Our aim in this prospective study was to evaluate the outcome of total shoulder replacement in the treatment of young and middle-aged active patients with primary glenohumeral osteoarthritis. We reviewed 21 patients (21 shoulders) with a mean age of 55 years (37 to 60). The mean follow-up was seven years (5 to 9). The same anatomical, third-generation, cemented implant had been used in all patients. All the patients were evaluated radiologically and clinically using the Constant and Murley score.

No patients required revision. In one a tear of the supraspinatus tendon occurred. Overall, 20 patients (95%) were either very satisfied (n = 18) or satisfied (n = 2) with the outcome. Significant differences (p < 0.0001) were found for all categories of the Constant and Murley score pre- and post-operatively. The mean Constant and Murley score increased from 24.1 points (10 to 45) to 64.5 points (39 to 93), and the relative score from 30.4% (11% to 50%) to 83% (54% to 116%). No clinical or radiological signs of loosening of the implant were seen.

For young and middle-aged patients with osteoarthritis, third-generation total shoulder replacement is a viable method of treatment with a low rate of complications and excellent results in the mid-term.

There are many options available for the treatment of glenohumeral osteoarthritis, including arthroscopy, hemiarthroplasty and total shoulder replacement (TSR). The latter seems to give better results than replacement of the humeral head only, in terms of relief from pain and improvement of function. However, long-term complications such as aseptic loosening, instability and tears of the rotator cuff have been reported after this procedure. Therefore strict indications have been recommended and many surgeons are reluctant to perform TSR in young or middle-aged patients.

Compared with hip and knee replacement, which are not infrequently performed in young patients, TSR has a lower rate of complications and total cost. However, there are only a few reports which describe the outcome of shoulder replacement in young or middle-aged patients. In these studies, varying diagnoses such as rheumatoid arthritis, post-traumatic osteoarthritis, and avascular necrosis, and methods of treatment such as hemiarthroplasty, and TSR have been reported. High levels of activity and an increased life expectancy put these patients at increased risk for mid- and long-term complications. Our aim therefore was to evaluate the outcome and complications in a group of young and middle-aged, active patients treated by a third-generation cemented TSR for primary glenohumeral osteoarthritis.

Patients and Methods

Between March 1998 and October 2002, we performed 198 shoulder replacements which included hemiarthroplasty, humeral resurfacing arthroplasty and TSR on 52 patients aged 60 years or less. Of these, 24 consecutive patients (24 shoulders) with primary glenohumeral osteoarthritis had TSR and formed the basis of our prospective study. Exclusion criteria were age more than 60 years, the presence of tears of the rotator-cuff pre-operatively, a history of previous surgery on the involved shoulders, and sensory and/or motor deficits of the involved limb, including palsy of the axillary nerve or brachial plexus.

During follow-up two patients died due to unrelated causes. Another was lost to follow-up, leaving 21 (12 men, nine women) (21 shoulders) available for review. In 13 patients, TSR had been performed on the dominant shoulder. The mean age of the patients at the time of operation was 55 years (37 to 60). Most of the operations (20) had been performed by the senior author (ML), while one had been carried out by another consultant orthopaedic surgeon (MR).
All the patients had been evaluated pre-operatively by the functional score of Constant and Murley,\textsuperscript{26,27} adjusted for age and gender. Additionally, active range of movement, including shoulder flexion, abduction and rotation was recorded. Flexion, abduction and external rotation were recorded in degrees, whereas internal rotation was graded according to the spinal level which each patient could reach with his or her thumb. Pain, activity, mobility and strength were graded using the Constant and Murley score (pain, 0 (severe) to 15 points (no pain); activity, 0 (no activity) to 20 points (full activity); mobility, 0 (no mobility) to 40 points (full mobility); strength, 0 (0 kiloponds) to 25 points (12.5 kiloponds)).

Radiographs of the shoulders were taken in standardised true anteroposterior (AP) and axillary views (Fig. 1). For an AP view the x-ray tube was angled by 40° so that the anterior and posterior rims of the glenoid fully overlapped. For the axillary view, the patient sat and leaned with the arm raised over the end of the x-ray table. The x-ray beam was directed perpendicular to the cassette and the shoulder. All radiographs were reviewed blindly by two consultant orthopaedic surgeons (ML, MR).

Pre-operatively, the rotator cuff was assessed clinically and by ultrasound. In all patients, the bone stock of the humeral head and the glenoid was evaluated by CT or MRI. In ten patients the morphology of the glenoid was recorded prospectively according to the classification of Walch et al.,\textsuperscript{28} and in 11 it was evaluated retrospectively using radiography, MRI or CT. Using the Walch classification, glenoid types A2, B1, B2 and C were found in three, nine, seven and two patients, respectively.

The radiolucent line score for the cemented glenoid component was calculated according to the classification of Mole et al.\textsuperscript{29} For this scoring system, six zones were used and the width of the lines graded as follows: grade 1 ($< 1$ mm), grade 2 (between 1 mm and 2 mm) and grade 3 ($> 2$ mm). A glenoid component was considered to be loose if the radiolucent line score exceeded 12 points.

Tears of the rotator cuff were not found in any patient intra-operatively. Post-operatively, all patients were evaluated using the same clinical and radiological protocol (Fig. 1) at six months, at one and two years and at the most recent follow-up examination. The mean follow-up was seven years (5 to 9). The post-operative outcome was rated...
Table I. Pre- and post-operative clinical details (mean, SD; range)*

<table>
<thead>
<tr>
<th></th>
<th>Pre-operative</th>
<th>Post-operative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant and Murley score</td>
<td>24.1 (9.3; 10 to 45)</td>
<td>64.5 (16.3; 39 to 93)</td>
</tr>
<tr>
<td>Range of movement (°)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexion</td>
<td>77.9 (25.4; 40 to 120)</td>
<td>128.6 (39.4; 50 to 170)</td>
</tr>
<tr>
<td>Abduction</td>
<td>60.5 (21.4; 20 to 90)</td>
<td>111.2 (41.1; 40 to 160)</td>
</tr>
<tr>
<td>External rotation</td>
<td>-2.4 (14.5; -20 to +30)</td>
<td>30.5 (23.6; 0 to 70)</td>
</tr>
<tr>
<td>Internal rotation</td>
<td>1.1 (1.7; 0 to 4)</td>
<td>5 (2.9; 4 to 10)</td>
</tr>
<tr>
<td>Pain</td>
<td>3.4 (2.1; 9 to 7)</td>
<td>12.6 (2.9; 7 to 15)</td>
</tr>
<tr>
<td>Power</td>
<td>2.8 (3.4; 0 to 11)</td>
<td>8.9 (6.5; 0 to 25)</td>
</tr>
<tr>
<td>Activity</td>
<td>7.1 (2.4; 2 to 11)</td>
<td>171 (3.1; 12 to 20)</td>
</tr>
<tr>
<td>Mobility</td>
<td>10.9 (4.9; 2 to 20)</td>
<td>26.4 (8.6; 10 to 40)</td>
</tr>
</tbody>
</table>

* All p-values were < 0.0001

subjectively by the patients as ‘very satisfied’, ‘satisfied’, ‘somewhat disappointed’, or ‘very disappointed’.

**Implants and operative technique.** In all cases, the same unconstrained, cemented, third-generation implant (Aequa-lis Primary Shoulder Prosthesis; Tornier Inc., Edina, Minnesota) was used. This comprised a modular humeral component with a matt surface finish, eccentric heads and variable inclination of the head. It was coupled to a keeled ultra-high-molecular-weight all-polyethylene glenoid com-ponent. A flat-back glenoid component was used in the first 12 patients and a convex component in the remaining nine. All the humeral and glenoid components were fixed with Palacos cement (Biotem Inc, Warsaw, Indiana). The deltopectoral approach was used. In all cases, end-stage osteo-arthritis was confirmed intra-operatively. Cementation of the humeral component was performed using third-generation cementing techniques with the use of a distal plug, retrograde filling and continuous pressurisation. The subscapularis was repaired using three to five non-absorbable tendon-to-tendon sutures. The drains were removed on the first post-operative day.

**Rehabilitation.** A shoulder abduction pillow was used for the first four weeks post-operatively to relieve tension from the subscapularis. The patients were mobilised during the first six weeks within a combined flexion and abduction arc of 60° and 0° of external rotation. Free range of movement was allowed at six weeks after operation.

**Statistical analysis.** The t-test was used for comparison of the pre- and post-operative paired data, including the range of movement and pain, power, activity and mobility, as derived from the Constant score. A p-value ≤ 0.05 was considered to be statistically significant.

**Results**

**Survival and complications.** At a minimum of five years’ follow-up, there were no revisions. In one patient, there was a transient brachial plexus palsy which resolved completely after six months.

**Clinical findings.** The mean Constant and Murley score improved from 24.1 points (10 to 45) pre-operatively to 64.5 points (39 to 93) post-operatively (p < 0.0001). When adjusted for age and gender, it improved from 30.4% (11% to 50%) pre-operatively to 83% (54% to 116%) post-operatively (p < 0.001). Significant differences were also found for relief from pain, power, activity, mobility and range of movement (p < 0.0001). The findings of the pre- and post-operative clinical evaluation are shown in Table I. Of the 21 patients 20 (95%) were either satisfied (n = 2) or very satisfied (n = 18) with the result. At the latest follow-up six patients (29%) were still in full-time employment. With regard to activity, 11 patients (52%) were able to participate in sports including tennis and handball more than twice a week.

One patient was diagnosed with a tear of the rotator cuff at seven years post-operatively and was somewhat disappointed with the end result. Her pre-operative Constant and Murley score improved from 26 points (relative score 35%) pre-operatively, to 72 (relative score 98%) at two years after operation. At seven years after surgery it decreased to 39 (relative score 54%). Nevertheless, this patient has enjoyed long-lasting relief from pain as indicated by her pain subscores of 3 points pre-operatively and 12 points at seven years after operation. At her last examination, shoulder flexion was 50°, abduction 40° and external rotation 20°.

**Radiological findings.** A radiolucent line at the cement-bone interface of the glenoid component was observed in ten patients (48%); this was complete in four and partial in six. None exceeded 1 mm in width. The mean radiolucent line score was 3.7 (2 to 6; Table II). There were no humeral or glenoid radiolucent lines on the first post-operative radiographs which were taken at three to six days after operation. The mean time to detection of a radiolucent line was 51.2 months (6 to 92). However, these were non-progressive in all patients. No radiolucent lines or other radiological signs of loosening were observed for the humeral components. In one patient, a symptomatic, non-traumatic, type 3 tear of the rotator cuff, according to Patte was diagnosed seven years after operation by ultrasound. It was accompanied by proximal migration of the humeral com-

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ponent on the AP radiograph (Fig. 2). In another patient, proximal migration was evident at two years after operation, without clinical or sonographic evidence of an associated tear of the rotator cuff.

Discussion

Hemiarthroplasty and TSR of the shoulder are well-established methods of treatment for patients with glenohumeral osteoarthritis. Good clinical results and symptomatic relief from pain have been reported.\textsuperscript{1,9,11,32,33} According to some single prospective studies, TSR seems to be better than hemiarthroplasty in terms of relief from pain and improvement of function.\textsuperscript{10,11,34} The possibility of future revisions is an important consideration in the decision-making process of the management of young and middle-aged, active patients. Both methods have potential disadvantages. Erosion of the glenoid can lead to failure of hemiarthroplasty and the need for conversion to TSR provided that there is adequate bone stock. Therefore alternative techniques, such as biological resurfacing\textsuperscript{2,35,36} or concentric reaming\textsuperscript{37} in conjunction with hemiarthroplasty have been introduced in an effort to reduce the incidence of problems arising from the glenoid. On the other hand, loosening of the glenoid component is a major concern in TSR.\textsuperscript{23,37} The high levels of activity and the increased life expectancy of young and middle-aged patients may potentiate the risk for complications, making many surgeons reluctant to choose TSR for this group of patients.\textsuperscript{17}

The results of shoulder replacement have been inconsistent for this group of patients. Sperling et al\textsuperscript{23,24} reported these results of prosthetic shoulder replacement after a minimum follow-up of five and subsequently 15 years. For TSR, unsatisfactory or unsuccessful results were reported in 50% of patients, after a minimum follow-up of five years, and in 48% after 15 years. The revision rate was 11% and 14% after a minimum follow-up of five and 15 years respectively. In the study of Burroughs et al\textsuperscript{25} on patients younger than 50 years treated by TSR or hemiarthroplasty, satisfactory results in 86% and a revision rate of 9% were reported at a mean follow-up of 5.6 years. In our study, the rate of patient satisfaction after TSR was 95%. The improvement in the range of movement was comparable with that reported by Sperling et al.\textsuperscript{23} Our patients had significant relief from pain (p < 0.0001; Table I) even in the mid term. Contrary to the aforementioned studies,\textsuperscript{23,24} we also observed a significant improvement in strength, function in daily activities and mobility (Table I). In the studies of Sperling et al\textsuperscript{23,24} and Burroughs et al,\textsuperscript{25} patients with multiple diagnoses were

\begin{table}
\centering
\begin{tabular}{|c|c|c|c|c|c|}
\hline
Case & Detection after arthroplasty (mths) & Time from detection to most recent follow-up (mths) & Zones & Progression\textsuperscript{1} & RLL score according to Mole et al\textsuperscript{22} & Component \\
\hline
1 & 6 & 60 & 1, 5 & No & 2 & Convex \\
2 & 12 & 75 & 1 to 6 & No & 6 & Flat-back \\
3 & 48 & 14 & 1 to 6 & No & 6 & Convex \\
4 & 48 & 13 & 1, 5 & No & 2 & Convex \\
5 & 54 & 39 & 1 to 6 & No & 6 & Flat-back \\
6 & 60 & 0 & 1 to 6 & N/A & 6 & Convex \\
7 & 60 & 0 & 1, 5 & N/A & 2 & Flat-back \\
8 & 60 & 37 & 1, 5 & No & 2 & Flat-back \\
9 & 72 & 20 & 1, 5 & No & 2 & Convex \\
10 & 92 & 0 & 1, 2, 5 & N/A & 3 & Flat-back \\
\hline
Mean & 51.2 & 37 & & & 3.7 & \\
\hline
\end{tabular}
\caption{Details of the glenoid components in ten patients with radiolucent lines (RLL)\textsuperscript{*}}
\end{table}

\textsuperscript{*} each radiolucent line was < 1 mm wide

\textsuperscript{1} N/A, not applicable

Fig. 2

Anteroposterior radiograph showing proximal migration of the humeral component, secondary to a tear of the supraspinatus tendon, detected at seven years post-operatively in the same patient as in Figure 1.
included and the indications for using hemiarthroplasty or TSR were not clear. Only two patients were treated by TSR for glenohumeral arthritis in the study of Sperling et al.\textsuperscript{23} and none in that of Burroughs et al.\textsuperscript{25} In these studies the function and satisfaction of the patients were evaluated by telephone interviews and written questionnaires. In our study all patients had identical diagnoses and had the same implant using a standardised operative technique and rehabilitation protocol. Furthermore, all patients were evaluated at pre-defined intervals post-operatively.

A weakness of our study was the higher mean age of the patients. Nevertheless, we believe that the design of the study, and the strict selection criteria which we used, allowed meaningful conclusions to be drawn, with respect to the prognostic long-term outcome of TSR in this group of patients.

In 2006, Bohsali et al.\textsuperscript{13} published a meta-analysis of the complications in 2540 shoulders after TSR. For unconstrained prostheses a rate of complication of 15.8\% was found at a mean follow-up of 5.3 years. In particular, secondary insufficiency of the rotator cuff and the ensuing proximal migration of the humeral component were major concerns. In another study of 107 shoulders, migration of the humeral component was found in 16\%.\textsuperscript{38} In our series proximal migration was detected in 10% of patients. At the time of latest follow-up no loosening was observed and there was no need for any revision surgery.

The reported prevalence of radiolucency around the glenoid component varies from 0% to 96%.\textsuperscript{44} In our cohort we found no evidence for radiolucency around the used flat-back and convex glenoid components on immediate post-operative radiographs (Table II). One reason for these findings may be the standardised use of a Jet Lavage, retrograde filling with bone cement and continuous pressurisation. The first radiolucent line occurred six months post-operatively (Table II).

In our study, we used cemented humeral components in all patients. Varying results have been reported for both cemented and cementless humeral components.\textsuperscript{39-43} We believe in the use of cement when performing a TSR, even in young or middle-aged patients.

In contrast to older patients with TSR, our patients had a high level of activity. However, we do not endorse participation in high-impact sports post-operatively. Nevertheless 11 (52\%) of our patients continued to play sports two or more times weekly after operation and three (14\%) of these were still playing high-impact sports, including tennis and handball at five to nine years after operation.

In our prospective study we have shown that TSR is effective in relieving pain and restoring function, and provides excellent mid-term results with few complications in young and middle-aged patients with primary glenohumeral osteoarthritis. We believe that appropriate design features of the implant, strict adherence to indications, patient education and proper rehabilitation are all necessary for a satisfactory result after this operation. Long-term studies will be required to confirm these observations.

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