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Instability of total hip prostheses at rotational stress

A roentgen stereophotogrammetric study

Roentgen stereophotogrammetric analysis (RSA) has been carried out on 24 total hip prostheses (24 patients), which were all painful at weight-bearing. The examinations were made with the hip at distraction, compression, external and internal rotation. One acetabular component showed instability only at distraction-compression and one showed instability only at rotation. Four femoral components showed instability at distraction-compression and at rotation, six only at rotation, but none showed instability only at distraction-compression.
Thus rotational provocation demonstrated instability in all unstable femoral components; rotational stress must be of importance in mechanical loosening of the femoral component.

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Roentgen stereophotogrammetric analysis (RSA), using tantalum bone markers, makes it possible to detect movements between body segments with high accuracy (Selvik 1974, 1983) and the technique has been used to disclose loosening of total hip prostheses. This method has been found superior to serial radiographic examinations.

In an earlier report (Mjöberg et al. 1984), RSA showed excessive migration (4.8 mm in 9 months) in the distal direction of one femoral component, but no instability at distraction-compression. At revision, the femoral component was found to be stable in the longitudinal direction, but unstable in the femoral canal at rotation.

In the present study, therefore, rotation has also been used to test instability of the prosthetic components.

Patients and methods

Twenty-four patients with 24 total hip prostheses were investigated by RSA (Mjöberg et al. 1984). There were 15 Lubinus, three Brunswik and six Charnley prostheses. Total hip replacement was performed because of osteoarthrosis (21), non-union after femoral neck fracture (2) and Mb Bechterew (1); there were nine revision arthroplasties. All the hips were painful at weight-bearing. There were radiographic changes indicating loosening (Mjöberg et al. 1984) of the acetabular component in five hips, and of the femoral component in ten, while there were no radiographic changes in ten hips. There were no signs of infection.

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. Detailed descriptions of the RSA technique and calculations have been given by Selvik (1974), Baldursson et al. (1979, 1980) and Mogensen et al. (1982).

The stereo exposures were made with the hip at distraction, compression, external rotation and internal rotation, with the patient in a supine position. These loads were applied manually by the examiner (B.M.) and were estimated to be 200–250 N and 30–35 Nm, respectively.

In our earlier report (Mjöberg et al. 1984), the lower limit for significant translations ($p < 0.01$) was found to be 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 along the x-(transversal), y-(frontal) and z-(sagittal) axis, respectively.

Results

Of the 24 hips, one acetabular component showed instability at distraction-compression (0.6 mm along the y-axis) and one at external-internal rotation (0.5 mm along the y-axis).

Of the 24 hips, four femoral components showed instability at distraction-compression (0.8–2.2 mm along the x-axis in two cases, 0.5–6.8 mm along the y-axis in all four cases and

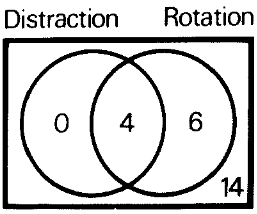

Figure 1. Instability of the femoral component revealed at distraction-compression and at rotation in 24 hips.

3.2 mm along the z-axis in one case) and at external-internal rotation (0.5–1.7 mm along the x-axis in three cases, 0.4–2.7 mm along the y-axis in two cases and 2.3–6.0 mm along the z-axis in two cases), six only at external-internal rotation(0.5–3.4 mm along the x-axis in all six cases and 0.7–2.5 mm along the y-axis in two cases), but none showed instability only at distraction-compression (Figure 1). Thus, distraction-compression revealed instability in four femoral components, none unstable at distraction-compression alone, whereas rotation revealed instability in ten femoral components and of these six were unstable only at rotation ($p < 0.02$, Fisher's exact test).

Discussion

In this study, the low rate of observed instability of the acetabular component, despite radiographic changes, may be due to a still efficient macrointerlock (by anchorage holes into the acetabulum) or to the registration of translations of the acetabular component centre only; rotation about this centre (Charnley 1979, Baldursson et al. 1980) may be a more common mode of instability.

Rotational stress has been ignored in almost all studies on loosening of the femoral component (Lee & Ling 1984); most clinical (Gruen et al. 1979), theoretical (Huiskes 1980) and experimental (Markolf et al. 1980, Savino et al. 1982) biomechanical models have been confined to the frontal plane. By direct measurement, using a strain gauge supplied femoral component in two living persons, Rydell (1966) showed that there is a considerable dorsally directed force acting on the head at heel-strike and in flexion. Indirectly, by gait analysis, Crowninshield et al. (1978) and Berme & Paul (1979) found a considerable axial torque acting on the femoral component and suggested that this may be of importance in mechanical loosening. Wroblewski (1979) found backward bending in 65 out of 70 fractured Charnley stems. Hampton et al. (1980), in a three-dimensional, finite element model of the femoral component, determined the stress distribution along the stem at bending in the sagittal plane due to a posteriorly directed load, but did not consider the associated rotational stress.

The radius of the femoral canal and of the femoral component is small compared to the moment arm from the femoral axis to the head; a considerable torsional shear stress develops at the bone-cement and the stem-cement interfaces, respectively. Thus, in addition to pistoning and bending, rotation must be a mode of loosening of the femoral component; rotational instability was found in all ten unstable femoral components and of these six were unstable only in rotation (Figure 1).

In conclusion, rotational provocation is important in demonstrating instability of hip prostheses, and rotational stress deserved attention in biomechanical models on loosening of the femoral component.

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