Monoblock and modular total shoulder arthroplasty for osteoarthritis


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There are theoretical and practical advantages to modular rather than monoblock designs of prostheses for shoulder arthroplasty, but there are no reported studies which specifically compare the clinical and radiological results of their use. We have compared the results of unconstrained total shoulder arthroplasty for osteoarthritis using both types of implant. The monoblock design was used between 1992 and 1995 and the modular design after 1995. Both had cemented all-polyethylene glenoids, the monoblock with matched and the modular with mismatched radii of curvature. There were 34 consecutive shoulders in each group with a mean follow-up of 6.1 years in the first and 5.2 years in the second.

There were no significant differences in improvement of pain scores, active elevation, external rotation, internal rotation, patient satisfaction, or the Neer ratings between the two groups. Two of 28 glenoid components in the first group and six of 30 in the second met the criteria for being radiologically at risk for loosening (p = 0.25). There were no significant differences in clinical outcome or radiological changes between the first- and second-generation designs of implant for shoulder arthroplasty.

Since Neer, Watson and Stanton, originally reported on total shoulder arthroplasty, the evolution of the design of prostheses for the shoulder has progressed. First-generation designs were based on the original prosthesis of Neer et al., and features of these initial unconstrained total shoulder arthroplasties included a monoblock humeral component and a keeled polyethylene glenoid prosthesis with a radius of curvature matched with the humeral head. These designs proved to be effective in improving pain, function and movement in patients with glenohumeral arthritis. Second-generation designs featured modularity between the head and the stem of the implant. This allowed greater flexibility, creating a more anatomical implant for each particular patient, with a better fit into the soft-tissue envelope of the shoulder. An additional characteristic of second-generation designs was a mismatch between the radii of curvature of the humeral head and the glenoid component. In theory, this minimised the ‘rocking’ moments which are applied to the glenoid and, hopefully, lessened the occurrence of radiolucent lines at the glenoid component which had been of concern. The clinical results for these modular second-generation components were also good, with relief from pain and function but continued appearance of radiolucencies around the glenoid.

While the clinical and radiological results have been reported for both first- and second-generation prostheses, no study has directly compared their function. Our aim was to compare the clinical and radiological findings between two similar groups of patients undergoing unconstrained total shoulder arthroplasty with either a first- or second-generation design, performed by a single surgeon for a single diagnosis, namely, osteoarthritis.

Patients and Materials

Between 1992 and mid-1995, the senior author (RC) used a monoblock humeral prosthesis with two sizes of head, four sizes of stem and tissue ingrowth on the undersurface of the humeral head for total shoulder or hemiarthroplasty. For total shoulder arthroplasty, it was combined with a cemented, all-polyethylene, keeled glenoid component in two sizes. The radius of curvature matched that of the humeral head (Cofield 1; Smith & Nephew, Memphis, Tennessee) (Fig. 1a). Beginning in late 1995, a second-generation system was used. The surface curvature of the humeral component was the same. In this modular system, there were nine sizes of head and seven sizes of stem with a tissue ingrowth surface limited to the metaphyseal region of the implant. The glenoid component was a...
cemented, all-polyethylene, keeled design in three sizes. The radius of curvature was 2 mm greater than that of the humeral head (Cofield 2; Smith & Nephew) (Fig. 1b). The patients were identified through a local total joint registry. All agreed to participate in the study which had the approval of the Institutional Review Board. Thirty-four consecutive monoblock replacements were reviewed in patients with osteoarthritis (Cofield 1, group 1). A group for comparison was formed by selecting the first consecutive 34 patients with osteoarthritis who had undergone replacement using a modular type of arthroplasty (Cofield 2, group 2). In total there were 68 shoulders in 63 patients. Group 1 included 19 shoulders of men and 15 of women with a mean age of 67.5 years (55 to 78). The mean clinical follow-up was for 6.1 years (2.2 to 10.2). Group 2 was comprised of 24 shoulders of men and ten of women with a mean age of 68.9 years (54 to 86). The mean clinical follow-up was for 5.2 years (2.1 to 6.3).

All procedures were carried out by a single surgeon with experience of performing total shoulder arthroplasty for 15 years before the start of the period of study. The technique of the operation has been previously described, and the post-operative rehabilitation was identical. Instruments were available for both groups for precise cutting of the bone of both the humerus and the glenoid. A firm fit was obtained for the tissue-ingrowth humeral components in both metaphyseal bone and within the shaft of the humerus. Similarly, the use of a cutting guide, reamer, and drills allowed the exact preparation of the subchondral plate and neck of the glenoid before pulsatile lavage to clean the cancellous bone of the neck of the glenoid, thorough drying of the glenoid with sponges and the introduction of cement prepared by vacuum mixing to minimise the porosity of the methylmethacrylate. The glenoid component was positioned with an impacting and holding instrument. After its definitive placement and trials of the humeral component in order to assess the range of movement and stability, the definitive humeral component was then introduced. For the modular system, once the optimal size of the humeral head had been determined, it was impacted on to the stem before being placed in the humerus. In addition to repair of subscapularis and the anterior capsule of the shoulder, damage to the rotator cuff which necessitated repair was present in six shoulders in group 1 and two in group 2.

The clinical assessment of all patients was recorded using a standard analysis sheet with data gathered prospectively for the pre- and post-operative periods. Pain was graded on a five-point scale. The range of movement (ROM) in active elevation and external rotation was recorded in degrees with internal rotation measured on the ability of the thumb to reach a posterior vertebral segment. Patient satisfaction was categorised as much better, better, the same, or worse. A modified Neer rating system was used. The result was considered to be excellent if the patient had no or only slight pain, was much better or better, had active elevation of at least 140° and external rotation of at least 45°. It was satisfactory if the patient had no or slight pain or moderate pain only with vigorous activities, was much better or better, had active elevation of at least 90° and external rotation of at least 20°. If these criteria were not met or if the patient underwent a revision operation, the result was considered to be unsatisfactory.

The radiographs reviewed included those taken in the early post-operative period of one to two months and at a minimum of two years after surgery. The radiological projections included 40° posterior oblique views in internal and external rotation and an axillary view. Immediate post-operative radiographs were available for 30 patients in group 1 and 29 in group 2. Radiological follow-up at two years or more was available for 27 patients in group 1 (mean 4.2 years) and 29 in group 2 (mean 4.2 years). Additionally, fluoroscopically-positioned spot views of the glenoid in the early post-operative period were assessed for 22 shoulders in group 1 and 21 in group 2. There were similar views taken at follow-up for 12 shoulders in group 1 and 14 in group 2. Radiological analysis of the component was performed as previously published. The glenoid components were divided into six zones (Fig. 2) and the humeral components into eight zones for evaluation of periprosthetic lucency (Fig. 3). Three independent observers, who were orthopaedic surgeons specialising in shoulder surgery, evaluated the radiographs for periprosthetic lucency and reached a consensus. They also looked for change in the position of the component between the early post-operative and follow-up radiographs. A glenoid component was considered to be ‘at risk’ for loosening if at least two of three independent observers identified medial migration or tilt, or if a complete lucent line was present with
some part of it being 1.5 mm or more in width. Similarly, a humeral component was defined to be ‘at risk’ if at least two of three observers identified tilt or subsidence, or if a lucent line of 2 mm or more in width was present in three or more zones.

**Statistical analysis.** Statistical analysis included both within-group and between-group comparisons. Within-group tests evaluated paired pre-operative and post-operative clinical measurements for both groups. The paired $t$-test was used when the distribution of the paired differences was approximately normal. For paired differences with significantly non-normal distributions, the Wilcoxon signed-rank test was used for paired comparisons. Between-group tests compared group-1 with group-2 shoulders on clinical and radiological observations and the pre-operative with the post-operative clinical changes between the groups. For between-group comparisons of nominal variables, the chi-squared test was used, except in situations when one or more expected counts was less than five, in which case, Fisher’s exact test was employed. The Wilcoxon rank-sum test was used for ordinal variables. The two sample $t$-test (for normally distributed data) and the Wilcoxon rank-sum test (for non-normal distributions) were used for continuous variables. In assessing the radiographs, the length of follow-up was assessed by a Cox proportional hazards regression adjusted for correlated data to compare group 1 with group 2.

Kaplan-Meier survival curves were plotted separately for group-1 and group-2 shoulders for the end-points of the glenoid ‘at risk’ of loosening and of the humerus similarly. In addition, the proportion of patients ‘at risk’ of loosening was compared between the two groups using a chi-squared or Fisher’s exact test. Associations between demographic or clinical variables in outcomes were assessed using tests for continuous, categorical, and time-to-event variables as described above. A p value of $\leq 0.05$ was considered to be significant for all analyses. The analysis was performed using SAS version 8.02 (SAS Institute Inc, Cary, North Carolina).

**Results**

**Complications.** There were five complications in group 1 but no patients underwent further surgery. Two patients had intra-operative fractures of the shaft of the humerus which were managed by the introduction of a long-stemmed component, cerclage wiring, and alterations in post-operative rehabilitation. Both fractures healed. One patient developed a brachial plexus neuropathy with recovery except for residual hypoaesthesia on the radial border of the hand. One patient had a pre-operative tear of the rotator cuff which did not heal well. Post-operative superior subluxation developed with compromised movement, leading to an unsatisfactory result. One patient with Parkinsonism disrupted the anterior shoulder arthroplasty and developed a fixed anterior dislocation.

There were also five complications in group 2, two of which required further surgery. Four patients developed post-operative instability. One had a posterior dislocation and remained unstable after two attempts at revision arthroplasty. Another disrupted the anterior repair and developed anterior instability. Revision surgery was unsuccessful in obtaining stability. Two other patients had lesser degrees of anterior instability but further surgery was not necessary. One patient had an injury after surgery which resulted in tearing of the superior aspect of the rotator cuff.
giving weakness and reduced active elevation, but the outcome remained satisfactory.

**Clinical outcome.** The mean pain scores decreased from 4.6 pre-operatively to 1.9 post-operatively in group 1 (p < 0.0001) and from 4.5 to 1.8 in group 2 (p < 0.0001). The mean active elevation increased from 92˚ to 144˚ in group 1 (p < 0.0001) and from 97˚ to 147˚ in group 2 (p < 0.0001). The mean external rotation increased from 21˚ to 56˚ in group 1 (p < 0.0001) and from 28˚ to 68˚ in group 2 (p < 0.0001). The median internal rotation increased from L1 to L3 in both groups (p < 0.0001). Patient satisfaction was rated as much better in 27, better in three, the same in two, and worse in two in group 1 and much better in 21, better in nine, the same in three, and worse in one in group 2. Using the Neer rating system, there were 12 excellent, 18 satisfactory, and four unsatisfactory results in group 1 and 18 excellent, 12 satisfactory, and four unsatisfactory results in group 2. The reasons for the unsatisfactory results in group 1 included inadequate relief from pain and poor movement in two patients, poor movement in one, and inadequate relief from pain in one patient. The reasons for the unsatisfactory results in group 2 included inadequate relief from pain and poor movement in one patient, poor movement and dissatisfaction in one, pain in one and dissatisfaction in one patient.

In comparing groups 1 and 2, there were no statistically significant differences between them with regard to their age (p = 0.40), gender (p = 0.21), and pre-operative clinical values (Table I). Post-operatively, there was no significant difference in regard to outcome measures (Table I). Post-operative external rotation was greater in group 2 than in group 1 (p < 0.01). However, when comparing the change from before to after surgery between the two groups, there was no significant difference with respect to improvement in external rotation (p = 0.23). There was no significant difference in improvement of pain, active elevation or internal rotation comparing groups 1 and 2.

**Radiological findings.** In group 1, 30 early post-operative radiographs were available. Two patients had a lucent line in one of the four zones surrounding the keel of the glenoid component and one in one zone around the humeral component. One patient who had also had a repair of the rotator cuff had moderate superior subluxation. In group 2, early post-operative radiographs were available for 30 patients. Two had a lucent line involving some part of the keel segment of the glenoid component. In one of these, the line was complete. No humeral components had a lucent line. Two patients had moderate superior subluxation.

In group 1, 27 patients had follow-up radiographs. Eleven shoulders had radiolucent lines involving the interface between the cement of the keel and the bone, one zone in seven, two zones in three, and three zones in one. One glenoid component was judged to have migrated medially and a second to have tilted upwards. Two humeral components had lucent lines, one in three zones and one in seven zones. The humeral component with lucent lines in seven zones had subsided.

In group 2, 29 shoulders had adequate radiological follow-up. Lucent lines were present in ten glenoid components involving some portion of the interval between the cement of the keel and the bone. These lines were present in one zone in five, two zones in three and three zones in two. Six glenoids had changed position. Three had tilted, two had migrated medially, and one had tilted and migrated medially. Three patients had incomplete humeral lucent lines limited to one or two zones. One patient had a complete line of 2 mm with subsidence and varus tilting of the humeral component. Five shoulders had moderate humeral subluxation. This was superior in four with some component of anterior subluxation in two, and was posterior in one.

When comparing groups 1 and 2, two glenoids in group 1 were judged to be radiologically ‘at risk’ for loosening while this was true for six glenoids in group 2. One humeral component in each group was judged to be radiologically ‘at risk’ for loosening. The difference between groups 1 and 2 for the glenoid was not statistically significant (p = 0.25) using Fisher’s exact test. However, when using the Cox model to account for differing lengths of follow-up, the difference approached statistical significance (p = 0.053). None of the patient characteristics of age, gender, or tearing of the rotator cuff was significantly associated with the glenoid being ‘at risk’. There was no association between having an ‘at-risk’ component and pain, ROM, patient satisfaction, or result rating. Radiological evidence of subluxation was not associated with the development of an ‘at-risk’ component.
risk’ glenoid. Those patients with an incomplete or early radiolucent line in the glenoid were not at increased risk for developing an ‘at-risk’ glenoid (p = 0.58). However, one patient in each group had a poor clinical outcome associated with radiological loosening of the glenoid, but neither was symptomatic enough to require revision.

Discussion
Our study has shown significant improvements in all clinical parameters in all patients in both groups. With regard to the radiological findings, there was a trend towards an increased number of ‘at-risk’ glenoid components in group 2. There was excellent radiological stability of the tissue-ingrowth humeral components with the ingrowth material either on the undersurface of the humeral head or in the metaphyseal region of the implant.

Modularity, with the ability to adjust the size of the humeral head, theoretically offers a number of advantages. If the component is too small, the moment arms of the deltoid and rotator cuff are decreased and this may lead to weakness and even instability. Conversely, a humeral head which is too large may ‘overstuff’ the glenohumeral joint and lead to poor movement and possible failure of the repair of subscapularis. By having a number of alternatives in the size of the humeral head, joint kinematics may be improved. The offset and height of the humeral component were not components of our study. The effect of these on shoulder function may be important for long-term comparisons.

An argument has been made for improvement in kinematics if there is a slight mismatch between the radius of curvature of the glenoid and the humeral head. However, this decreases the area of joint contact, leading to increased stresses at the point of articulation and a possible increase in polyethylene wear.

The main advantage of modularity of the humeral component is the ease of insertion. A large variety in size of the humeral stem, it is possible to obtain a tight fit in the diaphysis without additional reaming which avoids the few intra-operative fractures of the shaft which occur. Modularity should also allow for greater ease of adjustment of the tension of the capsule and rotator cuff, and improve both stability and ROM. However, our study has shown that when the total shoulder arthroplasty is performed by an experienced shoulder surgeon, no differences in outcome between the two designs can be identified. Radiological analysis shows no statistically significant differences, but there was a trend towards better radiological characteristics for the first-generation component. Longer follow-up is needed to define whether the changes observed will become statistically and clinically significant.

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References