MECHANICAL LOOSENING OF TOTAL HIP PROSTHESES
A RADIOGRAPHIC AND ROENTGEN STEREOGRAPHOMETRIC STUDY

BENGT MJÖBERG, GÖRAN SELVIK, LARS INGVAR HANSSON, ROLF ROSENQVIST, ROLF ÖNNERFÄLT

From the Lund University Hospital, Lund

Twenty patients were examined by standard radiography and roentgen stereophotogrammetric analysis (RSA) during a two-year period after total hip arthroplasty. Eleven of the acetabular components migrated cranially and three femoral components migrated distally. This migration was most rapid during the first four months after operation. Our findings support the possibility that mechanical loosening is initiated by thermal injury during polymerisation of the cement; the less frequent migration of the metallic femoral component compared with the polyethylene acetabular component may be because the metal acts as a heat sink. Standard radiographs were inadequate for assessment of early mechanical loosening, whereas RSA could reveal migration within four months of the arthroplasty.

There is need for an objective and accurate method of evaluating the results of hip arthroplasty (Galante 1985). Radiographic criteria for mechanical loosening are not well defined (Bergström, Lidgren and Lindberg 1974; DeSmet, Kramer and Martel 1977; Dussault, Goldman and Ghelman 1977; Tehraniadeh, Schneider and Freiberger 1981; Carlsson and Gentz 1984); opinions differ on the location, width and extent of radiolucency which should be used as diagnostic criteria. Consequently, the reported rate of radiographic loosening varies from 1% to 29% for the acetabular component and from 9% to 41% for the femoral component (Charnley 1979; Carlsson and Gentz 1980; Carlsson 1981; Olsson, Jernberger and Tryggö 1981; Salvati et al. 1981; Stauffer 1982; Sutherland et al. 1982; Johnston and Crowninshield 1983). Confusion arises also from the fact that only some of these hips are painful (Charnley 1979; Carlsson and Gentz 1980; Stauffer 1982; Gudmundsson, Hedeboe and Kjaer 1985).

Roentgen stereophotogrammetric analysis (RSA), using tantalum bone markers, makes it possible to detect movement between body segments with a high degree of accuracy (Selvik 1974; Selvik, Alberius and Aronson 1983) and thus at an early stage detect prosthetic loosening defined as migration (Mjöberg et al. 1985). We have studied the pattern of migration of the components of hip prostheses with RSA and have compared the results with those of conventional radiography.

PATIENTS AND METHODS

Twenty patients, each with a Lubinus total hip replacement for osteoarthritis, were examined by RSA at intervals for two years after operation. The operative technique included reaming with preservation of most of the subchondral bone in the acetabulum, brushing, lavage and the injection of cement into a plugged femoral canal. Palacos R bone cement with gentamicin was used. At operation from 4 to 7 tantalum balls, of 0.8 mm diameter, were implanted into the iliac bone, the greater and lesser trochanters, and into the acetabular component (Fig. 1). Patients were permitted to take full weight on the operated leg within two days.

Stereoradiography, using two x-ray tubes with 40° between their central rays, was used to make simultaneous exposures; a reference plate incorporating tantalum balls was placed in front of the films. Before these investigations on patients, a glass-plexiglass cage including tantalum balls at known positions was used as a calibration device, and the positions of the x-ray tubes and reference plate remained the same. RSA was performed soon after operation, after four months, one year and two years. All stereo exposures were made with the patient supine and the hip relaxed. The films were measured in a photogrammetric instrument (Wild Autograph A8) supplied with television magnification,
and data was processed on a Sperry 1100 computer. The displacement of the acetabular component in relation to the tantalum balls in the pelvis, and of the head of the femoral component in relation to the balls in the trochanters were determined. Detailed descriptions of the technique and calculation have been published (Selvik 1974; Baldursson et al. 1979; Selvik et al. 1983).

Migration of the prosthetic components (Mjöberg et al. 1985) rather than that of markers in the surrounding bone cement (Green et al. 1983) was recorded, so that failures of all types (Gruen, McNeice and Amstutz 1979; Stauffer 1982) could be detected. The accuracy of RSA was evaluated by double examinations. Both acetabular and femoral component displacements were calculated for most of these examinations and the standard deviations of the displacements from zero (that is the expected mean difference within pairs) were estimated. Using Student's t-distribution, we calculated the minimal significant translations (at p < 0.01) for each of the x (transverse), y (longitudinal) and z (sagittal) axes. Standard anteroposterior and lateral radiographs were also taken at each assessment and the width of any radiolucent zone was measured, using a scale loupe with a magnification of seven.

RESULTS

Accuracy of RSA. In order to determine the experimental error double examinations were performed on 30 acetabular and 23 femoral components. The standard deviations for error of measurement of the acetabular component were 0.10, 0.06 and 0.23 mm for the x, y and z axes respectively. The corresponding values for the femoral component were 0.13, 0.06 and 0.25 mm. The minimal significant (p < 0.01) translations were found to be 0.28, 0.15 and 0.62 mm for the acetabular component, and 0.36, 0.17 and 0.70 mm for the femoral component for the x, y and z axes respectively. In view of this, measured displacements were not considered to be significant unless they exceeded 0.4, 0.2 and 0.8 mm for either of the prosthetic components along these axes. Migration measured by RSA. In the 20 hips studied 11 acetabular and three femoral components had migrated significantly when they were examined two years after arthroplasty. In all of these, except one acetabular component, migration was seen at the examination four

![Fig. 1](image1.png)

Plain radiograph of a hip arthroplasty to show 0.8 mm diameter tantalum balls positioned in the ilium, in the greater and lesser trochanters and in the acetabular component.

![Fig. 2](image2.png)

Diagram to show the mean migration along the longitudinal axis of the migrating components, 11 acetabular and three femoral. Vertical bars indicate the s.e.m.
months after operation (Table I). After an initial period of rapid migration most of the migrating components moved more slowly (Fig. 2). After two years the 11 migrating acetabular components had moved from 0.2 to 1.8 mm cranially, one also had moved 0.8 mm medially, but none had moved along the z axis, while the three migrating femoral components had moved 0.3 to 0.6 mm distally, but none had moved along the other two axes. The remaining nine acetabular and 17 femoral components did not migrate during the period of observation.

**Radiographic observations.** An incomplete radiolucency zone between cement and bone had developed four months after surgery in all but two acetabular and four femoral components. No radiolucency was seen between the cement and the stem of the femoral components and no fractures were detected in the cement.

Of the two acetabular components without radiolucency one was migrating and one was not. All the other acetabular components (10 migrating, eight non-migrating) had an incomplete radiolucent zone with a maximum width of 0.5 to 1 mm at four months. The zone remained unchanged in all but the three acetabular components which showed the most rapid migration (0.7, 1.4 and 1.8 mm after two years); in these the zone became complete with a maximum width of 1 to 2 mm.

Four of the 17 non-migrating femoral components showed no radiolucency, while an incomplete zone adjacent to cortical bone, with a maximum width of 0.5 to 1 mm, developed within one year in seven patients and an incomplete zone adjacent to cancellous bone, with a maximum width of 0.5 to 2 mm, developed within one year in 12 patients. In one of the three migrating femoral components an incomplete radiolucent zone adjacent to cortical bone, up to 0.5 mm wide, developed within a year, but the other two had no radiolucent zone adjacent to the cortical bone. All three developed an incomplete radiolucent zone 0.5 to 1 mm wide at the interface with cancellous bone. There were no progressive radiolucencies around the femoral components after the first year, whether they were migrating or non-migrating. In all femoral components a 2 to 4 mm wide resorption zone in the cortical bone beneath the prosthetic collar developed, mainly within four months, but did not increase in width after the first year (Figs 3 to 6).

**DISCUSSION**

The pattern of initial migration in this series may be caused by thermal necrosis of bone during polymerisation of the cement (Feith 1975; Huiskes 1980; Mjöberg, Pettersson et al. 1984). During the first four months after operation most of this necrotic bone is resorbed and allows of rather rapid migration (Fig. 2). The more frequent migration of the polyethylene acetabular component compared to the metallic femoral component (Table I, p < 0.01, Fisher's exact test) may be explained by heat conduction away from bone and into the metal (Reckling and Dillon 1977; Huiskes 1980). After thermal necrosis, the cement becomes separated from the bone by a fibrous tissue membrane containing macrophages (Willert, Ludwig and Semlitsch 1974; Feith 1975) and this is capable of bone resorption when it is stimulated by micromovement (Goldring et al. 1983; Linder, Lindberg and Carlsson 1983; Linder et al. 1984) (Fig. 2).
Permanent anchorage of bone to titanium implants is possible (Brånenmark et al. 1977; Albrektsson et al. 1981) and close contact between viable bone and cement is also possible (Charnley 1979; Drenner 1981; Linder and Hansson 1983; Linder et al. 1984). In our series, of 10 acetabular and 17 femoral components which did not migrate initially, only one migrated 0.2 mm, the lower limit for significance, later in the period of observation (Table I).

Non-progressive resorption of bone beneath the collar of the femoral component (Figs 3 to 6) was found in all our cases, and may be explained by thermal necrosis during cutting of the bone (Tetsch 1974; Krause et al. 1982; Eriksson and Albrektsson 1983, 1984). The biomechanical advantage of a collar is debatable (Oh and Harris 1978; Charnley 1979; Jacob and Huggler 1980; Markolf, Amstutz and Hirschowitz 1980; Crowninshield et al. 1981; Lewis et al. 1984). The fact that most femoral components without collar to bone contact in our series did not migrate indicates, however, that the collar is not essential.

The reported pattern of clinical failures of total hip prostheses (Charnley 1979; Stauffer 1982; Sutherland et al. 1982) may also be explained by thermal injury during polymerisation followed by the induced stresses of normal activities. The femoral component is subject to greater shear stresses than the acetabular component during walking and, especially, during stair climbing and rising from a chair (Paul 1972; Crowninshield et al. 1978; Mjöberg, Hansson and Selvik 1984); slightly loose femoral components can be expected in time to develop larger micromovements and thus earlier clinical failure than most loose acetabular components. We found much more early loosening of acetabular than of femoral components (Table I); loose acetabular components can be expected to be more common in late clinical failures.

The presence of large resorption lacunae in bone adjacent to cement does not exclude there being other areas of close contact (Charnley 1979; Drenner 1981; Linder and Hansson 1983; Linder et al. 1984); in our series eight acetabular and 13 femoral non-migrating components had an incomplete radiolucent zone at the bone–cement interface. Conversely, the absence of a radiolucent zone does not exclude early loosening of a prosthetic component. Apart from the difficulty of determining the presence and the degree of radiolucency (Brand, Yoder and Pedersen 1985), the zone may gradually be obliterated by the migrating component. We found that one acetabular and two femoral components known to have migrated showed no radiolucent zone adjacent to the cortical bone. Thus, radiographic examination is inadequate in assessing mechanical loosening, but roentgen stereophotogrammetric analysis can reveal migration within four months of arthroplasty.

This study was sponsored by the Greta and Johan Kock Foundations, the Sven and Dagmar Salén Foundations and Alfred Österlund Foundation.

REFERENCES


BRIEF REPORT

A SIMPLE TECHNIQUE FOR ARTHRODESIS OF THE FIRST METATARSPORTHALANGEAL JOINT

J. E. PHILLIPS, G. HOOPER

Arthrodesis of the first metatarsophalangeal joint is often used to treat hallux rigidus and hallux valgus and, when correctly performed, the reported results have been excellent. Ideally the method of fixation should allow accurate positioning, it should result in firm fixation preferably with compression, and it should not require elaborate equipment (Fitzgerald and Wilkinson 1981). We have used a simple method of wiring based on the technique described by Lister (1978) for stabilising digits.

Technique. The joint is exposed through a dorsal incision centred over the joint. The extensor tendon is retracted laterally and sufficient soft tissue cleared from the metatarsal and proximal phalanx to allow subsequent insertion of the wire loop. The joint surfaces and any osteophytes are removed with gouges and a rongeur, care being taken to maintain the general contour of the joint. A loop of 20 SWG wire is passed through transverse drill holes made in the bones about 1 cm from the joint. A 0.062-inch Kirschner wire is driven obliquely into the