. Because the thickness increments are very small, there is minimum impact on the kinematics of the elbow. The appropriate medullary insert size is selected and placed in the humeral canal to the designated depth (Figure 3). The permanent implants are then inserted and fastened with PMMA cement.

The tendon of triceps is reattached using the stained blue area to ensure accurate repositioning. Four holes are drilled through the upper end of the ulna starting near the 4 corners of the area of triceps attachment and exiting on the posterior surface of the ulna approximately 3 cm from the tip of the olecranon. With the help of doubled-over wires, non-absorbable sutures are drawn through these holes, crossing the posterior border of the ulna. Free curved cutting needles lead the doubled suture threads through the peripheral limits of the stained area on the tendon over which the sutures are firmly tied. This process of attachment of the triceps allows early mobilization of the joint. The raised common extensor origin is reattached to the lateral epicondyle and secured with non-absorbable sutures through a drill hole in the epicondyle. The wound is closed in layers and in the skin, subdermal polyg-lycolic acid sutures with buried knots, draw the wound edges together and ensure that no sutures track through the skin. Radiographs of a completed arthroplasty are shown in Figures 4 and 5.

**RESULTS**

Pain was the overarching reason for elbow replacement, with stiffness being the second most common complaint. Patient characteristics appear in Table 1. The groups differed in age, gender, and occurrence of previous surgeries at surgery. Average follow-up was 7 years or more for all groups.

For many patients, the joint replacement followed many years of interventions, reflecting the 28 years of average duration of their conditions. Six patients had received prior same-side surgeries before receiving the S-Q prosthesis, 1 having had a single procedure, 2 patients with between 2 and 4 operations, and 3 having had >5 surgeries before elbow arthroplasty. Four patients had prior elbow surface replacements for rheumatoid arthritis (n = 3) or trauma (n = 1). Two elbows were completely ankylosed prior to surgery, 1 the result of juvenile rheumatoid arthritis, the other, hemophilia. Although patients with gross distortion of the elbow bones were excluded, 2 patients had significant distal humeral deformity as a result of supracondylar fracture in childhood.

Five patients had prior radial head excision after injury or in association with synovectomy for the treatment of rheumatoid arthritis and had insufficient remaining radial neck to support a radial implant. The humero-ulna relationship nonetheless remained intact in 4 and functioned well. One patient with humeral deformity and a permanently displaced radial head after supracondylar fracture as a child had the radial head removed. Her ulna now tracks on the groove between trochlea and capitellum, but she has a painless elbow with a stable functional range of 45° to 140°.

**Survivorship Analysis**

The Kaplan-Meier curve (Figure 6) shows that the hemophiliac group had the best outcomes overall, with all 8 lasting at least 60 months, and only 1 of 8 experiencing a failure for a functional rate of 87.5% at study end. The rheumatoid arthritis group and the “other” group showed a similar pattern, although 23/32 (72%) of the rheumatoid arthritis replacements were still functional at the time of censoring while 6/11 (55%) of the “other” group were functional. However, these
Complications, Revisions, and Removals of S-Q

A total of 18 implants were revised or replaced once, and of these, 4 were revised twice. Of these, 15 implants were removed, 12 of which were replaced (Table 2). Seven were likely due to nosocomial infection (discussed below), 4 occurred due to traumatic loosening in non-rheumatoid arthritis patients, 2 patients with rheumatoid arthritis had aseptic loosening, and 2 were removed or revised due to infection and complex health problems. Although group differences were not statistically significant, there may be clinical importance to the fact that these involved 13.5% of the hemophilia group, 27% of the rheumatoid arthritis group, and 50% of the “other” group. The final status of the 15 removals was 10 received Coonrad-Morrey, 2 received new S-Qs, and 3 were fail. Three patients, all with rheumatoid arthritis, had revisions that required ulnar stabilization, triceps plication, or a change of polyethylene insert. All retained their original S-Q prostheses.

Seven patients developed infection at some time after the operative procedure, with the shortest time between surgery and recorded infection being 3 weeks, and the longest, 9 years. Five of the patients with infections had rheumatoid arthritis and were immunocompromised by the disease and their treatment with steroids and/or methotrexate. One infected case with posttraumatic osteoarthritis had 7 previous operative procedures before presenting for replacement. The remaining patient who had the shortest postoperative time to infection, 3 weeks, had psoriatic arthropathy, previous splenectomy, was hepatitis C positive, had chronic liver failure, and had serious drug addictions.

Three of 8 arthroplasties in patients with hemophilia showed some evidence of osteolysis between the host bone and bone cement around both the humeral and ulnar components. One arthroplasty required complete

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Hemophilia (N=7)</th>
<th>Rheumatoid Arthritis (N=27)</th>
<th>Othera (N=10)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at surgery, y</td>
<td>43±9 (28-54)</td>
<td>55±12 (24-77)</td>
<td>48±8 (34-62)</td>
<td>.033</td>
</tr>
<tr>
<td>Years affected at surgery</td>
<td>24±13 (9-46)</td>
<td>30±11 (10-57)</td>
<td>27±20 (7-69)</td>
<td>.62</td>
</tr>
<tr>
<td>Follow-up, mo</td>
<td>100±19 (66-120)</td>
<td>89±53 (2-148)</td>
<td>84±49 (5-144)</td>
<td>.78</td>
</tr>
<tr>
<td>Frequency, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>7 (100)</td>
<td>9 (33)</td>
<td>6 (60)</td>
<td>.006</td>
</tr>
<tr>
<td>Prior elbow surgery</td>
<td>0 (0)</td>
<td>9 (33)</td>
<td>6 (70)</td>
<td>.011</td>
</tr>
<tr>
<td>Follow-up status</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lost to follow-up</td>
<td>1 (14)</td>
<td>1 (4)</td>
<td>1 (10)</td>
<td>.86</td>
</tr>
<tr>
<td>Seen at clinic (2009)</td>
<td>2 (29)</td>
<td>6 (22)</td>
<td>2 (20)</td>
<td></td>
</tr>
<tr>
<td>By telephone (2009)</td>
<td>3 (43)</td>
<td>13 (48)</td>
<td>6 (60)</td>
<td></td>
</tr>
<tr>
<td>Died</td>
<td>1 (14)</td>
<td>7 (26)</td>
<td>1 (10)</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviation: SD, standard deviation.

aIncludes osteoarthritis (3), traumatic arthritis (5), psoriatic arthritis (1) and reactive arthritis (1).

bIf the patient died with a functional S-Q, this was included as functional.

cP values are based on independent samples t tests (continuous data) or chi-square tests (categorical data).

Figure 6: Kaplan-Meier curve comparing prosthetic survival time for the 3 groups. Log rank test for differences between groups: X²=2.22, P=.136.
revision, and 1 other may need revision in the future. This radiological appearance has been assumed to result from hemorrhage around the implant, as the individuals have all been young, hardworking men who did not stay strictly to Factor 8 protocol.

The joint proved to be very stable. In this series, only 2 patients subluxed early, 1 with 7 previous operations, and the other with tissues badly weakened by rheumatoid arthritis. The second, a patient with a deformity from childhood and no radial head, tracks her ulna in the groove between trochlea and capitellum of the humeral component.

There were 2 cases of prolonged ulnar nerve injury (4%) from the time of surgery. Three cases of temporary ulnar neuritis (6%) occurred in patients with rheumatoid arthritis, all of which cleared.

### Pain and Functional Outcomes

The numbers of patients and percentages of groups in each pain category pre- and postoperative appear in Table 3. Means and confidence intervals for ranges of motion and functional outcomes pre- and postoperative appear in Table 4. Changes in range of motion and functional outcomes are shown in Table 5. There were no statistically significant differences between groups in pain, range of motion or function before surgery. Pain data (Table 3) shows that 55% rated their pain as ‘complete disability’ or ‘severe’ preoperatively, whereas 73% rated their pain as ‘slight’ or ‘none’ postoperatively. The hemophilia and rheumatoid arthritis groups made total range of motion gains of 59° and 40° respectively, with the ‘other’ group’s changes not reaching significance (Table 5). Gains in forearm motion were significant only for the rheumatoid arthritis group, with 49° improvement derived from nearly equal increases in pronation and supination. Average functional assessment gains, ranging from 17 to 21 points, were significant for all groups, and not different between groups. This represented an average of nearly 2 grades (eg, from ‘with much difficulty’ to ‘no difficulty’ or from ‘with aid’ to ‘with little difficulty’).

All patients who were employed prior to their elbow replacement returned to their previous occupations, some of which required significant elbow muscle strength and stability. The occupations included working at a supermarket checkout counter, computer programming, horse breeding, cattle breeding, farming, and other forms of intensive

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**Table 2**

<table>
<thead>
<tr>
<th>Reason for Removal/Replacement</th>
<th>Final Status</th>
<th>Diagnosis</th>
<th>Months to S-Q Revision/Removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Likely nosocomial infection (N=7)</td>
<td>4 Coonrad-Morrey, 2 new S-Q, 1 flail</td>
<td>5 RA, 1 OA, 1 O</td>
<td>2-12</td>
</tr>
<tr>
<td>Traumatic loosening (N=4)</td>
<td>4 Coonrad-Morrey</td>
<td>3 OA, 1 H</td>
<td>48-84</td>
</tr>
<tr>
<td>Aseptic loosening (N=2)</td>
<td>1 Coonrad-Morrey, 1 flail</td>
<td>2 RA</td>
<td>27, 78</td>
</tr>
<tr>
<td>Infection, trauma, multiple comorbidities (N=2)</td>
<td>1 Coonrad-Morrey, 1 flail</td>
<td>1 RA, 1 O</td>
<td>7, 9</td>
</tr>
</tbody>
</table>

**Reason for Revision Without Removal**

- Stabilize ulnar component (N=2)
  - Original S-Q
  - 2 RA (8, 3)
- Triceps plication, change polyethylene insert (N=1)
  - Original S-Q
  - 1 RA (10)

*Abbreviations: H, hemophiliac; OA, osteoarthritis; O, other; RA, rheumatoid arthritis.*

**Table 3**

<table>
<thead>
<tr>
<th>Pain Category</th>
<th>Hemophilia (N=8)</th>
<th>Rheumatoid Arthritis (N=32)</th>
<th>Other (N=11)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
</tr>
<tr>
<td>Complete disability</td>
<td>3 (38)</td>
<td>0 (0)</td>
<td>5 (17)</td>
</tr>
<tr>
<td>Severe</td>
<td>2 (25)</td>
<td>0 (0)</td>
<td>10 (35)</td>
</tr>
<tr>
<td>Moderate/severe</td>
<td>2 (25)</td>
<td>0 (0)</td>
<td>8 (28)</td>
</tr>
<tr>
<td>Moderate on activity</td>
<td>0 (0)</td>
<td>3 (38)</td>
<td>2 (7)</td>
</tr>
<tr>
<td>Slight</td>
<td>1 (13)</td>
<td>2 (25)</td>
<td>2 (7)</td>
</tr>
<tr>
<td>None</td>
<td>0 (0)</td>
<td>3 (38)</td>
<td>2 (7)</td>
</tr>
</tbody>
</table>

*Abbreviations: Post, postoperative; Pre, preoperative.

*Percentages do not always equal 100 due to rounding.*
physical work. One patient, within 1 year of surface replacement, won 2 golf championships and a longest drive competition (315 yards). The golfer continues, 12 years after his replacement, to play competitive golf.

DISCUSSION

Survivorship

The hemophilic group had the best outcomes overall with a functional rate of 87.5% at study end, which was a mean of 100 months. In the rheumatoid arthritis group, 72% of the replacements were still functional at the time of censoring (mean, 89 months), while this was true for 55% of the “other” group (mean, 84 months). Although survivorship has been seldom reported, for the unlinked Souter-Strathclyde prosthesis, authors have reported average 5-year survivals to be 96%, 10-year 89%, 10-year 76%, and 15-year to be 83%. For rheumatoid arthritis patients, the unlinked Kudo 5 has shown its estimated 12-year survival to be 74%. For the semi-constrained Coonrad-Morrey, Prasad and Dent reported 100% surviving at 60 months; Throckmorton et al, using end points of revision or resection, have reported the 5-year survival rate to be 92%, 10-year survival 78%, and 15-year survival to be 70%. The results of the present series are considered satisfactory considering the length of follow-up. Consistent with previous observations, total elbow arthroplasty appears not as durable for the treatment of posttraumatic arthritis as it is for the treatment of the hemophilic or rheumatoid elbow.

Complications

A complication rate of 35% in this study, which included removals, replacements, and revisions, compares favorably with literature values, which vary from 14% to 80%. One factor influencing this number in all studies is the condition of the patients at the time of surgery. In this series, in many instances, surgery was seen as a final opportunity to alleviate pain and/or to improve elbow function.

The infection rate of approximately 16% is higher than post-1989 reports, which has reached a low of approximately 4%. Two factors may account for this. First, many patients had pre-existing conditions and prior surgery that added to the occurrence of complications. Cheung et al reported that a third of total elbow arthroplasties that became infected had previous elbow surgery. Second, one simple procedural change was found to be of importance in reducing infections in the current series. In the early part of this clinical trial, standard, multi-use, clean, but non-sterile tourniquets were being applied to the arm and could have been a source of infection, especially in the rheumatoid arthritis patients. After changing to sterile, disposable, single-use tourniquets, no infections occurred. The group that had nonsterile tourniquets accounted for 14% of the 16% of infections.

The rate of loosening in this study was 12%. As a comparison, in Little’s review, the loosening across all prosthetic types was reported to be about 9%, with sloppy hinge devices showing the lowest rates and fixed hinges the highest, and values appearing to be the highest for rheumatoid arthritis patients. However, others have reported that 14% of the Kudo type 5 unlinked prostheses required revision at 6 years because

<table>
<thead>
<tr>
<th>Preoperative</th>
<th>Hemophilia (N=8)</th>
<th>Rheumatoid Arthritis (N=32)</th>
<th>Other (N=11)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elbow ROM flexion</td>
<td>96 (62, 131)</td>
<td>98 (87, 109)</td>
<td>117 (105, 128)</td>
<td>.23</td>
</tr>
<tr>
<td>Elbow ROM extension</td>
<td>48 (19, 78)</td>
<td>42 (31, 52)</td>
<td>41 (20, 62)</td>
<td>.84</td>
</tr>
<tr>
<td>Elbow ROM total</td>
<td>48 (4, 92)</td>
<td>57 (44, 69)</td>
<td>76 (51, 100)</td>
<td>.26</td>
</tr>
<tr>
<td>Forearm pronation</td>
<td>46 (15, 77)</td>
<td>41 (30, 53)</td>
<td>62 (39, 84)</td>
<td>.23</td>
</tr>
<tr>
<td>Forearm supination</td>
<td>60 (26, 94)</td>
<td>40 (27, 54)</td>
<td>68 (47, 89)</td>
<td>.08</td>
</tr>
<tr>
<td>Forearm ROM total</td>
<td>106 (45, 167)</td>
<td>87 (64, 111)</td>
<td>129 (98, 159)</td>
<td>.18</td>
</tr>
<tr>
<td>Functional total</td>
<td>21 (14, 28)</td>
<td>15 (11, 19)</td>
<td>13 (4, 21)</td>
<td>.28</td>
</tr>
<tr>
<td>Postoperative</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elbow ROM flexion</td>
<td>129 (108, 151)</td>
<td>129 (121, 137)</td>
<td>135 (125, 144)</td>
<td>.77</td>
</tr>
<tr>
<td>Elbow ROM extension</td>
<td>23 (0, 45)</td>
<td>33 (26, 40)</td>
<td>40 (27, 53)</td>
<td>.19</td>
</tr>
<tr>
<td>Elbow ROM total</td>
<td>107 (67, 147)</td>
<td>96 (85, 107)</td>
<td>92 (77, 107)</td>
<td>.62</td>
</tr>
<tr>
<td>Forearm pronation</td>
<td>60 (28, 92)</td>
<td>71 (63, 79)</td>
<td>55 (32, 77)</td>
<td>.18</td>
</tr>
<tr>
<td>Forearm supination</td>
<td>63 (30, 97)</td>
<td>68 (60, 77)</td>
<td>63 (42, 83)</td>
<td>.77</td>
</tr>
<tr>
<td>Forearm ROM total</td>
<td>123 (69, 178)</td>
<td>138 (125, 152)</td>
<td>117 (81, 153)</td>
<td>.34</td>
</tr>
<tr>
<td>Functional total</td>
<td>40 (37, 44)</td>
<td>32 (29, 36)</td>
<td>34 (20, 47)</td>
<td>.14</td>
</tr>
</tbody>
</table>

Abbreviation: ROM, range of motion.

| a,b | All joint angles and range of motion in degrees, with full extension equal to 0. |
| c | Confidence Intervals indicate whether the between-group differences are significant. If the confidence intervals of 2 groups overlap, the differences between them are not statistically significant. |
| d | P value is based on the one-way ANOVA for between-group differences. |
| f | Function total is based on 11 items (eating, telephone use, turning knobs, etc); each item is scored from 4 (no difficulty) to 0 (impossible); scores range from 0 to 44. |
of loosening of the ulnar component, and another reported a revision rate of 29% at 10 years for Kudo Type III prostheses. The results of the current study are therefore considered satisfactory.

The complications of prolonged nerve injury (4%) and temporary ulnar neuritis (6%), all of which cleared, compare favorably with those of Rispoli et al., who reported ulnar neuropathy in 5% to 10% of total elbow replacements.

**Pain and Function**

Pain showed marked improvement after surgery. Because pain was a primary reason for seeking the surgery, the improvement was gratifying, though not unexpected. In the few studies that report pain separately, good results have generally been found.

The hemophilia and rheumatoid arthritis groups, with flexion/extension range of motion gains of 59° and 40°, exceeded greatly the average improvement of only 20° reported in 46 studies of unlinked prostheses. Other studies do not report forearm gains, which were high for the rheumatoid arthritis group (49°).

**Differences Between Diagnostic Groups**

Because numbers of patients in 2 groups were small and variances large, limited interpretations can be made. Preoperatively, the rheumatoid arthritis group was older, though years affected at surgery and follow-up times were not substantially different. Also, 70% of the “other” group had received prior elbow surgery, whereas only 33% of the rheumatoid arthritis group had, and the hemophilic group had none. With respect to elbow range gains, the “other” group was the only one not making significant range of motion total gains, though the average gain was 17°. Examining for preoperative differences that might explain this finding, there was a trend for this group to have more flexion (average 21° and 19°) and a greater total range (27° and 19°) at baseline than the hemophilia and rheumatoid arthritis groups respectively. Their modest gains resulted in similar average flexion ranges as the other 2 groups but substantially less extension than the other 2 groups (17° and 7°), although the values did not reach significance. The function gains were as large as those of the other groups and placed them, on average, in the “performance with little difficulty” category. Because half of this “other” group had posttraumatic arthritis, these are encouraging results.

The positive results of the rheumatoid group suggest more optimistic outcomes and less guarded approaches than previously advised.

Despite small variations in outcomes, the minor differences between groups do not suggest any group preference for implantation of the S-Q prosthesis.

**Importance of Design and Surgical Method**

We believe the postoperative joint stability and increases in joint range and function, combined with satisfactory survival and complication rates, are due to the unique design of the S-Q prosthesis, which was directed to restoring normal elbow kinematics, and to surgical procedures directed to achieving normal joint kinematics and early postoperative movement.

The human elbow joint is inherently stable in its natural state, and the S-Q prosthesis was designed to reproduce normal geometry. This included replication of the trochlear flanges on the humeral surface of the S-Q prosthesis, which ensures that joint forces can be applied with no unnatural stresses. Using simulated loads and a full range of motion, Inagaki et al. concluded that the unconstrained S-Q elbow replacement simulated the geometry of the normal articular surface and demonstrated normal motion patterns under conditions of medium and high muscle loading. They showed that the radial head component enhanced the dynamic contribution to stability of muscle loading, particularly in extension. Any relative laxity, as exists in the normal elbow, was reduced with increased muscle loading. Similarly, in his 2002 series, Inagaki et al showed the inherent stability of the S-Q implants when precisely placed because of their reproduction of the normal surface geometry.
The design and surgical method insures that the components be placed exactly on the natural axis of motion, which is important for recovery of normal joint function and avoidance of abnormal stresses. Having located the position of the axis of flexion and extension by the slicing technique, metal templates used in surgery ensured that the humeral component of the S-Q implant was correctly located. Because loads during simple activities of daily living can be very large, the triceps tendon was carefully preserved and firmly replaced on its original position on the olecranon. Failure to do so can lead to weak fixation of the tendon or complete loss of attachment. Furthermore, because the triceps tendon was secured to its original location with such firm reattachment, the patients were able to begin extending the elbow on postoperative day 1, which may have facilitated early gains in range of motion.

The S-Q surface arthroplasty has demonstrated long-term effectiveness in patients with a variety of elbow joint pathologies showing good stability, reduction in pain, large gains in joint range and function, and good long-term survival.

REFERENCES

15. SPSS (for Windows) [computer program]. Version 18.0. Chicago, IL; 2009.