We have investigated the mid-term outcome of total shoulder replacement using a keeled cemented glenoid component and a modern cementing technique with regard to the causes of failure and loosening of the components.

Between 1997 and 2003 we performed 96 total shoulder replacements on 88 patients, 24 men and 64 women with a mean age of 69.7 years (31 to 82). The minimum follow-up was five years and at the time of review 87 shoulders (77 patients) were examined at a mean follow-up of 89.1 months (60 to 127). Cumulative survival curves were generated with re-operations (accomplished and planned), survivorship of the prosthesis, loosening of the glenoid (defined as tilt > 5° or subsidence > 5 mm), the presence of radiolucent lines and a Constant score of < 30 as the endpoints.

There were two re-operations not involving revision of the implants and the survival rate of the prosthesis was 100.0% for the follow-up period, with an absolute Constant score of > 30 as the endpoint the survival rate was 98%. Radiological glenoid loosening was 9% after five years, and 33% after nine years. There was an incidence of 8% of radiolucent lines in more than three of six zones in the immediate post-operative period, of 37.0% after the first year which increased to 87.0% after nine years. There was no correlation between the score of Boileau and the total Constant score at the latest follow-up, but there was correlation between glenoid loosening and pain (p = 0.001).

We found that total shoulder replacement had an excellent mid-term survivorship and clinical outcome. The surgical and cementing techniques were related to the decrease in radiolucent lines around the glenoid compared with earlier studies. One concern, however, was the fact that radiolucent lines increased over time and there was a rate of glenoid loosening of 9% after five years and 33% after nine years. This suggests that the design of the glenoid component, and the implantation and cementing techniques may need further improvement.

In osteoarthritic shoulders total shoulder replacement (TSR) can improve function considerably.\textsuperscript{1,5} The addition of a glenoid component gives better function according to the score of Constant and Murley,\textsuperscript{6} and increased range of movement and reduces pain more efficiently in the mid term compared with hemiarthroplasty.\textsuperscript{7-11} However, loosening of the glenoid component remains a major factor affecting the long-term survivorship of TSR.\textsuperscript{7,12-15} In the past decade we have used improved cementing techniques in an attempt to reduce the number of radiolucent lines occurring around the glenoid and to prevent loosening. We carried out survivorship analysis using one design of cemented glenoid at five to ten years after operation to examine the fixation of the glenoid component and the presence or absence of its loosening. Our hypothesis was that the use of a modern cementing technique might positively influence the outcome.

Patients and Methods
Between 1997 and 2003, we performed 103 consecutive TSRs. Two which had keeled glenoids (Biomet, Warsaw, Indiana), two with pegged glenoids (Tornier, Lyon, France) and three which had a repair of the rotator cuff were excluded. The remaining 96 TSRs were carried out on 88 patients, 24 men and 64 women with a mean age of 69.7 years (31 to 82) using a curved-back, keeled cemented glenoid (Tornier). A cemented stem (Tornier) was used in 93 shoulders and a cementless stem (Tornier) in three. In 76 shoulders the diagnosis was osteoarthritis, in two rheumatoid arthritis, in nine post-traumatic arthritis, and in seven osteonecrosis of the
humeral head. Two were revision procedures, one to exchange the humeral head because of overstuffing and the other to implant a glenoid component because of pain in a patient who had undergone hemiarthroplasty.

**Operative technique.** The operative technique for TSR with a cemented glenoid component has been described previously.16-19 The glenoid is reamed to fit the curved back of the component and a trough for the keel prepared by drilling three vertical holes and then impaction of the bone with a pyramid-shaped instrument to create a keel within the glenoid. Cancellous bone is not curetted from the vault. A cancellous bone keel is used to create a trough within the glenoid and the face of the glenoid. The humerus is prepared in a similar fashion and the cement applied in a doughy state distally to proximally with a cement restrictor in place. The prosthesis is introduced slowly while pressurising the cement with a thumb at the entrance to the medullary canal.

All the patients were included in our total joint registry and returned for annual or biannual evaluation whenever possible. This included standardised radiographic analysis of polyethylene glenoid components using a 40° posterior oblique (true anteroposterior) view in the neutral rotation, an axillary view, clinical evaluation of the active and passive range of movement, and measurement of the Constant score. The clinical examination was performed by an orthopaedic surgeon (GP) who had not been involved in the original operation and using the standardised assessment form of the Aequalis group.9 Movement was measured with a goniometer to determine the angle between the arm and thorax.

A review of all the patients was carried out between December 2007 and April 2008. The minimum clinical and radiological follow-up was five years. At the time of the final review, six patients had died and five had been lost to follow-up. Eight of these had been treated for osteoarthritis and three for avascular necrosis of the humeral head. The remaining 77 patients (87 shoulders) were examined at a mean follow-up of 89.5 months (60 to 127).

**Radiological analysis.** This was performed as previously reported.19-23 The glenoid was divided into six and the proximal humerus into eight zones for the evaluation of periprosthetic lucency (Fig. 1).20-24 Two orthopaedic surgeons (PK, PR) who specialise in shoulder surgery and were blinded to the identity of the patients and clinical results evaluated the immediate and subsequent post-operative radiographs for periprosthetic lucency and reached agreement. The presence, location and thickness of the radiolucent lines were assessed. The maximum thickness of the lines was measured to the nearest millimetre. All the radiographs were sized as 100% relative to the conventional films. Radiolucency identified on any follow-up radiograph was considered to be permanent even if it did not appear on subsequent radiographs. The amount of radiolucency was scored according to Boileau et al23 for all radiographs in the anteroposterior and axial views. This score is the sum of the thickness of the radiolucent line of each zone. Since previous studies have used a score of > 12 as an indicator of loosening,9 we also adopted this figure. The location of any radiolucent lines immediately post-operatively was compared with those seen at the last radiological follow-up of a minimum of four years (mean 6.8, range 4 to 10).20 The observers also independently assessed any change in the position of the component. They examined the glenoid for medial migration > 5 mm or tilting > 5° with reference to anatomical landmarks such as the coracoid,24 scapular spine and the lateral margin of the scapula. The humeral component was assessed for subsidence of > 5 mm or varus/valgus change of > 5° in angulation within the canal (inter-observer agreement kappa = 0.67, p < 0.01).13 These shifts

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**Fig. 1a**

Diagram showing the zones which were assessed radiologically around the glenoid (a) and the humerus (b).5,20 Figure 1a reproduced from Pfahler M, Iena F, Neyton L, Sirveaux F, Mole D. Hemiarthroplasty versus total shoulder prosthesis: results of cemented glenoid components. J Shoulder Elbow Surg 2006; 15:154-63 with permission from Elsevier. Figure 1b reproduced from Miletti J, Boardman ND III, Smerling JW, et al. Radiographic analysis of polyethylene glenoid components using modern cementing techniques. J Shoulder Elbow Surg 2004;13:492-8 with permission from Elsevier.
were considered to indicate loosening. This was also noted
if there were radiolucent lines in more than three zones
(interobserver agreement kappa = 0.92, p < 0.001).13 We
chose these criteria because they develop initially more
often at the face of the glenoid which has three zones
according to Boileau et al,23 and a glenoid with radiolucent
lines extending around the keel is more likely to become
loose.19 According to Martin et al,12 the glenoid is classified
as being ‘at risk’ if there are radiological signs of loosening
defined above (migration of > 5 mm or tilting of > 5°) or
clinical signs of loosening, such as pain requiring revision.

Survivorship and statistical analysis. Survivorship
analysis was performed using the Kaplan-Meier method, with 95%
confidence intervals (CIs) around the curves as determined by
the Greenwood formula.25 A power analysis indicated that a
sample size of 77 patients would provide 0.95% power
(α = 0.05) to construct the survivorship curves with CIs. End-
points were re-operation (undertaken or planned), survivor-
ship of the prosthesis, loosening of the glenoid (tilt > 5° or
subsidence > 5 mm), a radiolucent line score > 12, radiolucent
lines in more than three zones on the anteroposterior view and
radiological loosening. Glenoid loosening represents all the glenoids at risk. Since there were no revisions undertaken or planned, the Kaplan-Meier curve of glenoid loosening represented all glenoids at risk in our study. The numbers below show the survivorship after one, five and nine years with 95% confidence intervals (CI).

In the follow-up period there was no operation for a
loose glenoid component and no revisions were planned. The
survival rate was consequently 100.0% (Fig. 2). The
survival rate with an absolute Constant score of > 30 as the
endpoint was 98% and with an adjusted Constant score >
30% it was 100.0% (Fig. 2). Glenoid loosening slowly
increased with time, reaching 9% after five years and 33%
after nine years which reflects the number at risk (Fig. 3).
Since there were no revisions undertaken or planned for
clinical signs of loosening, the Kaplan-Meier curve of gle-

The correlation of the adjusted Constant score and the
total score of radiolucent lines at the latest follow-up was
calculated using the Spearman coefficient. A pain score of
nine (out of 15 in the Constant score) or less was correlated
with signs of glenoid loosening using the chi-squared test. The
data were analysed using SPSS for Windows version
12.0 (SPSS Inc., Chicago, Illinois) and a two-tailed p-value
≤ 0.05 was considered to be significant.

Results
Intra-operative complications included two fractures of the
humeral shaft which required cerclage wire, one fissure of the
glenoid and one of the greater tuberosity which healed with-
out additional treatment, five perforations of the glenoid
which necessitated bone grafting to cover the perforation from
within, and one posterior subluxation. Post-operative compli-
cations included one superficial wound infection, one case of
heterotopic ossification, and one of periprosthetic fracture,
two temporary and one permanent injury of the brachial
plexus and three anterior subluxations. Of the last, one patient
had refixation of subscapularis and later transfer of pectoralis
major.26

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the latest follow-up, there was a correlation between glenoid loosening and pain (chi-squared test, \( p = 0.001 \)).

The radiolucent lines were mainly around the baseplate (16% to 30%) with fewer around the keel (4% to 11%) on the immediate post-operative radiographs. This increased to 64% to 76% behind the baseplate with additional radiolucent lines around the keel in 39% to 48% at a mean of 6.8 years (4 to 10) (Fig. 5). At the latest follow-up after a mean of 89.5 months (60 to 127) there was an increase in the mean raw Constant score from 25.2 (SD 10.3) to 66.6 (SD 6.9) and of the mean relative Constant score from 34.2% (SD 14.5) to 87.3% (SD 17). Mean flexion increased from 63.9° (0° to 150°) to 140.8° (50° to 180°) and mean abduction from 53.9° (0.0° to 100.0°) to 127.3° (30.0° to 180.0°).

**Discussion**

The options for fixation of the glenoid component in TSR include the use of ingrowth components, cemented metal-backed components and cemented all-polyethylene components.8,9,12,23,27-30 Of these, cemented all-polyethylene glenoids give the most reliable results in the mid and long term8,9,12,23,29-33 and are the most popular. Uncemented metal-backed glenoids have higher clinical and radiological rates of failure.31,32 For example, Martin et al12 found that the rates of failure of 147 uncemented components fixed by
screws were higher than those in earlier studies using cemented polyethylene components with a similar duration of follow-up. Tammachote et al\textsuperscript{39} reported that TSR with a cemented metal-backed glenoid component for the treatment of osteoarthritis had a high rate of glenoid peri-prosthetic lucency and the results were no better than those reported for an all-polyethylene cemented glenoid component. Data from the Mayo TSR registry including 1542 TSRs with six types of glenoid design showed that the survival of a cemented TSR was better than that of other designs.\textsuperscript{32}

Our data have shown that the survival rate and clinical outcome assessed by the Constant score were excellent at five to ten years after TSR using a cemented glenoid. Although the number of radiolucent lines increased steadily during the follow-up period, the total Boileau score did not inversely correlate with the Constant score. Other groups have reported the incidence of radiolucent lines to range from 30%,\textsuperscript{18} 67.9%\textsuperscript{9} to 84%.\textsuperscript{34} In 1982, Neer et al\textsuperscript{16} reported an incidence of 30% of glenoid radiolucent lines, with 24% being present in the immediate post-operative period, but with no evidence of clinical loosening. They attributed this to a faulty cementing technique, by incomplete removal of blood from the cancellous bone. Torchia et al\textsuperscript{14} reviewed the long-term results, including the patients in the study of Cofield,\textsuperscript{17} and found an overall incidence of radiolucent lines of 84%. Of this group, 44% of implants were radiologically loose, with 5.6% requiring revision. In this study, loosening of the glenoid component correlated with increased pain, which is consistent with our findings. Godeneche et al\textsuperscript{13} reviewed 268 TSRs and found radiolucent lines in 58%, of which 23% were progressive. They also found a correlation between the presence of radiolucent lines and pain. The rate of glenoid loosening of cemented glenoids was 11% in the series of the Aequalis study group\textsuperscript{19} (705 TSRs) after 3.6 years and 11.3% (70 TSRs) in the Mayo group\textsuperscript{19,29} after 3.9 years. In our series the rate of glenoid loosening was slightly lower at 4.5% after four years (Fig. 3).

A high incidence of radiolucent lines has been noted in the immediate post-operative period.\textsuperscript{16,27} Therefore, emphasis has been placed on the surgical technique in regard to the placing of the glenoid component. The evolution of the cementing technique began with total hip replacement and includes meticulous preparation of the canal, pulsatile lavage, drying of cancellous bone, restriction of cement and pressurisation and vacuum mixing to reduce porosity.\textsuperscript{27} Norris and Lachiewicz\textsuperscript{13} first reported the relationship between modern cementing techniques, and survivorship in TSR and Miletti et al\textsuperscript{1} reported that 87% of patients had minimal or no radiolucent lines in the immediate post-operative period using modern cementing techniques. In our series, 92% glenoids had either no radiolucent lines or they were present in less than three zones post-operatively. Consequently, there is evidence that a proper cementing technique can minimise the number of radiolucent lines thereby reducing the probability of glenoid loosening.\textsuperscript{27}

Preparation of the glenoid may also play a role.\textsuperscript{36} Bone impaction proved to reduce the incidence of radiolucent lines compared with a curettage technique at follow-up at two years.\textsuperscript{36} Also, positioning of the glenoid component is crucial. In clinical\textsuperscript{12} and finite-analysis studies\textsuperscript{38} retroversion of more than 15° was found to be detrimental to a good long-term outcome. With glenoid retroversion of 15° stresses at the cement-bone interface and glenohumeral contact pressures have been shown to increase more than 200%.\textsuperscript{39} Another important aspect is mismatch between the glenoid and humeral components. In cadaver studies, it was found that a radial mismatch of 4 mm best reproduced the glenohumeral translation.\textsuperscript{40} Collins et al\textsuperscript{19} recommended a mismatch of 3 mm to 5 mm, whereas Walch et al\textsuperscript{41} recommended 6 mm to 10 mm. A finite-analysis study by Terrier et al\textsuperscript{18} supported the finding that a mismatch of more than 10 mm should be avoided.

Our results indicate that TSR has an excellent mid-term survivorship and clinical outcome. In our study the surgical and cementing techniques were found to decrease the rate of incidence of radiolucent lines around the glenoid compared with previous studies. A major concern, however, was that these increased over time and there was a rate of glenoid loosening of 9% after five years and 33% after nine years. This suggests that the design of the glenoid component, its implantation and the cementing technique may require further improvement.

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References


