The natural history and significance of radiolucent lines at a cemented femoral interface
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We studied 185 total hip replacements and related the identification of radiolucent lines (RLLs) at two years to the later development of lytic lesions and loosening. Linear polyethylene wear was also measured. RLLs appeared in 34 hips at a mean of 2.0 years after operation, and lytic lesions in ten hips at 5.7 years. Of 151 THRs without RLLs there was neither rapid migration nor loosening and only one developed a possible lytic lesion. Of 23 hips with non-progressive RLLs there was neither rapid migration nor loosening, but six developed a lytic lesion. By contrast, 11 THRs with progressive RLLs migrated rapidly and seven developed a lytic lesion. Six THRs with progressive RLLs failed. The wear rates were the same in all groups, although limited numbers were available for study.

If the surgeon achieves secure initial fixation as shown by slow or no migration and no RLLs during the first two years, it is likely that no lytic lesions will develop by five years or aseptic loosening by ten years. If an imperfect, but adequate, interface is achieved, as shown by slow migration and non-progressive RLLs, lytic lesions adjacent to the RLLs may develop by five years, but aseptic loosening will be unlikely at ten. Insecure initial fixation, as shown by more rapid migration and progressive RLLs at two years, is likely to lead to the formation of lytic lesions at five years and loosening at ten. The outcome after THR is therefore determined at the initial operation and may be predicted at two years. The presence of lytic lesions reflects soft tissue at the interface as shown by the RLLs which accompany and promote loosening but, in our study, did not cause it.

The presence of a linear radiolucency between radiopaque cement and a line of sclerosis in the adjacent bone has long been considered to carry a poor prognosis after total hip replacement (THR). The tissue within the radiolucent line (RLL) is soft with poor mechanical properties, implying local lack of fixation between bone and implant and hence the possibility of relative movement between them. Cells in this soft tissue are capable of destroying bone. In spite of these adverse features there is a clinical impression, however, that not all RLLs carry a poor prognosis.

If the prognostic significance of RLLs can be determined, ideally as early as two years after THR, it may be possible to distinguish between those THRs which are at risk of early aseptic loosening from those that are not.

In order to examine this possibility, we studied 185 hips between two and ten years after THR with a cemented femoral component. We related the radiological situation at two years to the later development of RLLs or their progression, and the development of lytic lesions and loosening.

Patients and Methods
A total of 185 patients (57 men and 128 women) of mean age 68.3 ± 6.7 years (46 to 83) underwent a primary THR using a cemented Freeman (Corin Medical UK and Finsbury Instruments Ltd, UK) femoral component at the Royal London Hospital. Those with previous surgery to the proximal femur and those in whom infection had developed were excluded. Patients who were included had had at least three available radiographs taken during the first two years after surgery and had a known outcome at two to ten years after surgery. The mean radiological follow-up was 5.4 ± 2.6 years (2 to 10); 11 patients (6%) were followed by telephone with a last radiograph at two to four years. The diagnosis was osteoarthritis in 165 patients and rheumatoid arthritis in 13. Seven patients had THR for other reasons.

Operative technique and prosthesis. Proximally, the prosthesis is shot-blast to give a surface roughness of about 3mRa. Distally, the stem is a polished taper. A routine anterolateral exposure was used for all operations. The femoral neck was retained and the prosthesis was fitted into a slot made within it to assist rotational and vertical stabilisation. The canal was reamed using a circular tapered reamer until the cortex was felt. The femur was then lightly

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curetted, irrigated, brushed, occluded and packed with swabs soaked in an adrenaline solution. Cement was mixed in a gun and, after removal of the packing, injected retrogradely. Cement which overflowed proximally was irrigated with warm saline to form a ‘skin’ of more polymerised cement as a proximal seal. The prosthesis was then inserted.

**Radiological assessment.** RLLs were sought only on standardised anteroposterior radiographs with 10% magnification. Their site and length were classified using the method of Gruen, McNeice and Amstutz\(^7\) and their width was measured at the widest point. They were deemed to have progressed if either they lengthened into an additional zone or widened by at least 1 mm. Lateral radiographs were not used as they are hard to standardise and are often of poor quality.

Lytic lesions were identified as ‘balloon-shaped’ rather than linear lucencies, and not surrounded by a sclerotic line. Migration of the prosthesis, relative to the bone, was measured using the method of Braud and Freeman.\(^5\) The prosthesis has a sharp point at its superolateral shoulder, from which the distance to the tip of the greater trochanter was measured using a digitiser. The principle of this method has been validated for total knee arthroplasty by Carlsson et al.\(^6\) and the presentation and calculation of the results have been discussed by Freeman and Plante-Bordeneuve.\(^7\) We could not measure separately the movement of the prosthesis from that of the cement.

Migration at two years could not be calculated in 12 hips for technical reasons, usually myositis in the region of the greater trochanter. Initially, we attempted to measure the thickness of the cement mantle, but abandoned it as we, and others,\(^8\) found the results to be unreliable.

Measurements of wear were made using the method of Livermore, Ilstrup and Morrey\(^9\) with an Orthographics digitiser (Orthographics Inc, Salt Lake City, Utah) for 101 THRs for which a radiograph was available at five years and the annual volumetric wear (mm\(^3\)) calculated by the method of Charnley, Kamangar and Longfield.\(^10\)

**Statistical analysis.** An unpaired \(t\)-test analysis of variance with a Bonferroni-Dunn post-hoc test, the chi-squared test, and the post-hoc chi-squared test of Fisher’s exact test were applied as appropriate using StatView 4.51 (Abacus Concepts Inc, Berkeley, California).

**Results**

The outcome was classified as satisfactory with a functional femoral component in 179 hips. Six THRs were considered to be failures; three with aseptic loosening were revised, but three with symptoms resulting from the THR being completely surrounded by RLLs were not, either because the patient declined revision or it was contraindicated for medical reasons. The radiological status and outcome of the femoral components are shown in Figure 1 and the site and progression of RLLs and lytic lesions in Figures 2 and 3.

**Development of RLLs.** Of the 23 THRs which developed non-progressive RLLs, 17 (five after 2 years and two on the last radiograph) have not developed lytic lesions (group A) and, at a mean of five years after surgery, six have (group B). None of the hips with non-progressive RLLs, had failed at the completion of the study. Of the 11 THRs which developed a progressive RLL at a mean of 3.4 ± 1.4 years after surgery, seven developed a lytic lesion (group C), and four did not (group D). There were 151 hips with no RLL at two years (group E); none failed although one had a possible lytic lesion in zone 7.

At two years, the mean migration was 0.5 mm for group A, 0.3 mm for group B and 0.4 mm for group E. These rates are not significantly different. Thus, fixation, as reflected by early migration and late failure, does not appear to have been affected by the development of non-progressive RLLs before two years. THRs with RLLs are, however, slightly more likely to develop a lytic lesion than those without, but this difference was not statistically significant (\(p = 0.06\)).

By contrast, progressive RLLs were associated with more rapid migration, with the mean migration at two years being 1.8 mm for group C and 2.9 mm for group D (non-progressive RLL vs progressive RLL, \(p = 0.003\)). This difference persisted for eight years. There was also a higher incidence of failure; there were no failures in THRs with non-progressive or absent RLLs, but four of the seven in group C and two of the four in group D failed (non-progressive RLL vs progressive RLL; \(p = 0.0003\)). All six THRs which failed, including the three revised for aseptic loosening, had significantly increased migration at two years when compared with all the remaining THRs (\(p < 0.0001\)).

**Lytic lesions.** A total of 13 THRs developed a lytic lesion at a mean of five years after operation. The lesion was always preceded by and always contiguous with an RLL which was non-progressive in six hips (group B) and progressive in seven (group C), a non-significant difference. There were no isolated lytic lesions. One THR, without an RLL, developed an erosion of the proximal, medial neck which was classified as a possible lytic lesion in zone 7. Lytic lesions therefore appeared to follow and be associated with RLLs, regardless of whether the RLL was progressive (failure of fixation) or non-progressive (adequate fixation).

The migration at two years in THRs with a lytic lesion was not significantly greater than that in all remaining THRs (\(p = 0.0539\)). A significant increase in migration, however, was seen in hips which developed lytic lesions when migration was calculated at five (\(p = 0.02\)) and eight (\(p = 0.02\)) years. Thus, increased migration did not precede, but followed the development of a lytic lesion. Among THRs with a non-progressive RLL there was no difference of migration at two years between those which developed a lytic lesion and...
Fig. 1

The radiological findings to ten years and the mean migration at two years.
The incidence of RLLs and lytic lesions in all hips.

The incidence of RLLs and lytic lesions in hips with progressive RLLs (groups C and D).
those which did not. Of THRs with progressive RLLs, there was a non-significant trend towards more rapid migration at two years in hips which developed lytic lesions. In those hips the rate of migration was doubled.

Wear. Acetabular polyethylene wear was measured for all THRs with radiographs at five or more years. The results (Table I) showed no significant differences between any two groups, but only one THR was measured in group D. Neither the presence of RLLs nor lytic lesions were associated with increased polyethylene wear.

Discussion

Of the 185 THRs there was evidence of satisfactory fixation in 151 (group E); these developed no RLLs within the first two years and migrated very slowly. Subsequently, none loosened, none developed RLLs (up to ten years, in the small number followed to this point) and only one developed a possible lytic lesion. In a second group of 23 hips (groups A and B), a non-progressive RLL was seen within two years in 17 THRs and later in six, typically in zones 1 or 7. These zones are longer than usual with this prostheses, however, migrated at the same slow rate and none loosened, suggesting that the rest of the interface was adequate to provide fixation. Of these, 25% developed a lytic lesion which was contiguous with a pre-existing RLL. Since the rate of formation of wear debris was the same in groups E, A and B, this suggests that lytic lesions developed because the presence of soft tissue allowed the penetration of debris at the interface. Lysis did not lead to loosening during the period of this study.

By contrast, it is likely that in groups C and D the THR was poorly fixed initially. The evidence for this is that the rate of migration which was identified at two years, was significantly greater than in the other two groups and RLLs not only appeared within the first two years, but were progressive. Six of these loosened and over half developed lytic lesions. The incidence of loosening was not, however, affected by the presence or absence of a lytic lesion. Since rapid migration and progressive RLLs were present from the outset, it would appear that loosening in these THRs was due to failure of the operative technique. It would seem that the cement had not been properly injected, allowing it movement relative to the bone inducing progression of the RLLs, eventual loosening and the entrapment of debris causing lysis within the periprosthetic bone. We believe that eventual loosening occurred, not because of lysis, but because this represented the endpoint of a process which had been present subclinically from the time of implantation.

Lysis was not associated with increased rates of wear at five years. When lysis developed it typically did not do so for five years, whereas evidence of loosening was present from the outset. Thus, loosening preceded lysis which was presumably due to the greater ease with which debris could penetrate the soft tissue at the interface with poorly fixed femoral components.

On the basis of this experience of one prosthesis in the hands of one team of surgeons, we believe that two unfavourable situations, only one of which was observed in this study, may be present at the interface between a cemented femoral stem and bone. First, the cement may fail to interlock with the bone at the time of implantation. This results in progressive loosening, which is first apparent as rapid migration. As the prosthesis loosens, RLLs progress. The movement of the prosthesis and the poor fit at the interface facilitate the entry of wear debris which causes lysis. Secondly, it is possible that the cement may interlock imperfectly without such a disastrous outcome. This would result in non-progressive RLLs, typically in zones 1 and 7, but no increase in migration or in eventual loosening. Once again, however, debris may penetrate the interface to cause lysis. Theoretically, the second adverse outcome is the late development of lysis induced purely by the reaction to wear debris at an intact cement-bone interface, but we did not observe this.

Lysis in the first ‘scenario’ is a consequence of loosening strictly of soft tissue at the interface and is not a cause of loosening. It may lead to further bone loss, but does not itself initiate the process of loosening. We speculate that this is due to poor technique as revealed by relatively rapid migration during the first two years combined with RLLs which progress. These two findings presage and constitute failure of fixation and the likely eventual need for revision.

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References


