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Instability, migration and laxity of total hip prostheses

A roentgen stereophotogrammetric study

Roentgen stereophotogrammetric analysis was used in the evaluation of clinical and/or radiographic problems in 28 total hip replacements without suspicion of infection. Instability of the acetabular and/or the femoral component was revealed in 14 cases. In 21 cases, examined twice, migration of the acetabular component was found in eight cases and migration of the femoral component in 15 cases. The method allows instability and migration of the prosthetic components as well as joint laxity to be determined with a high degree of accuracy.

Key words: biostereometrics; hip; hip prosthesis; joint prosthesis, loosening; roentgen stereophotogrammetry.

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Mechanical loosening has become the most common reason for revision arthroplasty (Ahnfelt et al. 1982). Conventional radiography, contrast arthrography and scintigraphy however, provide insufficient information about loosening. A technique for roentgen stereophotogrammetric analysis (RSA) has been developed (Selvik 1974) and used in analysing skeletal problems. In the present study loosening, i.e. instability and/or migration, but also joint laxity were recorded by RSA in cases with clinical and/or radiographic problems following hip arthroplasties.

Patients and methods

Patients

Twenty-eight hips (26 patients) with primary arthroplasty because of osteoarthrosis were investigated 6 (0.5–12) years after surgery. There were 11 Lubinus, two Brunswik, 14 Charnley and one Christiansen prostheses. The patients were submitted to RSA because of pain and/or radiographic changes. There was pain in 24 hips, while four hips were pain-free. Twenty-one hips were subjected to RSA twice or more often. The period of investigation was 10 (5–20) months.

Two asymptomatic hips without radiographic changes (two patients) with primary arthroplasty according to Charnley because of osteoarthrosis were used as controls.

Hip arthroplasties with a suspicion of infection based on clinical, radiographic or laboratory findings were excluded.

Method

Radiographic changes indicating loosening were considered to be present if there was:

1. A radiolucent zone between cement and bone of 2 mm or more;
2. A radiolucent zone between a prosthetic component and cement; or
3. A fracture of cement or of the femoral component.

Under local anaesthesia with the aid of fluoroscopy 3–5 tantalum balls, diameter 0.8 mm, were implanted percutaneously into the os ilium and into the trochanter major. A detailed description of the RSA technique and calculations has been presented by Selvik (1974). See further Baldursson et al. (1979, 1980) and Mogensen et al. (1982).

One stereoexposure was made with the hip loaded and one with the hip unloaded. Load was applied to the hip either by standing on the examined leg only or by the examiner compressing the hip in the axial direction with the patient in a supine position. The unloaded examination was performed either with the leg hanging or by distraction of the joint with the patient supine.

The term "instability" is used for bone-prosthetic component displacement under loading, "migration" for corresponding displacement with time (between loaded positions) and "laxity" for displacement between the components under loaded and unloaded positions at the same investigation.

The accuracy of the method was evaluated by double examinations under weight-bearing conditions. The acetabular and femoral component displacements were calculated for these double examinations and the standard deviations of the displacements (errors) were determined using the formula

$$s_r = \sqrt{\frac{1}{n}\sum_{i=1}^{n} \Delta r_i^2}, \quad r = x, y, z.$$

Then, using Student's *t*-test, the significant translations ($p < 0.01$) were determined for the x- (transversal), y- (frontal) and z-(sagittal) -axis.

Results

Radiographic changes

Among the 24 painful hips there were radiographic changes indicating loosening of the acetabular component in six and of the femoral component in 17, while there were no radiographic changes in seven hips. In the four pain-free hips there were radiographic changes of the acetabular component in one hip and of the femoral component in all four hips.

Accuracy of RSA

Ten pelvic and 14 femoral double examinations were obtained. The standard deviations for the acetabular component were 0.29, 0.14 and 0.54 mm for the x-, y- and z-axis, respectively. The corresponding values for the femoral component were 0.12, 0.13 and 0.51 mm. Using Student's *t*-test, the minimal significant translations ($p < 0.01$) were found to be 0.91, 0.44 and 1.72 mm for the acetabular component, and 0.35, 0.38 and 1.52 mm for the femoral component for the x-, y- and z-axis, respectively. However, because of the not quite Gaussian character of the distribution of errors, especially for the acetabular component, displacements were not considered significant unless they exceeded 1.0, 0.5 and 2.0 mm for the acetabular component and 0.4, 0.4 and 1.6 mm for the femoral component for the x-, y- and z-axis, respectively. The significance limits for the acetabular component were also used for laxity.

The two hips that were pain-free and without radiographic changes showed no instability or migration of any component during 9 and 25 months, respectively. One case showed 1.7 mm laxity while the other case showed no laxity at all.

Instability

Two acetabular components showed instability only along the x-axis, five only along the y-axis, four along both the x- and y-axes, but none showed instability along the z-axis. The distribution of instability of the acetabular component along the y-axis is shown in Figure 1. Three acetabular components were unstable for about 3 mm along the x-axis.

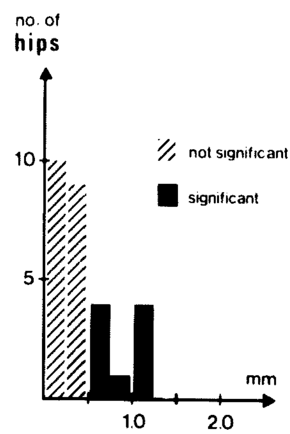

Figure 1. Instability of the acetabular component along the frontal axis in 28 hips.

Of the 11 unstable acetabular components, only three showed corresponding radiographic changes, while three acetabular components without instability showed radiographic changes (Figure 2).

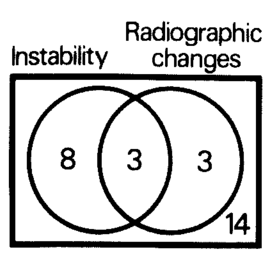

Figure 2. Correlation between instability and radiographic changes of the acetabular component in 28 hips.

Three femoral components showed instability only along the x-axis, three only along the y-axis, five along two or all three axes, but none showed instability along the z-axis alone. The distribution of instability of the femoral component (IF) along the y-axis is shown in Figure 3. One femoral component was extraordinarily unstable (IF_x = 9.3, IF_y = 6.1 and IF_z = 1.6 mm) and a subsequent radiograph showed fracture of the femoral stem.

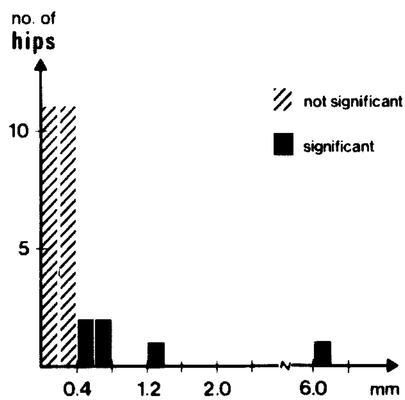

Figure 3. Instability of the femoral component along the frontal axis.

Of the 11 unstable femoral components, ten showed corresponding radiographic changes, while eight femoral components without instability showed radiographic changes (Figure 4).

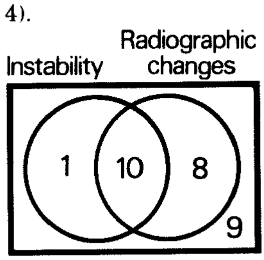

Figure 4. Correlation between instability and radiographic changes of the femoral components in 28 hips.

There was no instability of any component in 14 hips.

Migration

Two acetabular components migrated only along the x-axis, two only along the y-axis, four along both x- and y-axes, but none along the z-axis. The distribution of migration of the acetabular component along the y-axis is shown in Figure 5. One acetabular component migrated 3.1 mm along the x-axis in 11 months and one migrated 3.5 mm along the y-axis in 16 months.

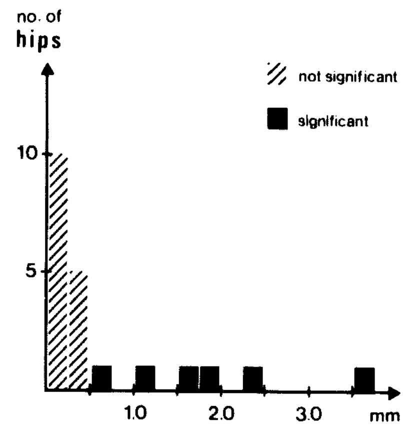

Figure 5. Migration of the acetabular component along the frontal axis in 21 hips.

Of eight unstable acetabular components, six migrated and of eight migrating acetabular components six were unstable (Figure 6). Of the eight acetabular components with migration, three showed radiographic changes. No acetabular component without migration showed radiographic changes.

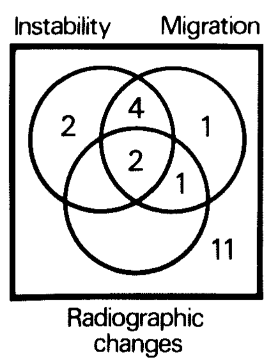

Figure 6. Correlation between instability, migration and radiographic changes of the acetabular components in 21 hips.

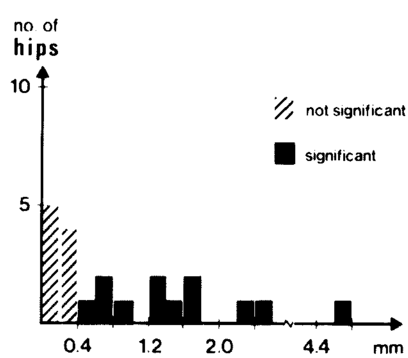

Figure 7. Migration of the femoral component along the frontal axis in 21 hips.

One femoral component migrated only along the x-axis, five only along the y-axis, six along two or three axes, but none along the z-axis alone. The distribution of migration of the femoral component (MF) along the y-axis is shown in Figure 7. One femoral component showed an extraordinary migration (MF_x = 1.7, MF_y = 4.8 and MF_z = 4.4 mm) in 9 months.

Of seven unstable femoral components five migrated, but of 12 migrating femoral components, only five were unstable (Figure 8). Of the 12 femoral components with migration, ten showed radiographic changes. Four femoral components without migration showed radiographic changes.

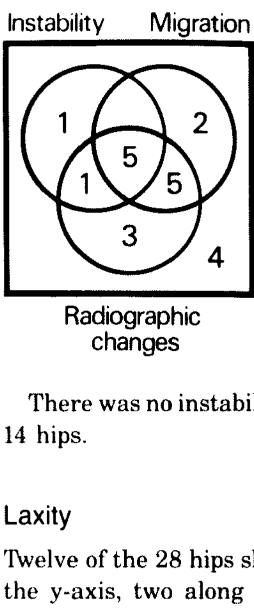

Figure 8. Correlation between instability, migration and radiographic changes of the femoral component in 21 hips.

There was no instability of any component in 14 hips.

Laxity

Twelve of the 28 hips showed laxity only along the y-axis, two along the x- and y-axes, but none along the z-axis. Four showed more than 2 (max 4.7) mm laxity.

Discussion

Mechanical loosening has now become the most common serious local complication after total hip replacement. In a recent report of reoperated cases in a Swedish multicentre study (Ahnfelt et al. 1982), change or extraction of one or both prosthetic components was performed because of mechanical loosening in 75 per cent and joint dislocations in 10 per cent, but because of infection only in 15 per cent.

In conventional radiography, radiolucent zones, migration of a prosthetic component and fractures of the cement or of the femoral component have been used to define mechanical loosening. The reported rate of loosening in the metal-to-polyethylene type of prosthesis varies between 11 and 29 per cent for the acetabular component and between 30 and 41 per cent for the femoral component in 10-year follow-up studies (Charnley 1979, Salvati et al. 1981, Stauffer 1982, Sutherland 1982). However, only some of these hips are painful (Charnley 1979, Carlsson & Gentz 1980).

Some pain-free hips show fractures of the cement at the tip of the femoral component. This could be explained by subsidence of the femoral component to a new stable position (Weber & Charnley 1975). Two types of zones at the bone-cement interface have been characterized (Salvati et al. 1976): one innocuous zone not exceeding 2 mm and one zone that progressively widens beyond 2 mm, indicating infection or mechanical loosening. Gruen et al. (1979) have characterized several modes of loosening of the femoral component, but Miller et al. (1978) and Stauffer (1982) suggested that there are only two basic failure mechanisms: failure at the stem-cement interface as a result of cement fracture and failure at the bone-cement interface.

RSA has been used in Lund since 1976 to study instability, migration and wear of total hip replacement (Baldursson et al. 1979, 1980, Mogensen et al. 1982). Similar techniques have been employed (Lippert et al. 1978, Hunter et al. 1979, Probst 1980), but simultaneous exposures of both projections were not used. In the present study simultaneous stereo exposures were taken with the hip loaded or unloaded, and the radiographic equipment was carefully calibrated.

There was a good correlation between instability and migration of the acetabular component (Figure 6). Most unstable components migrated, but many migrating femoral components were stable (Figure 8). This supports the suggestion that the femoral component can subside to a lower and stable position (Weber & Charnley 1975).

Most unstable and/or migrating acetabular components showed no radiographic changes

(Figure 6). Thus, the radiographic criteria are not sensitive enough in detecting loosening of the acetabular component.

Almost all unstable and/or migrating femoral components showed radiographic changes, but in several cases there were radiographic changes without instability and/or migration (Figure 8). Thus radiographic changes are almost necessary but not sufficient for instability and/or migration of the femoral component detectable by RSA.

All hips with laxity showed laxity along the frontal axis. This stands to reason in the light of the geometry of the acetabular component. However, no hip had presented problems related to laxity.

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