Survivorship and radiological analysis of the standard Souter-Strathclyde total elbow arthroplasty
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We undertook a radiological analysis of 186 standard Souter implants to determine survivorship and to analyse the pattern of failure in those needing revision. The implants had been inserted as a primary procedure in patients with rheumatoid arthritis of the elbow at our hospital over the last 12 years.

Taking revision as an endpoint, the survivorship after 12 years was 87%. If, however, revision and loosening, defined as the Hindex value equivalent to demarcation of 1 mm around the whole implant, are also included, the survivorship falls to 80%. Of the 24 implants revised, 18 (75%) were for problems with the humeral component, three (12.5%) with the ulnar component and three (12.5%) for instability.

Loosening of the humeral component occurred when the implant extended into the humerus, with the tip moving anteriorly on to the anterior humeral cortex. Our study indicates that loosening can be predicted by the rate of change in this angle of extension of the prosthesis.

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The development of total arthroplasty of the elbow has lagged behind that of many other joints, but the experience and results from a number of centres are becoming available. Most refer to the Capitellocondylar, Coonrad Morrey or the GSBIII prostheses.

We have used the implant designed by Souter and Nicol (Howmedica International, London, UK). Apart from several small series with short follow-up, little is known of the long-term outcome. Souter\(^1\) reported 250 cases over a ten-year period with satisfactory functional results, although a number of complications were noted, particularly ulnar neuritis (15%). Fracture and instability were seen in 5.5% and radiological loosening in 12%.

We have inserted 186 standard Souter implants as a primary procedure in patients with rheumatoid arthritis (RA) of the elbow. We now present survivorship figures and analyse the pattern of failure of those loosening or undergoing revision.

Patients and Methods

The details of the 186 patients are given in Table I. There were 42 men and 144 women with a male-to-female ratio of about 1:3. The mean age of the men was 66 ± 5.83 years and of the women 57.2 ± 11.83 years. Some had incomplete sets of radiographs resulting in a total of 432 films available for analysis. Almost all the operations were undertaken for RA (96%).

Standard anteroposterior (AP) and lateral radiographs of the elbow were taken before and immediately after operation, after one year and at the latest follow-up appointment. Separate AP films were taken of the distal humerus and proximal ulna. The Wrightington method of numbering and measuring migration and demarcation on the radiographs was used (Fig. 1). This involves making measurements perpendicular to fixed reference points in order to minimise subjective errors. A total of 12 measurements is made on each radiograph. As shown in Figure 1, in the AP view of the humerus, the varus/valgus angle is measured along with Hap2 to Hap4, which represent measurements of the humeral component in relation to the distal end of the humerus. In the lateral view of the humerus, the extension/flexion angle is measured together with Hlat1 to Hlat4. The varus/valgus angle is also measured from the AP view of the ulna together with the extension/flexion angle in the

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<th>Male</th>
<th>Female</th>
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<td>Left</td>
<td>21</td>
<td>63</td>
</tr>
<tr>
<td>Right</td>
<td>21</td>
<td>81</td>
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<tr>
<td>Revision</td>
<td>6</td>
<td>18</td>
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<td>Mean (±SD) age in years</td>
<td>66.02 ± 5.83</td>
<td>57.21 ± 11.83</td>
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lateral view. A total of 21 measurements was taken from the four films. These were designated Hapd1 to Hapd5, Hlatd1 to Hlatd5, Uapd1 to Uapd6 and Ulatd1 to Ulatd5.

A database was constructed using information from the case notes together with the measurements obtained. Each radiograph was considered as one case in the database.

The date of the latest postoperative radiograph determined withdrawal from the analysis. For survivorship analysis, the endpoints were taken as revision or loosening as defined by radiological demarcation of 1 mm on all sides around the implant. It was then calculated using the method of Dobbs. Confidence limits were based on the ‘effective number at risk’ and determined using Rothman’s method.

Statistical analysis

Data reduction using principal component analysis (PCA). The database was converted into the SPSS (SPSS Inc, Chicago, Illinois) format and a PCA was carried out on the 12 variables measuring migration. A second PCA was carried out on the 21 measurements defining demarcation. A characteristic of PCA is the capability of examining information by a multivariate technique in order to see whether there is some underlying pattern of relationships which allow it to be reduced to a smaller set of components to account for the observed interrelations. The respective principal components were then used to produce scores which were used in subsequent analyses.
Linear multiple regression of principal component coordinates. The principal components of the demarcation data were then regressed with the 12 migration measurements to produce a prediction equation for humeral loosening.

Results

The first principal component constructed from the migration measurements is dominated by Hlat_deg, the humeral extension/flexion angle. The valgus/varus angle of the humeral component is included and is negatively associated with Hlat_deg. The first component seems to represent migration of the humeral prosthesis in two planes, lateral extension and varus rotation.

The first principal component calculated from the data derived from PCA included all variables of demarcation in the humerus and could be considered as a humeral loosening component. The second principal component included all variables of demarcation in the ulna and represented ulnar loosening.

The component scores of the humeral loosening component could represent a humeral loosening index (Hindex), and those pertaining to the ulna an ulnar loosening index (Uindex). The Hindex and Uindex scores were each regressed against the migration variables using a step-up multiple regression method.

Regression analysis on the Uindex was not significant (p > 0.05) while that on the Hindex produced a prediction equation as follows:

$$\text{Hindex} = \text{Hlat}_\text{deg} \times 0.08 - 0.62 \ (\text{Rsq} \% 53)$$

where Rsq is the square of the product moment correlation.

This was highly significant (f = 483.9; d.f.1, 430, p < 0.0001), which indicated that a linear function of the angle of extension of the humerus accounted for 53% of the total variation in humeral loosening. The scatterplot of this prediction equation is shown in Figure 2.

Step-up multiple linear regression was applied to the measurements made in those patients who eventually required revision. A prediction equation was derived thus:

$$\text{Hindex} = \text{Hlat}_\text{deg} \times 0.1 - 0.84 \ (\text{Rsq} \% 70)$$

This was also highly significant (f = 155.4; d.f.1, 66; p < 0.0001) and contained a linear function of the angle of extension of the humerus which accounted for 70% of the total variation in the data.

Thus, the analysis could be reduced from 10 variables \times 21 variables to that of 1 component score \times 1 variable. The regression equations show a significant linear association between migration of the humeral prosthesis and loosening which becomes even more pronounced when only those patients who eventually required revision surgery, were considered.

The Souter database was used to produce a life table of the 186 operations measured with revision as the endpoint. The 24 primary revisions were all performed for aseptic loosening. The cumulative failure over 12 years was slightly under 13%. A cumulative survival curve was also constructed. If revision is taken as the endpoint there is an 87% survival after 12 years (Fig. 3) and 95% confidence limits spread over time. If revision and loosening, that is with a Hindex > 1 (equivalent to demarcation of 1 mm surrounding the whole implant), are taken as failure, survival falls to 80% over 12 years (Fig. 4).

The reasons for failure included loosening of the humeral component in 18 (75%), loosening of the ulna in three (12.5%) and instability in three (12.5%).

Discussion

A number of authors have reported their experience of elbow arthroplasty. Good results for the Capitellocondylar design were reported by Ewald et al\textsuperscript{5} who described a long-
term follow-up of 202 implants. Significant functional improvement was seen with revision of the prosthesis in only six cases. There were, however, a number of other long-term complications. There was radiological evidence of loosening in eight humeral and 19 ulnar components, but most of these demarcation lines were incomplete and less than 1 mm wide.

Results for the Coonrad Morrey prosthesis, which is a linked implant, albeit with a sloppy hinge, were first reported in 1981 by Morrey et al.\(^6\) In their series, 80 implants were followed up for a mean of four years. Again, there was a satisfactory functional outcome with regard to pain and range of movement. There was, however, an incidence of postoperative complications of 55%, with 19 (24%) of the initial implants being revised principally for loosening, but some for infection.

In 1992, results using an improved design from the same Institution in a group of patients suffering from RA showed pain relief in 91% and a satisfactory range of movement.\(^7\) Nevertheless, a complication rate of 22% was reported although there was little evidence of radiological loosening. Overall, it was noted that 91% had a good or excellent result.

Gschwend, Simmen and Matejovsky\(^8\) reported their experience with the GSBIII design, which is again a linked prosthesis with a sloppy hinge. They found an overall complication rate of 15.2% and a revision rate of 12.5%. In cases of RA, however, these figures were reduced to a complication rate of 11% and a revision rate of 8.4%. Consequently, these authors expressed the opinion that the results of elbow arthroplasty were approaching those of the hip and knee.

From our analysis of the Souter prosthesis, we believe that the survivorship rates over 12 years are comparable to any of the above series. We feel that this implant can be used confidently in patients with RA. We have identified the mode of failure, specifically as a tilting of the humeral component (Fig. 5). This occurs in 75% of cases of aseptic loosening. The reason for this remains unclear at present. We can, however, speculate that the forces transmitted through the humeral component during flexion/extension...
lead to this tilting action. For this reason a number of surgeons, including ourselves, now use a longer-stemmed humeral component.

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References