SUBSIDENCE OF THE FEMORAL PROSTHESIS IN TOTAL HIP REPLACEMENT IN RELATION TO THE DESIGN OF THE STEM

JAMES R. LOUDON, JOHN CHARNLEY

From the Victoria Infirmary, Glasgow and The Hip Centre, Wrightington Hospital, Wigan

A method is described of measuring radiological subsidence of a femoral prosthesis in relation to the femur after total hip arthroplasty. The method depends on measuring the distance from the tip of the femoral prosthesis to a fixed point in the bone.

Subsidence after the use of a conventional design of femoral stem is compared with that after the use of a stem with a dorsal flange (Cobra). A significant reduction in the incidence and amount of subsidence was found when using the dorsal flange. There was also a notable absence of transverse fractures involving the cement near the tip of the stem, which occurred in 26 per cent of the cases using a conventional prosthesis.

To make accurate radiological measurements of the subsidence of a femoral prosthesis in relation to the cement, and the cement in relation to the femur, would necessitate a complex technique with devices implanted for this purpose at the time of the operation. In the absence of special radiological aids the best that can be done is to compare the level of the tip of the femoral prosthesis with a point in the system of wires used to attach the trochanter chosen as a datum to represent the femur. After testing the accuracy of the method it is hoped that in the clinical application the number of measurements which lie outside the limits of error will be sufficient to permit firm conclusions to be drawn.

METHOD

A constant point in the wiring of the trochanter is the site where a double wire passes through a drill hole in the lateral femoral cortex about one inch distal to the vastus lateralis ridge. At this point the wire is also partially fixed by cement. The wire must remain at this point even though the wires may be distorted, or even fractured, at other parts in the wiring system. The reference point for the femoral prosthesis is the most distal level of the tip of the stem.

All measurements are made in a line parallel to the axis of the distal two-thirds of the stem of the Charnley prosthesis, which in the anteroposterior view has the configuration of a straight taper. The levels of the datum points for the prosthesis and the bone are drawn as perpendicularly to the longitudinal axis of the stem. In this way errors which could result from different amounts of lateral rotation are minimised; this would not be the case if measurements were made obliquely between the tip of the prosthesis and the wire.

The practical details of making the measurements are important. The radiograph is placed on a horizontal viewing box and two mid-points are measured on the distal (straight) part of the stem and marked on the film. A line indicating the central axis of the stem is ruled through these points and extended proximally. A T-square and a 90 degree protractor are used to draw a fine pencil line vertically on a sheet of tracing paper permanently fixed to the face of the viewing box. All radiographs are temporarily attached to the surface of the viewing box with easily detachable adhesive labels, and the axis of the stem which is already marked on the film is made to coincide with the line drawn on the viewing box. The T-square is then used to draw lines perpendicular to the axis of the stem of the prosthesis through the three datum points (Fig. 1): C is tangential to the summit of the prosthetic femoral head, B is at an agreed point where the wire passes through the lateral femoral cortex, and A is tangential to the distal tip of the stem.

Fig. 1
The method of ruling lines on the radiographs.

AC and AB are measured to the nearest 0.5 millimetre. From the measurement AC the radiological magnification can be calculated because the same measurement on the unmagnified prosthesis is known to be 155 millimetres. (For speed of working a table covering the common range of magnified images to the nearest 0.5 millimetre was previously constructed. As measurements are taken to the nearest 0.5 millimetre it is important to calculate the magnification factor to four places of decimals.) All measurements are made on standard clinical radiographs, at a distance of one metre from the tube which is centred on the symphysis pubis in order to include both hips.

Accuracy of the method. The following experiments were made to assess the accuracy of the method.

Experiment 1. Fifty different radiographs were measured twice. After
the first measurement the pencil lines were erased and new lines were drawn for the second measurement. For each pair of readings subtraction of the first from the second measurement (corrected for magnification) in this series should have given a zero result, but the average for the series of 100 measurements fell on the side of subsidence by the very small amount of 0.04 millimetre. The standard deviation from the mean was 0.38 millimetre. In the interests of accuracy it was decided to exclude all cases where the subsidence was less than four times the standard deviation derived from this test. This meant discarding all cases with subsidence of less than 1.6 millimetres. Experiment 2. The two authors measured independently the early and late radiographs of 14 patients, the second observer erasing the other's pencil lines and drawing his own. After calculating the magnification, the results for subsidence were compared. In 11 of the 14 hips (78.6 per cent) the measurements were within 1.5 millimetres of each other and of the remaining three, one differed by 1.9 millimetres, and two by 2.0 millimetres.

**CLINICAL MATERIAL**

Two groups of patients were studied: one group had the conventional design of prosthetic femoral stem, the other the Charnley design of flanged (Cobra) stem. The conventional design of prosthesis stem sheds much of its load on to the cement in the region of the medial femoral neck, over an area corresponding to a projection of the thickness of the upper part of the stem. The Charnley design of flanged stem (Fig. 2) increases the area of cement receiving the load in the upper end of the femur by means of the larger area of the flanges lying anterior and posterior to the stem. In order to standardise surgical technique as far as possible the cases had all been operated on by the senior author (JC).

The group representing the conventional design of stem comprised 100 consecutive hips operated on over the period 1971 to 1972. The group with flanged stems comprised 75 consecutive hips operated on in 1977. The control radiograph was that taken just before discharge from hospital, which was usually 14 days after operation. The film for comparison was that made about 12 months after operation and in some cases again after two years.

Scrutiny of the radio-opaque cement for the purpose of quantitating abnormal signs proved unsatisfactory, with the exception of transverse fractures of the cement in the vicinity of the tip of the prosthesis. This radiological sequel can be recognised unequivocally and previous work (Weber and Charnley 1975) has shown that the majority of instances presented before the end of the first year.

**RESULTS**

**Subsidence.** Taking measurements in excess of 1.6 millimetres as proof of subsidence, 43 (43 per cent) of the 100 prostheses with conventional stems showed subsidence. However, with the same criteria, only four (5.3 per cent) of the 75 prostheses with the flanged (Cobra) design of stem showed subsidence. The distribution of subsidence is shown as histograms in Figures 3 and 4. The mean subsidence for the 100

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**Figure 3**—A histogram showing the subsidence of prostheses with the conventional design of stem. **Figure 4**—A histogram showing the subsidence of prostheses with the Charnley design of flanged stem.
conventional stems was 1.92 millimetres and for the 75 flanged stems was 0.53 millimetre.

In the case of the conventional design of stem 43 prostheses subsided by over 1.6 millimetres, the maximum being 10 millimetres. Only four Cobra prostheses subsided by more than 1.6 millimetres, and none by more than 3.0 millimetres. 

**Cement tip fracture.** The appearance of a fracture of the cement, especially when the transverse gap measures more than one or two millimetres, is logically ascribed to subsidence of the prosthesis within the cement (Figs 5 and 6). In the series with conventional design of stem, 26 hips (26 per cent) showed transverse fractures of cement in the vicinity of the tip of the prosthesis and this was associated with subsidence averaging 3.86 millimetres ± 2.09 millimetres. There were no cases of fractures of the cement tip in the series with the flanged design of prosthetic stem.

Figure 5—Radiograph 14 days after operation. Figure 6—Radiograph 14 months after operation. The subsidence measured radiographically was two millimetres which is of the same order as the gap in the separation of the fractured cement.

Figure 7—A typical gap between the cement and convex lateral border of the upper part of the stem with a conventional design of prosthesis. Figure 8—The line of condensation between the metal of the prosthesis and the cancellous bone of the trochanter, without intervention of cement, in the case of the flanged design of femoral prosthesis.
Demarcation of the convex lateral border. Subsidence of a prosthesis can sometimes be detected by the appearance of a gap between the convex lateral surface of the upper part of the stem of the prosthesis and the adjacent cement. It is a difficult sign to quantify because routine radiographs, which are not centred on the prosthesis, can minimise its appearance. Due to the lack of precision in grading the sign has not been included in this study, but it is important to record that a radiographic appearance suggestive of subsidence has been seen with the flanged prosthesis unaccompanied by measurable subsidence (Figs 7 and 8). It seems certain that this feature is produced by a quite different cause—a thin line of sclerosis on the cut cancellous surface of the trochanter facing the convex lateral surface of the prosthesis with no cement intervening. This does not occur with the conventional design of prosthetic stem because the exposure of the lateral surface of the stem is never as great as when a stem with the wide dorsal flange is used.

DISCUSSION

The decision not to accept any measurement of subsidence less than 1.6 millimetres resulted in only 5.3 per cent of the hips with flanged prostheses and 43 per cent of the non-flanged series being valid for study. In the whole study of 175 hips there were 35 (20 per cent) where the results seemed to indicate that the prosthesis had ascended in the medullary canal, but because these were all within the 1.6 millimetre limit they were ignored. In view of the limits of accuracy of the method the existence of a number of results apparently indicating ascent of the prosthesis is to be expected, especially where in fact no subsidence has taken place. Therefore cases of apparent ascent confirm the assessment of accuracy made in the original direct tests.

The efficacy of the flanged design of prosthesis in reducing the incidence and the amount of subsidence is clearly established by these findings, but they cannot be used to distinguish between subsidence inside the cement and subsidence of the prosthesis together with the cement. The fact that 26 per cent of the non-flanged stems showed transverse fractures of the tip of the cement suggests that subsidence within the cement is the most likely mechanism with the non-flanged design of stem. The incidence of transverse fracture of the cement in the vicinity of the tip of the femoral prosthesis has received rather different estimates by different workers in this unit. Weber and Charnley (1975) estimated the incidence using conventional stems at 1.5 per cent, but Bocco, Langan and Charnley (1977) found an incidence of 20.2 per cent when a conventional prosthesis was inserted in the medial femoral neck with cement averaging only 4.5 millimetres in thickness, and 3.1 per cent when the thickness of the cement at this point averaged 13.2 millimetres. The latter thickness of cement is the result of the valgus position in male subjects. In a study by Griffith et al. (1978) the incidence of transverse fracture of the cement near the tip of the conventional prosthesis was 8.6 per cent.

The combination of no fractures at the tip of the cement combined with a significantly reduced incidence and amount of subsidence indicates that the flanged design of prosthesis must be making better use of the cement in the upper levels of the medullary canal than does the non-flanged design. This evidence supports the possibility of reducing the incidence of fatigue fractures of femoral prostheses by means of the design of the stem rather than by metallurgy alone.

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REFERENCES

