Plain radiographs inadequate for evaluation of the cement-bone interface in the hip prosthesis

A cadaver study of femoral stems

Maarten E. Jacobs, Eric M. J. Koeweiden, Tom J. J. H. Slooff, Rik Huiskes and James R. van Horn

To determine whether plain radiographs accurately represent the true cement-bone interlock, a comparison was made between radiographs and macroscopic morphology on cross sections of 11 human femora into which a cemented endoprosthesis had been inserted. Four femora had been retrieved postmortem from patients with a hip arthroplasty, and seven cadaver femora were cemented under varying conditions. All the femora were radiographed and then cut for macroscopic inspection of the cement-bone interface with respect to gross interposition, depth of cement penetration, integrity of the bone bed, and lamellation of the cement.

The quality of the cement-bone interlock is essential for the fixation of a total hip replacement. Plain radiography is widely considered as an important tool for assessing implant loosening. Authors use different terms to describe the radiographic appearances, e.g., radiolucency, radiolucent lines or zones, looseness, loosening, migration, subsidence, demarcation, cystic lysis, etc. Many investigators have studied the correlation between radiographic appearances and clinical results, using different criteria to assess loosening.

The purpose of this study was to determine to which extent the radiographic appearance of the cement-bone interface actually represents its true nature. This study was carried out using cadaver and autopsy femoral specimens, which were radiographed and sectioned.

Institute of Orthopedics, St. Radboud Hospital, University of Nijmegen, The Netherlands

Correspondence: Dr. Tom J. J. H. Slooff, Institute of Orthopedics, University of Nijmegen, P.O. Box 9101, 6500 HB Nijmegen, The Netherlands

Materials and methods

In seven human cadaver femora fixed in formaldehyde, a Charnley-Müller curved-stem hip prosthesis was cemented using a variety of cementing techniques. In four specimens, contemporary cementing techniques were used; in three specimens inadequate fixation was simulated by using a poor cementing technique. Palacos® cement was used in all the femora (Table 1). Another four femora from four total hip replacement patients were obtained postmortem. Two of the patients died on the first postoperative day; in both cases, modern cementing techniques had been used. The other 2 had lived for about 10 years following total hip replacement; and in these, poor cementing techniques had been used. Palacos® cement had been used in all the hips (Table 2).

To facilitate precise level orientation on the radiographs, all the femora were radiographed with a specially designed marking device, visible on both the bone and the radiographs (Figure 1).

After the conventional radiographs were made, the prostheses were removed and the femora were cut into sections of 0.5 mm, using a 0.5-mm-blade circular saw. The slices were photographed and contact-radiographed. The interface morphology was compared with the appearance of the interface on the conventional radiographs at identical locations.

Table 1. In vitro specimens

Case	Age	Sex
Modern technique[1]		
1	63	F
2	59	F
3	68	M
4	72	M
Poor technique[1]		
5	65	M
6	73	F
7	76	M

[1] Medullary plug, pressurization and bone lavage were used only with the modern cementing technique.

Table 2. In vivo specimens

Case	Age	Sex	Postoperative time	Type of prosthesis
8	86	F	10 years	Thompson
9	83	F	0 days	Müller straight stem
10	85	M	1 day	Müller straight stem
11	70	F	11 years	Charnley- Müller

Medullary plug, pressurization, and bone lavage had been used in Cases 9 and 10.

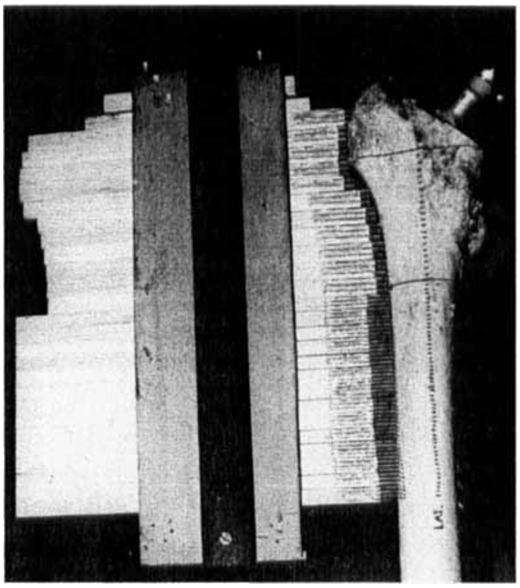

Figure 1. Marking device that can be contoured to the femur. A row of sliding boards, each of which carries three pins at the end, is radiographed alongside the femur. The pins will appear on the film, flanked by parallel lines to be numbered in correspondence with ink marks on the bone.

Results

In vitro cemented femora

It was not possible to differentiate from radiographs between good penetration of cement in the intratrabecular spaces and accumulations of broken trabeculi trapped within the cement. Sharply delineated radiolucencies were definitely not just related to interposition of blood, soft tissue, or air between bone and cement; similar radiolucencies were also seen as the result of either a specific arrangement in the proximity of the interface and in the femoral wall, or an irregular configuration of the border between cortex and cement, with macroscopically good alignment (Figures 2 and 3).

In the trochanteric region, the interpretation of radiolucencies was rendered highly speculative, because various structures in a cross section are superimposed on the plain radiographs (Figure 4).

In vivo cemented femora

In the two early postoperative specimens, thin patches of blood and small accumulations of broken trabeculi between bone and cement were clearly identified by macroscopic observation. The plain radiographs again were not conclusive, as was also the case in the in vitro cemented femora described above.

In the two late postoperative specimens, thin, but solid, sheets of new cortical bone, enveloping the cement and strutted by radially oriented trabeculi, were observed around the cement along the full length of the implant. On the plain radiographs, these sheets blended with the opacity of the cement, and thus were not visible (Figures 5 and 6).

Discussion

Although postoperative radiographic control is important to document major inadequacies (fractures, malpositioning, etc.), and serves as a baseline for later follow-up, a plain radiograph cannot be relied upon as a means to study the morphology of the cement-bone interface. In all the specimens, it was found that the predictive value of the conventional plain radiographs is extremely poor.

Our findings do not support the view of Lee and Ling (1983) that a lucent line, evident by visual inspection of films, is an indication of interposition of radiolucent material between bone and cement. The isolated radiograph of a cemented femur does not realistically represent the anatomic reality of the cement-bone interlock in terms of quality of implant fixation.

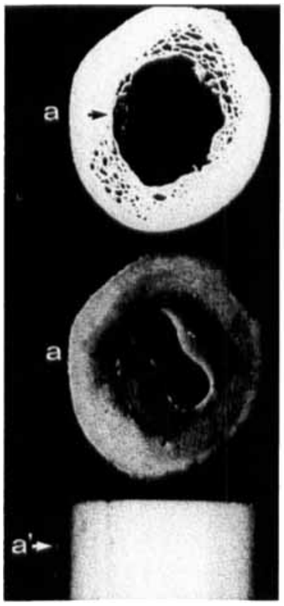

Figure 2. In vivo cementation. Patient succumbed postoperatively. Gross interposition of blood (a), giving a radiolucent line on plain radiograph (a´).

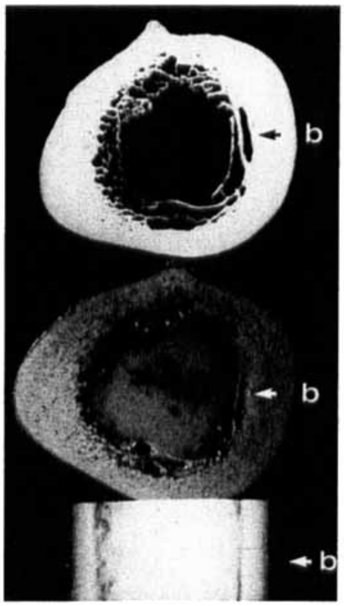

Figure 3. In vitro cementation following bone lavage and drying. No interposition, but specific trabecular arrangement in the femoral wall (b) giving radiolucent line on plain radiograph (b´).

Figure 4. In vitro cementation. Cross section at level of trochanter minor. The nonhomogeneous and lamellated appearance of the cement on the slices is not seen on the radiograph. The radiographic projection of the complex bone structure obscures the cement bone interface.

Interpretation of Figures 2, 3, 4, and 6. The figure at the bottom represents a part of the plain radiograph. The white line indicates at which level the cross section in the center of this figure is taken. The figure at the top is a contact radiograph of the same cross section. The cross sections at the top and the center are viewed from above.

Figure 5. In vivo cementation. Patient died 10 years postoperatively. No hip complaints. Radiograph suggestive of "poor quality cancellous bone."

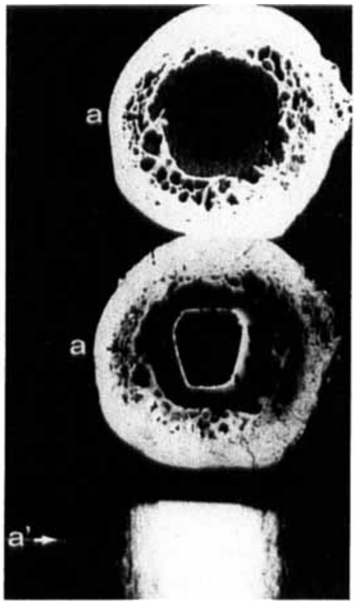

Figure 6. Cross section at white arrow level in Figure 5. The well-developed circumferential neocortical sheet anchoring the implant (a) is not detectable on the plain radiograph (a´).

Reference

Lee A J C, Ling R S M. Loosening. In: Complications of total hip replacement (Ed. Ling R S M). Churchill-Livingstone, Edinburgh 1983:110–45.