THE DEFINITION AND MEASUREMENT OF ACETABULAR ORIENTATION

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The orientation of an acetabulum or an acetabular prosthesis may be described by its inclination and anteversion. Orientation can be assessed anatomically, radiographically, and by direct observation at operation. The angles of inclination and anteversion determined by these three methods differ because they have different spatial arrangements. There are therefore three distinct definitions of inclination and anteversion. This paper analyses the differences between the definitions and provides nomograms to convert from one to another. It is recommended that the operative definitions be used to describe the orientation of prostheses and that the anatomical definitions be used for dysplastic acetabula.

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Numerous terms are used to describe acetabular orientation. These include inclination, anteversion, cover, abduction, tilt, opening and flexion (Ackland, Bourne and Uhthoff 1986; Herrlin, Pettersson and Selvik 1988). Inclination and anteversion are the most commonly used terms but they have several different and imprecise definitions (Herrlin, Selvik and Pettersson 1986; Calandruccio 1987). Different definitions are used in operative, radiographic and anatomical assessments of orientation and have been named accordingly. The aim of this investigation is to offer precise definitions and to develop a simple method for converting the results from one method of assessment to another. The definitions describe the orientation of the acetabular axis which passes through the centre of the socket and is perpendicular to the plane of the socket face (Calandruccio 1987).

DEFINITIONS AND CONVERSION METHOD

Operative definitions. Acetabular components are frequently positioned with jigs, and these usually have two rods perpendicular to each other. The inclination of the component is set by placing one of these rods parallel to the transverse axis of the patient and the other parallel to the longitudinal axis (McKee 1970; Charnley 1979; Harris 1980). Anteversion is achieved by rotating the longitudinal rod about the transverse axis, a movement akin to hip flexion (McKee 1970; Harris 1980). The anteversion angle is that through which the longitudinal rod is swung, and is measured in the sagittal plane. The *operative anteversion* (OA) is thus the angle between the longitudinal axis of the patient and the acetabular axis as projected on to the sagittal plane (Fig. 1). This is sometimes called the ϕ angle (Lewinnek et al 1978).

The inclination, preset by the jig, is the angle between the acetabular axis and the longitudinal rod. When the prosthesis is anteverted the longitudinal rod remains in the sagittal plane, and the preset inclination remains the same, being the angle between the acetabular axis and the sagittal plane. The *operative inclination* (OI) is therefore the angle between the acetabular axis and the sagittal plane (Fig. 1). It is the angle of abduction of the acetabular axis.

Radiographic definitions. The orientation of the acetabular component can be determined postoperatively on anteroposterior radiographs from the alignment of radio-opaque markers (with corrections for distortion caused by X-ray beam divergence and pelvic rotation (Goergen and Resnick 1975; Sellers, Lyles and Dorr 1988). The inclination is the angle between the face of the cup and the transverse axis (Lewinnek et al 1978; Woo and Morrey 1982; Ackland et al 1986; Sarmiento et al 1990) which is the same as the angle between the longitudinal axis and the acetabular axis when this is projected on to the radiograph. The *radiographic inclination* (RI) is therefore defined as the angle between the longitudinal axis and the acetabular axis when this is projected on to the coronal plane (Fig. 2). It is sometimes called the projected inclination or θ angle (Lewinnek et al 1978; Herrlin et al 1988).

The technique for assessing acetabular anteversion depends on the type of radio-opaque marker. When this is an encircling wire, which is projected radiographically as an ellipse, anteversion is calculated from the relative size of the major and minor diameters of the ellipse (McLaren 1973; Lewinnek et al 1978; Ackland et al 1986). The result of these calculations gives the angle between the axis of the acetabulum and the coronal plane. The *radiographic anteversion* (RA) is therefore defined as the angle between the acetabular axis and the coronal plane (Fig. 2). This is sometimes called the planar anteversion or the α angle, and can also be determined approximately from lateral radiographs (Lewinnek et al 1978; Woo and Morrey 1982; Herrlin et al 1988).

Anatomical definitions. In anatomical studies of both normal and dysplastic hips the angle between the plane of the face of the acetabulum and the transverse plane is considered to be the inclination of the acetabulum (Walker 1977; Tönnis 1987). This is equivalent to the angle between the acetabular axis and the longitudinal axis. The *anatomical inclination* (AI) is therefore defined as the angle between the acetabular axis and the longitudinal axis (Fig. 3). Anteversion is the angle between the acetabular axis and the coronal plane when viewed in a cranio-caudal direction (McKibbin 1970; Walker 1977; Calandruccio 1987). The *anatomical ante-*

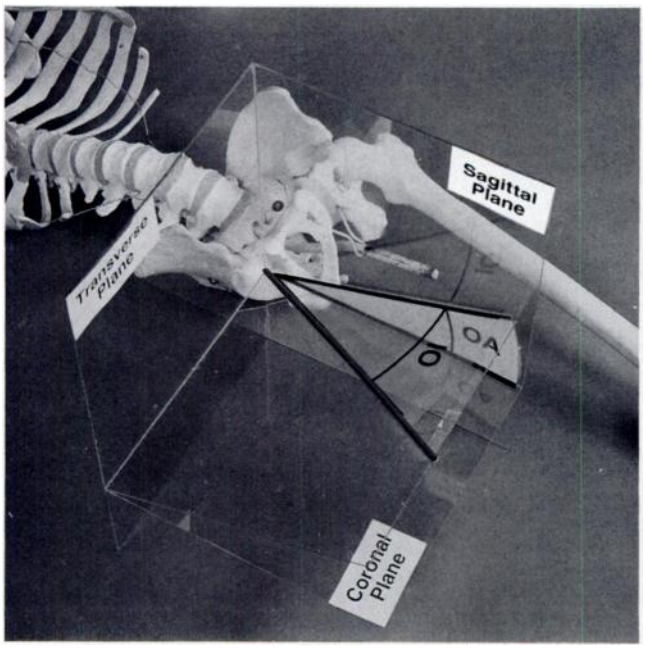

Fig. 1
Operative anteversion (OA) and inclination (OI).

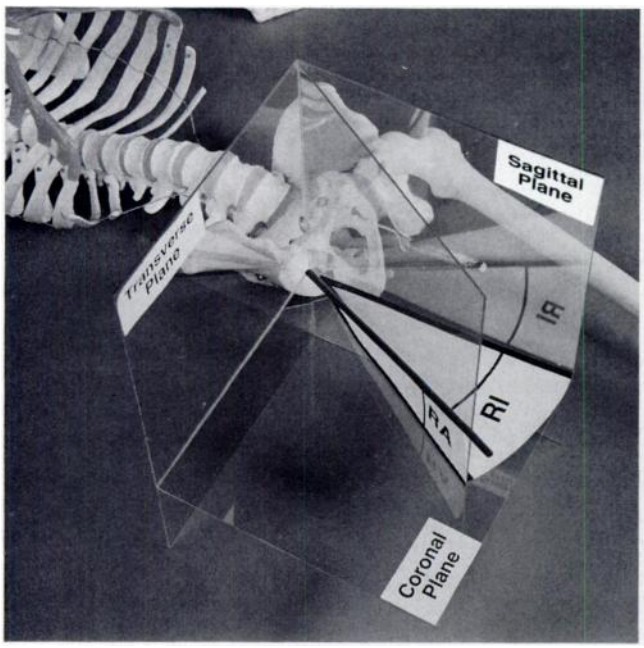

Fig. 2
Radiographic anteversion (RA) and inclination (RI).

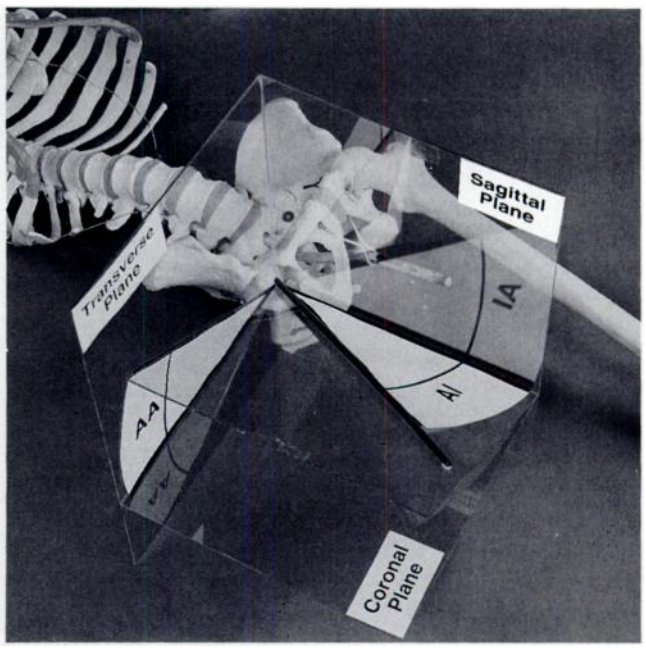

Fig. 3
Anatomical anteversion (AA) and inclination (AI).

version (AA) is therefore defined as the angle between the transverse axis and the acetabular axis when this is projected on to the transverse plane (Fig. 3). It is similar to internal rotation of the acetabulum about a longitudinal body axis. Anatomical inclination and anteversion are occasionally referred to as true or three-dimensional inclination and anteversion (Herrlin et al 1986, 1988).

Method. For any acetabular position the inclination and anteversion defined in each of the three ways can be determined (Figs 4, 5). The three definitions can therefore be connected mathematically, and equations to do this have been derived (Appendix 1). As these equations are complex, nomograms have been constructed which may be used to convert from operative to anatomical and vice versa (Fig. 6), from radiographic to operative (Fig. 7) and from radiographic to anatomical (Fig. 8).

The nomograms are used as in the following example. Harris (1980) advocated that acetabular prostheses should be inserted, at operation, with 30° of inclination and 20° of anteversion. The nomogram (Fig. 6) is used to convert these operative angles to anatomical angles. The operative orientation (H) is plotted on the nomogram using the horizontal and vertical guidelines; the operative inclination (30°) is the X (horizontal) co-ordinate, and the operative anteversion (20°) is the Y (vertical) co-ordinate. The *anatomical anteversion* is obtained by selecting the dashed curve nearest to the plotted orientation. The angle printed beside this curve (30°) is approximately the anatomical anteversion. A more precise anatomical anteversion (31°) can be determined by interpolation from the dashed curves above and below the plotted orientation.

The *anatomical inclination* is obtained from the continuous curves. The curve nearest the plotted deformity is selected and followed until it crosses the X axis. This point gives the approximate anatomical inclination (35°). A more precise anatomical inclination (36°) is determined by interpolation from the curves above and below.

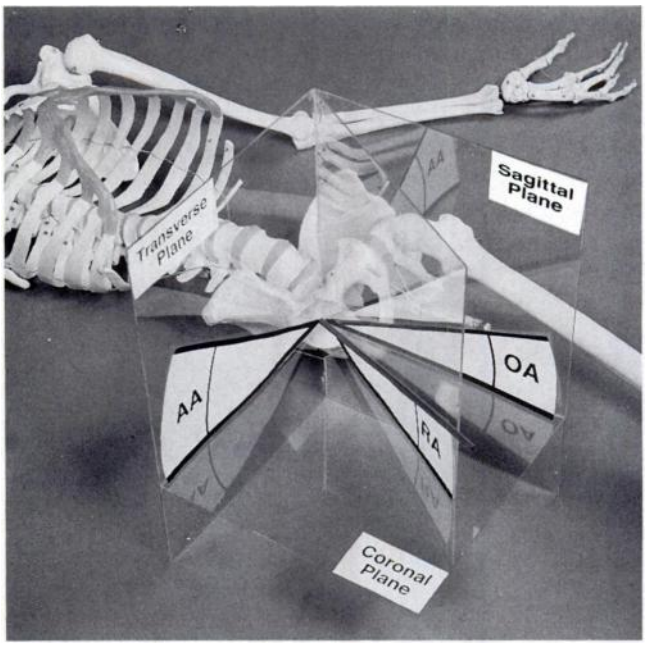

Fig. 4

The different definitions of anteversion.

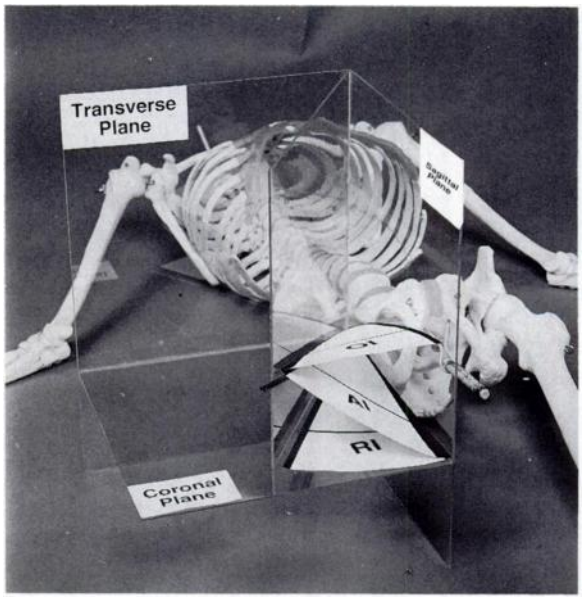

Fig. 5

The different definitions of inclination.

DISCUSSION

The photographs in Figures 4 and 5 show that the various definitions of anteversion and inclination are different. The fundamental difference is that operative anteversion is measured around a transverse axis, anatomical anteversion around a longitudinal axis and radiographic anteversion around an oblique axis. They give, however, little indication of the magnitude of the differences. This is best appreciated by considering examples. Harris (1980) advocated that acetabular implants should have 30° of operative inclination and 20° of operative anteversion. This is equivalent to 36° of anatomical inclination and 31° of anatomical anteversion. The differences between these angles are important because, though most acetabular jigs (like that of Harris) use the operative definitions, some, like Müller's (1970), use the anatomical definitions. Dysplastic hips commonly have 60° of inclination and 30° of anteversion. These are the anatomical angles and are appreciably different from their operative equivalents, which are 48° and 41° respectively. It is therefore essential that whenever acetabular orientation is discussed the words anteversion and inclination should be qualified so that their precise definitions are known.

Acetabular prostheses are anteverted to allow hip flexion. As operative anteversion is a measure of acetabular flexion we recommend that the operative definitions should always be used when total hip

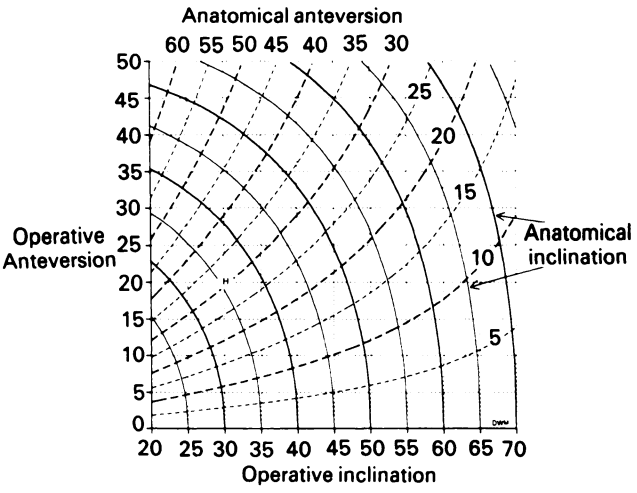

Fig. 6

Nomogram to convert operative orientation to anatomical orientation and vice versa. The operative orientation (H) is plotted with its X co-ordinate being the operative inclination, and its Y co-ordinate being the operative anteversion. The anatomical inclination is determined from the continuous curves, the anatomical anteversion from the dashed curves. To convert anatomical to operative, the anatomical orientation is plotted using the curves and the operative orientation is determined from the grid lines (see text).

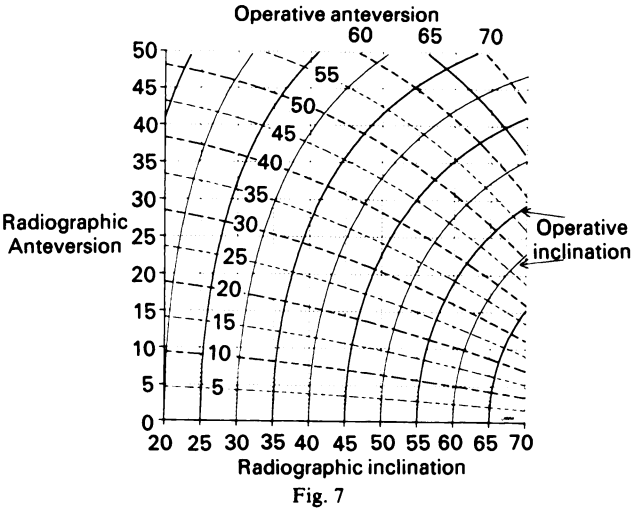

Fig. 7

Nomogram to convert radiographic orientation to operative orientation and vice versa. The radiographic orientation is plotted with its X co-ordinate being the radiographic inclination, and its Y co-ordinate being the radiographic anteversion. The operative inclination is determined from the continuous curves, the operative anteversion from the dashed curves. To convert operative to radiographic, the operative orientation is plotted using the curves and the radiographic orientation is determined from the grid lines (see text).

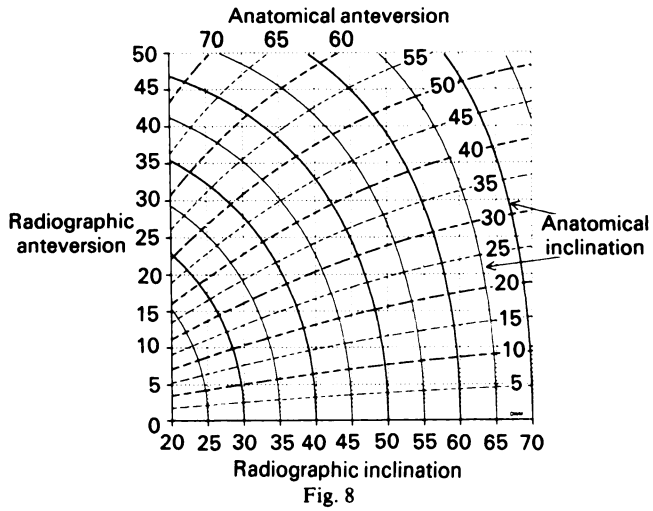

Fig. 8

Nomogram to convert radiographic orientation to anatomical orientation and vice versa. The radiographic orientation is plotted with its X co-ordinate being the radiographic inclination, and its Y co-ordinate being the radiographic anteversion. The anatomical inclination is determined from the continuous curves, the anatomical anteversion from the dashed curves. To convert anatomical to radiographic, the anatomical orientation is plotted using the curves and the radiographic orientation is determined from the grid lines (see text).

replacements (THR) are described. The use of these definitions has other advantages. Operative anteversion is easily assessed at operation, as the prosthesis is viewed from a lateral position; and the influence of pelvic and lumbar spine flexion can be allowed for since it can be numerically added to operative anteversion. The radiographic orientation, determined from an anteroposterior radiograph, should always be converted to the operative orientation before being quoted. If this is not done it may cause confusion. For example, Lewinnek et al (1978) found that, after THR, anterior dislocation occurred only if the acetabular cup was in more than 25° of radiographic anteversion, and that when this was so, 15% of THRs, dislocated anteriorly. If their data are recalculated using the operative definitions then anterior dislocation occurred only in cups with more than 38° of anteversion, and above 38° some 21% of the THRs dislocated anteriorly. The study should therefore have concluded that acetabular components should be implanted with less than 35°, not 25°, of (operative) anteversion.

Acetabular anteversion and inclination are often difficult to measure from anteroposterior radiographs (Appendix 2) and are better assessed by an image intensifier or, possibly, by CT (Goergen and Resnick 1975; Ghelman 1979; Schneider et al 1982; Calandruccio 1987; Hoiseth, Reikeras and Fonstelien 1989). The latter is not ideal as the image is distorted by the metal implant, and because it measures anatomical anteversion. In contrast, an image intensifier can directly measure operative orientation. It is initially aligned vertically over the hip and is then rotated around the transverse axis of the body until the X-ray beam is directed across the face of the acetabulum. The operative anteversion is the angle through which the image intensifier has been rotated, and the operative inclination is that seen on the screen.

In assessing dysplastic acetabula, it is necessary to know not only the degree of cover of the femoral head superiorly but also the relative cover anterosuperiorly and posterosuperiorly. This is best quantified by the anatomical anteversion. We therefore recommend that when discussing dysplastic acetabula the anatomical definitions be used. The anatomical anteversion angle can be determined directly from CT scans or from

magnetic resonance images with transverse cuts (Browning, Rosenkrantz and Tarquinio 1982; Gugenheim et al 1982; Hoiseth et al 1989; Anda, Terjesen and Kvistad 1991). As the inferior acetabular margin is difficult to define, the anatomical inclination is not often used in clinical practice. Instead, superior acetabular cover is quantified by the centre-edge angle (Wiberg 1939) which is simpler to determine.

Conclusions. The anatomical, operative, and radiographic definitions of anteversion and inclination are all different. It is therefore essential, whenever acetabular orientation is discussed, to qualify the words anteversion and inclination so that their precise definitions are known. We present nomograms which can be used to convert from one definition to another.

Operative definitions should be used to describe the alignment of acetabular prostheses. The orientation is best determined by the use of an image intensifier rotated about the transverse body axis. If the orientation is determined from an anteroposterior radiograph it should be converted to operative orientation before being quoted.

Anatomical definitions should be used for describing the orientation of normal and dysplastic acetabula. Anatomical anteversion is best determined from CT or MR images, since it is measured in the transverse plane.

APPENDIX 1

Equations connecting operative (O), radiographic (R), anatomical (A), inclination (I), and anteversion (A):

$$\text{Tan(OA)} = \text{Tan(RA)} \div \text{Cos(RI)}^{*}\ \text{Sin(OI)} = \text{Sin(RI)} \times \text{Cos(RA)}$$
$$\text{Tan(OA)} = \text{Sin(AA)} \times \text{Tan(AI)}\ \text{Sin(OI)} = \text{Sin(AI)} \times \text{Cos(AA)}$$
$$\text{Tan(AA)} = \text{Sin(OA)} \div \text{Tan(OI)}\ \text{Cos(AI)} = \text{Cos(OI)} \times \text{Cos(OA)}$$
$$\text{Tan(AA)} = \text{Tan(RA)} \div \text{Sin(RI)}\ \text{Cos(AI)} = \text{Cos(RI)} \times \text{Cos(RA)}$$
$$\text{Sin(RA)} = \text{Sin(OA)} \times \text{Cos(OI)}\ \text{Tan(RI)} = \text{Tan(OI)} \div \text{Cos(OA)}$$
$$\text{Sin(RA)} = \text{Sin(AA)} \times \text{Sin(AI)}\ \text{Tan(RI)} = \text{Tan(AI)} \times \text{Cos(AA)}$$

* this is the same as $\text{Tan}\alpha = \text{Tan}\phi \times \text{Cos}\theta$, which was quoted by Lewinnek et al (1978), and used by Ackland et al (1986) to construct a numerical table.

APPENDIX 2

The method for determining radiographic inclination from anteroposterior radiographs depends on the type of radio-opaque marker. When this is an encircling wire, which is projected as an ellipse, the inclination is the angle between the major axis of the ellipse and the transverse body axis (Lewinnek et al 1978; Ackland et al 1986). When the marker is a semicircular wire which passes over the top of the socket, the apparent inclination (CI) is the angle between the transverse body axis and a line joining the ends of the wire. If the socket is not anteverted the wire lies in the sagittal plane and the apparent inclination is the same as the radiographic inclination. If the socket is anteverted then the apparent inclination is an overestimate of the radiographic inclination:

$$\text{Tan(RI)} = \text{Tan(CI)} \div \text{Cos}^2\text{(OA)}$$

The greater the anteversion the greater the overestimate: if, for example, the socket is anteverted 30° then the overestimate is 20%.

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