THE MEASUREMENT OF MIGRATION OF THE ACETABULAR COMPONENT OF HIP PROSTHESES

D. NUNN, M. A. R. FREEMAN, P. F. HILL, S. J. W. EVANS

From the London Hospital Medical College, London

Individual components of a total hip replacement are difficult to evaluate and quantify. We have studied the assessment of the acetabular component, and conclude that the measurement of migration allows the comparison of implants, although there is no established link between migration and significant loosening. A method of measurement based on clinical radiographs has been developed, and its limitations estimated. The accuracy of the technique was calculated to be ±3 mm.

Individual components of total hip replacement cannot be assessed by clinical means, since symptoms are not component-specific. Furthermore, clinical features are difficult to quantify reliably. Radiological assessment, however, offers a practical method to obtain objective information about a specific component.

What is the radiological evidence of failure of implant fixation, and how can it be measured? Failure of fixation may be considered with respect to movement of the implant relative to the pelvis and abnormalities of the interface between the implant and the bone. When either of these factors is gross or progressive the diagnosis of loosening is straightforward. However, minor changes are hard to assess and their clinical significance is not established, although there is general agreement that a complete, concentric radiolucency of 2 mm indicates a 'loose' prosthesis (DeLee and Charnley 1976; Ranawat, Dorr and Inglis 1980; Dorr, Takei and Conaty 1983). The demonstration of radiolucent lines, however, depends on X-ray penetration, patient position and the contrast between juxtaposed materials of different radiodensity. They are only visible when the X-ray beam is directed perpendicular to a parallel-sided interface, and are difficult to quantify.

Small movements (range 0.1 to 1.0 mm) between the prosthesis and bone can also occur, and may indeed be universal (Ryd 1986). Migration is a term that may be used to denote such micromotion over time. Measurement of migration of an acetabular component requires the detection of relative motion between the prosthesis and the pelvis. At the acetabulum, roentgen stereophotogrammetric analysis (RSA) can detect translational migration of about 0.5 mm along all three axes and rotation to fractions of a degree (Baldursson et al 1980). In contrast, 'pencil and ruler' estimations have been reported as accurate to within 5 mm (Sutherland et al 1982). Unfortunately, RSA requires the insertion of ball markers into the prosthesis and the bone at operation and expensive radiographic and computer facilities; it is thus not practical in the assessment of large numbers of patients and cannot be used retrospectively.

What radiographic views are required? If two radiographs are to be compared, it is essential that the views should be as nearly as possible identical. To this end an anteroposterior radiograph of the pelvis is preferable to one of the hip alone because the position of the centre beam is more easily standardised and because the detection of rotational differences in a series of radiographs is easier. Lateral and oblique views are much more difficult to standardise, since positioning of the patient is often awkward and in obese patients the beam cannot be centred easily. Interpretation is difficult because contralateral structures are superimposed on the hip.

We believe that the measurement of migration offers a quantifiable method of evaluation and comparison; but in practice, without the aid of RSA, migration can only be measured in the plane of the radiograph, that is in two dimensions only. We have, therefore, sought to measure the apparent vertical and mediolateral 'migration' of a single point on the image of the acetabular component on standardised anteroposterior pelvic radiographs. We
hoped that, although incomplete, this description of prosthetic migration would provide a clinically useful, discriminatory and quantifiable account of implant behaviour.

The next problem is that of the choice of fixed points on the radiographic image. On the pelvic side, the 'teardrops' are a reasonably constant landmark, being a projection of the inferior margin of the acetabulum, and lying in the same plane as the prosthesis (Sutherland et al 1982; Callaghan et al 1985). A fixed point in the component is more difficult to place. An unmarked polyethylene cup is radiolucent. Ball markers can only be placed eccentrically, and if rotation of the implant then occurs, movement of the markers could be misinterpreted as translation in the vertical or horizontal planes. Rotation of the cup has been measured using a wire ring in the periphery of the prosthesis (Sutherland et al 1982), but all markers are obscured if the prosthesis is metal-backed.

As an alternative, the centre of the prosthetic femoral head may be used as an indirect marker. Three assumptions must then be made: that the head is always in concentric contact with the cup, that the head is always projected as a circle on the radiograph, and that the wear of the polyethylene is negligible. The last of these assumptions limits the method for long-term use since wear does occur, and is reported in Charnley sockets to be 0.15 mm per year (Wroblewski 1985). The use of the centre of the femoral head is also limited by the projection of metal-backed acetabular prostheses, but the cup used by one of us (MARF) subtends only 140° leaving sufficient space for the head itself to be visible.

**TECHNIQUE OF MEASUREMENT**

**Radiography.** With the patient lying supine, the beam is centred 3 cm above the symphysis pubis with the tube at a distance of 90 cm from the plate.

**Measurement.** The centre of the femoral head and the most inferior points on both teardrops are marked on the anteroposterior radiograph of the pelvis. A line is drawn through the latter two points and extended below the hip under study. A vertical line is drawn from this to the centre of the head, and the following four measurements are made: the diameter of the head, the inter-teardrop distance (ITD), the vertical distance from the head centre to the inter-teardrop line, and the horizontal distance from the head centre to the ipsilateral teardrop (Fig. 1). This procedure can be done ‘by hand’ or with a digitising tablet linked to a desk-top computer for the subsequent calculations.

All measurements are corrected for magnification by multiplication by the true diameter of the prosthetic head and division by the measured diameter. A correction is then made for mal-rotation of the pelvis. After magnification correction, the largest ITD in an individual’s series of films must approximate most closely to the true ITD, since rotation from a true anteroposterior view can only decrease the apparent ITD. The horizontal distance shown on a particular film can therefore be corrected (at least partly) for rotation by multiplication by the largest ITD in the series and division by the ITD for that radiograph. A similar correction for the variation of vertical distances was attempted, but abandoned, since there is no easily definable vertical line in the same plane as the acetabulum that can be used in the same way as the ITD.

**MEASUREMENT ERRORS**

Failure to identify the same fixed points on the teardrops is a source of potential error. Therefore, all the radiographs for each patient were displayed simultaneously in order to use the same landmarks on each film. The average magnification factor proved to be 0.8 (20%). The estimated error in measurement of the diameter of the femoral head was ±0.5 mm, and therefore the average error produced by the magnification correction was ±(0.8 × 0.5) = ±0.4 mm.
The centre of the head was marked by use of a transparent sheet showing concentric circles, which could be matched to the circumference of the head. A mark was then made through a hole in the centre of the circles. Location of the centre of the femoral head involved measurement errors of ±0.5 mm in both the horizontal and the vertical planes.

To assess inter-observer and intra-observer errors, three hips were randomly selected to be measured by three observers. Table I shows the variability (standard deviation) for each measurement and for each observer. The total measurement error for a variable is the sum of the estimated errors, which in this study is the variable measurement error, plus the inter-observer error, plus the intra-observer error, plus the magnification error. For vertical migration an estimate of the total error is approximately ±(0.5 + 2.63 + 1.11 + 0.4) mm, which equals ±4.6 mm. For horizontal migration the estimate is ±(0.5 + 0.87 + 1.11 + 0.4) mm, which equals ±2.9 mm.

These estimates apply to a multi-observer study. If the measurements are made by a single observer, inter-observer errors are removed so that the error is reduced to ±1.97 mm for vertical, and ±2.03 mm for horizontal migration. To allow for unaccounted errors, we regarded an acceptable estimate of the error of measurement when made by a single observer to be ±3 mm. Errors of this method must be compared with those of RSA, which have been reported to be ±0.4 mm in the mediolateral axis, ±0.2 mm in the vertical axis, and ±0.8 mm in the anteroposterior axis (Mjöberg et al 1986).

STATISTICAL ANALYSIS

In a comparative study, on the assumption that the errors are random and the same for each group and that the sample size is adequate, a difference can be shown to be statistically significant even if this difference is smaller than the estimated error.

The simplest way to present the results of a study of migration by this method would be to plot the mean migration for a population of hips against time. Comparison of various groups can then be made at a particular time with, for example, Student’s t-test. If this method is used, there are advantages in the use of serial radiographs taken at regular time intervals since this allows the confirmation of trends, the fitting of lines to data and thus the calculation of migration rates.

In practice, in longitudinal studies, not every subject contributes data at each time interval. The means then calculated at any particular time point are biased towards those patients with more complete records and longer follow-up. This difficulty can be addressed by fitting a regression model to each patient’s data to describe the migration over time. We have used a ‘jack-knifed’ regression (Barnett and Lewis 1978). Once the jack-knifed regression coefficients are obtained, they may be averaged over each group and a graph of estimated migration against time plotted. From these data the angle of the slope of the graph at a specific time point can be calculated to provide a migration rate at that time. The slopes for different prostheses or techniques can then be compared. In comparisons of several prostheses, multiple t-tests can exaggerate the differences between the groups, and an appropriate adjustment such as the Student–Newman–Keuls procedure should be used.

CONCLUSIONS

The measurement of vertical and horizontal migration on standardised anteroposterior radiographs of the pelvis provides a means of assessment of an acetabular component, although the relation between migration and eventual loosening is not established. The measurement can be made to an accuracy of 3 mm but statistically valid comparisons can be made between means for two groups even when they differ by only fractions of a millimetre. Further statistical examination can provide quantitative comparisons between two groups and a description of group behaviour over time.

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REFERENCES


