Clinical and radiological evaluation of revision hip arthroplasty using the cement-in-cement technique

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We reviewed 44 consecutive revision hip replacements in 38 patients performed using the cement-in-cement technique. All were performed for acetabular loosening in the presence of a well-fixed femoral component. The mean follow-up was 5.1 years (2 to 10.1). Radiological analysis at final follow-up indicated no loosening of the femoral component, except for one case with a continuous radiolucent line in all zones and peri-prosthetic fracture which required further revision. Peri-operative complications included nine proximal femoral fractures (20.4%) and perforation of the proximal femur in one hip. In five hips wiring or fixation with a braided suture was undertaken but no additional augmentation was required. There was an improvement in the mean Japanese Orthopaedic Association score from 55.5 (28 to 81) pre-operatively to 77.8 (40 to 95) at final follow-up ($p < 0.001$). Revision using a cement-in-cement technique allows increased exposure for acetabular revision and is effective in the medium term. Further follow-up is required to assess the long-term results in the light of in vitro studies which have questioned the quality of the cement-in-cement bond.

Aseptic loosening is a major cause of failure in total hip replacement (THR),¹⁻³ and in many cases an acetabular component is loose in the presence of a well-fixed cemented femoral component.⁴ Revision of the acetabular component is difficult and often requires wide exposure of the acetabulum if the femoral component is left in place. In such cases, trochanteric osteotomy or extensive soft-tissue mobilisation with anterior or posterior translation of the proximal femur are often considered. However, trochanteric osteotomy may jeopardise the intact bone-cement interface and cause nonunion of the greater trochanter,⁵ and extensive soft-tissue releasing can damage neurovascular structures and cause instability of the reconstructed hip joint.⁴ Correction of leg-length discrepancy or a gain in optimal joint tension to avoid dislocation can prove difficult when extensive acetabular reconstruction is performed in revision surgery with the femoral component left in place. Therefore, simultaneous revision of a loose acetabular component and well-fixed femoral component is often considered. In addition, revision of a well-fixed femoral component should be considered when recurrent dislocation occurs due to malpositioning of the component, or there has been proximal stem breakage.^{6,7}

The cement-in-cement technique provides an option for revision of a well-fixed cemented stem; this method was first described by Eftekhari⁸ in 1978 and validated experimentally by Greenwald, Narten and Wilde,⁹ with clinical results reported by several authors.^{6,7,10,11} However, the use and indications of this technique are not commonly known, presumably in part because no detailed radiological evaluation has been reported. Therefore, the purpose of this study was to review a series of revision THRs using the re-cementing technique, focusing on radiological changes at the cement-bone interface.

Patients and Methods

Between April 1996 and June 2004, 44 consecutive revision THRs in 38 patients were performed by several orthopaedic surgeons (including KK) using the cement-in-cement technique in our hospital. All the patients were followed up for more than two years and reviewed retrospectively. There were 37 women and one man with a mean age of 66 years (48 to 78), mean weight of 52.3 kg (33 to 67), and mean body mass index (BMI) of 24.0 kg/m² (16.6 to 31) at the time of revision. The original diagnosis was primary or secondary osteoarthritis in all patients, and the mean time from the initial to the revision sur-

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gery was 15.3 years (7.9 to 30.2). A total of 40 THRs were revised for loosening of the acetabular component and four bipolar hemiarthroplasties were revised for penetration of the bipolar head. The femoral components which were revised comprised 26 Charnley components (Thackray, Leeds, United Kingdom), ten Bioceram (Kyocera, Kyoto, Japan), seven KC (Kyocera) and one unknown type.

Revision operations were performed through a direct lateral approach (26 Hardinge¹² and 18 Dall approaches¹³). In 41 hips a transtrochanteric approach had been undertaken at the primary surgery. In each of these cases the trochanteric wires were removed before proceeding with the revision. The cement-bone and cement-stem interfaces in the proximal femoral portion were carefully identified and the original cement mantle at the stem shoulder was meticulously curetted out. The femoral component was then carefully hammered out to avoid introducing torsional movement that could lead to damage to the rest of the original cement mantle. The proximal femur was retracted distally and posteriorly, and the acetabular component was revised with wide exposure. Subsequently, the proximal femoral cement mantle in zones 1 or 7, as described by Gruen, McNeice and Amstutz,¹⁴ and the underlying fibrous or osteolytic granulation tissue were curetted out thoroughly to a depth where cement-bone contact could be visually confirmed. Neocortex in the proximal femur¹⁵ was removed with a high-speed burr, and any disuse osteoporotic lesions formed by stress shielding outside the neocortex were also curetted out. We then attempted to insert a femoral component of a similar shape and size (or marginally smaller) to those of the retrieved component. The inner surface of the distal cement mantle was roughened with a high-speed burr, and the internal cavity of the cement mantle was carefully enlarged with the burr if insertion of the new component into the original position proved difficult. After lavage to wash out debris and clots, the cement mantle cavity was dried with gauze, and polymethylmethacrylate (PMMA) bone cement of relatively low viscosity was injected with a gun prior to insertion of the new femoral component.

The new femoral components were PHS (physio-hip-system) type 6 (30), KC (seven), PHS type 7 (three), and HS-3 (four), all produced in titanium alloy by Japan Medical Materials, Osaka, Japan. The modular heads (Japan Medical Materials) were 22 mm alumina in seven cases, 22 mm zirconia in 27 cases, and 26 mm zirconia in ten cases. Using the cement-in-cement technique, CMW 3 bone cement (DePuy, Blackpool, United Kingdom) was used in 12 hips and Endurance bone cement (DePuy) in the remainder. For revision of the acetabular component, reconstruction was performed using a Kerboul acetabular reinforcement device (Howmedica, Hérouville, France) in eight hips and a KT plate (Japan Medical Materials) in 33. In total 43 PHS acetabular components (Japan Medical Materials) were used and one CLHO acetabular component (Japan Medical

Fig. 1

Mean Japanese Orthopaedic Association (JOA) scores pre-operatively and at one and two years post-operatively. The error bars indicate standard deviation. Statistical significance was found between the pre-operative and post-operative scores at each interval (* ANOVA, $p < 0.001$).

Materials). The mean operation time was 210 minutes (141 to 271) and the mean blood loss during surgery was 661 g (240 to 1440).

The mean follow-up period was 5.1 years (2 to 10.1). Standard anteroposterior radiographs of the pelvis were taken immediately post-operatively, at two, four, six and eight weeks and three, six, nine and 12 months, and six-monthly or annually thereafter. Radiological loosening was assessed according to the criteria of Harris, McCarthy and O'Neill¹⁶ with peri-prosthetic radiolucencies evaluated in the Gruen zones. The presence of heterotopic ossification was recorded using the Brooker classification.¹⁷ Hip function was evaluated using the Japanese Orthopaedic Association (JOA) score,¹⁸ which is based on pain (40%), range of movement (20%), ability to walk (20%) and activities of daily living (ADL) (20%). The total score is 100 points for a normal hip. Peri- and post-operative complications were identified from the medical records.

Statistical analysis. Repeated analysis of variance (ANOVA) was used to compare the pre-operative and follow-up JOA score. Kaplan-Meier analysis with 95% confidence intervals (CI) was performed to evaluate the period to the appearance of a radiolucent line exceeding 1 mm in width. Log-rank testing was undertaken to test the relationship between possible risk factors and radiolucent line-free survival. The possible risk factors included age, BMI, body weight, pre-operative JOA score, type of femoral component, surgical approach, pre-operative presence of radiolucent lines, and peri-operative fractures. In log-rank tests for the first four of these variables, the cases were divided into two groups based on the mean value of each variable. All statistical analyses were carried out using JMP IN software version 5.1.2 (SAS Institute

Fig. 2a

Fig. 2b

Radiographs of a 66-year-old woman with acetabular loosening who had revision surgery 15.4 years after primary hip replacement. a) Pre-operative anteroposterior (AP) radiograph, in which no femoral radiolucent line was found but stress shielding was evident, and b) AP radiograph 5.6 years after revision, showing a radiolucent line in Gruen zone 1 (arrow).

Fig. 3a

Fig. 3b

Radiographs of a 56-year-old woman with acetabular loosening who had revision surgery 9.9 years after primary hip replacement. a) Pre-operative anteroposterior (AP) radiograph, in which a radiolucent line in zones 1, 2 and 7 was evident and b) AP radiograph seven years after the revision and immediately prior to further revision. The radiolucent line had extended to all zones, with widening and osteolysis in zones 2 and 6 where a proximal femoral fracture was confirmed (arrows).

Inc., Cary, North Carolina) and SAS software version 9.1 (SAS Institute Inc). Two-sided p -values < 0.05 were considered statistically significant.

Results

Peri-operative fractures occurred in ten cases (22.7%), involving the greater trochanter or proximal femur in nine (20.9%), of which five required fixation; with wiring in four hips (20.4%) and braided sutures in one. In two hips trochanteric fractures were left without fixation; producing asymptomatic pseudarthroses. In one hip perforation of the distal femur resulted in an extensive cement extrusion, which was removed intra-operatively and required no further treatment. Early post-operative complications included dislocation in three hips (6.8%), which required closed reduction, and one recurrent dislocation which became stable by the end of the first post-operative year. Class 3 heterotopic ossification¹⁷ developed in one hip, but there were no associated symptoms, and there were no cases with peri-prosthetic infection or deep-vein thrombosis. The mean JOA score improved from 55.5 (28 to 81) pre-operatively to 78.8 (57 to 93) at one year post-operatively, 80.4 (55 to 96) at two years post-operatively, and 77.8 (40 to 95) at final follow-up (Fig. 1). The differences between the pre-operative and one- and two-year post-operative scores were statistically significant (ANOVA, $p < 0.001$).

Radiological analysis at final follow-up, according to the criteria of Harris et al,¹⁶ indicated no definite, probable or possible loosening of the femoral component (Fig. 2), except in one hip with possible radiological loosening and

peri-prosthetic fracture (Fig. 3). This was in a 56-year-old woman who required a further revision with strut allograft augmentation seven years after the initial revision surgery. There were no other radiolucent lines or osteolysis beyond zone 1 or 7 in any hip. Changes in the extent of the pre- and post-operative radiolucent lines and radiological osteolysis are summarised in Tables I to III.

Kaplan-Meier analysis using the appearance of a radiolucent line 1 mm in width in any zone as the endpoint indicated survival rates of 71.5% (95% CI 52.3 to 84.1) at five years and 53.5% (95% CI 30.2 to 72.1) at ten years (Fig. 4). Log-rank tests showed that all the possible risk factors examined had no significant influence on the appearance of a radiolucent line > 1 mm in any area (Table IV).

Discussion

In our series 18 hips (41%) had radiolucent lines or osteolysis confined to Gruen zones 1 and 7 pre-operatively. These proximal gaps between the cement and bone must be regarded as a potential pathway for wear debris, which is thought to initiate osteolysis.¹⁹⁻²² In our single hip requiring further revision, the pre-operative radiolucent line could still be identified post-operatively, indicating that removal of the fibrous membrane or sclerotic neocortex¹⁵ with underlying osteoporotic regions had been inadequate. Lieberman²³ suggested that the neocortex must be removed when performing a cemented femoral revision to obtain adequate interdigitation between the new cement and the bone. Removal of part of the proximal cement mantle is necessary to permit the safe extraction of the original component, especially for a proximally curved device such as a

Table I. Hips with a radiolucent line greater than 1 mm or osteolysis preceding revision and at final follow-up

	Preceding revision (%)	Final follow-up (%)
Osteolysis	14 (31.8)	2 (4.5)*
Radiolucent line	5 (11.4)	13 (29.5)*

* including the revision case

Table II. Distribution of radiolucent lines greater than 1 mm or osteolysis present. The number of hips with a radiolucent line present in the same zone pre-operatively as post-operatively at final follow-up is shown in parentheses

	Preceding revision (n = 19)	Final follow-up (n = 14)
Zone 1 or 7, or 1 and 7	18	13 (10)
Beyond zones 1 and 7	1*	1*

* revision case

Table III. Time post-operatively at which a radiolucent line greater than 1 mm was first identified

Time	Number of cases
Immediately post-operatively	3 of 14*
Less than three years	6 of 14
Over three years	5 of 9

* including the revision case

Charnley prosthesis, and to confirm that the bone-cement interface is intact. In our single hip requiring further revision it is also possible that the radiolucent lines might have extended to the distal femur, because the lateral radiolucent line was found to reach zone 2 on the pre-operative radiograph. In such cases, visual confirmation of the distal bone-cement interface is hard to achieve. The cement-in-cement technique should probably not be undertaken where a radiolucency extends beyond zones 1 or 7.

Kaplan-Meier analysis estimated a survival rate of 53.5% for the appearance of a radiolucent line > 1 mm in width in any area at ten years, but a post-operative radiolucent line in excess of 1 mm was not identified beyond zone 1 or 7 in any hips except the revision case. This suggests that removing the femoral component and recementing it in the old cement mantle did not have a detrimental effect, and this supports the use of the cement-in-cement technique. The incidence of peri-operative femoral fractures in our series was high, occurring in nine hips (20.4%), which is greater than described in previous reports of cemented revisions.^{24,25} The removal of a well-fixed femoral component is itself clearly a risk for femoral fracture compared with removal of a loosened stem. The removal of the trochanteric wires required in 41 of our hips (93%) may have weakened the greater trochanter and contributed to

Fig. 4

Kaplan-Meier analysis using the appearance of a femoral radiolucent line wider than 1 mm in any area as the endpoint. The dotted lines indicate 95% confidence intervals.

the subsequent fractures. None of the fractures required additional treatment other than wiring.

In order to revise a loose acetabular component with a well-fixed, cemented femoral component, complete removal of cement and insertion of a new stem is often advised in order to avoid future femoral problems arising from older cement. However, removal of a distal cement mantle with an intact bone-cement interface is time-consuming and risks femoral fracture and perforation.²⁶⁻²⁸ A perforation rate as high as 16% has been reported,^{26,27} but we only encountered this problem once. In an *in vitro* study,²⁹ the shear strength of the cement-bone interface has been shown to diminish to 20.6% of its initial value with

Table IV. Variables examined as possible risk factors using log-rank tests

Variable*	Value	p-value
Mean age at surgery in yrs (range) [†]	66 (48 to 78)	0.79
Mean body weight in kg (range) [†]	52.3 (33 to 67)	0.53
Mean BMI in kg/m ² (range) [†]	24.0 (16.6 to 31)	0.82
Pre-operative JOA score [†]	55.5 (28 to 81)	0.51
Surgical approach		
Hardinge	26	0.27
Dall	18	
Applied femoral prostheses		
PHS type 6	30	0.73
KC	7	0.29
PHS type 7	3	0.20
HS-3	4	0.80
Fracture or crack during surgery		
Greater trochanter	7	0.36
Proximal femoral crack	2	0.66
Lucent line over 1 mm or osteolysis before surgery		
Yes	19	0.21
No	25	

* BMI, body mass index; JOA, Japanese Orthopaedic Association

[†] for log-rank tests, cases were divided into two groups based on the average for each variable

the first revision and to 6.8% on the second revision. In contrast, good clinical results have been reported with the cement-in-cement technique,³⁰ which were comparable to the results we obtained, although previous reports have included less radiological information.^{6,7,10}

In order to increase the shear strength between old and new cement, the inner surface of the old cement requires roughening. Greenwald et al⁹ evaluated the cement-in-cement technique *in vitro* and showed that where the old cement surface was rasped and dried, the shear strength between old and new cement was reduced by only 6%, compared with the strength of uniform cement specimens. However, in practice, we found it difficult to roughen all the inner surface of the old cement mantle to a uniform extent, because the whole of the mantle is difficult to visualise. This sometimes results in the unintentional creation of a pit or defect in the mantle, which is seen on post-operative radiographs as enlargement of the mantle or cement leakage. These defects did not seem to have a detrimental effect on the cement mantle or the clinical results. However, Li, Ingle and Dowell³¹ showed *in vitro* that the presence of a thin layer of blood and marrow debris at the interface weakens the cement-to-cement bond by 80% to 85%. Accordingly, our patients require careful follow-up to determine whether any interface defects will emerge.

An application for cement-in-cement technique includes recurrent dislocation due to malposition of the femoral component, and proximal breakage of the femoral component with an intact distal cement mantle.^{6,7} All the femoral revisions in our series were performed to increase exposure

of the acetabulum, or because of a mismatch between an old femoral component and the intended revision acetabular component. Good clinical results were obtained in all but one hip at a mean follow-up of 5.1 years.

No long-term follow-up of revision cases using the cement-in-cement technique has been reported, and there are only a few studies of the mechanical aspects of this technique.^{9,31,32} However, our mid-term results suggest that this technique is appropriate for revision surgery in selected cases.

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