Reducing the risk of dislocation after total hip arthroplasty

THE EFFECT OF ORIENTATION OF THE ACETABULAR COMPONENT

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Malposition of the acetabular component is a risk factor for post-operative dislocation after total hip replacement (THR). We have investigated the influence of the orientation of the acetabular component on the probability of dislocation. Radiological anteversion and abduction of the component of 127 hips which dislocated post-operatively were measured by Einzel-Bild-Röentgen-Analysis and compared with those in a control group of 342 patients.

In the control group, the mean value of anteversion was 15° and of abduction 44°. Patients with anterior dislocation after primary THR showed significant differences in the mean angle of anteversion (17°), and abduction (48°) as did patients with posterior dislocation (anteversion 11°, abduction 42°). After revision patients with posterior dislocation showed significant differences in anteversion (12°) and abduction (40°).

Our results demonstrate the importance of accurate positioning of the acetabular component in order to reduce the frequency of subsequent dislocations. Radiological anteversion of 15° and abduction of 45° are the lowest at-risk values for dislocation.

Post-operative dislocation remains a common, major complication after total hip replacement (THR)[1-6] with an overall incidence of 2% to 3%[7] but ranging from 1% to almost 10% after primary THR. The incidence can be as high as 20% after revision surgery.[1-5,8,9] Malposition of the acetabular component has long been recognised as an important cause of dislocation,[1,2,4,8,10-13] but is difficult to assess accurately.[2,4,8,9]

Using a posterolateral approach for implantation of the prosthesis, Lewinnek et al[14] proposed a radiological safe range of the position of the cup as anteversion of 15° (SD 10°) and abduction of 40° (SD 10°), although this was based on only nine dislocations. They found a rate of dislocation of 1.5% within this range, although outside this the rate was 6.1%. Similar findings have also been reported by others.[2,15] In order to prevent impingement and dislocation, McCollum and Gray[1] determined that the safest range for the position of the cup was 30° to 50° of abduction and 20° to 40° of flexion from the horizontal. Dorr and Wan[6] considered malposition as anteversion of less than 15° or more than 30° and an abduction angle of 55° or more. In order to obtain true anteversion values, they added 5° to the angle measured on the anteroposterior radiograph of the pelvis. Ali Kahn et al[8] graded radiological anteversion of the acetabular component as excessive if it exceeded 15° and considered that it was too vertical if the abduction angle exceeded 50°. They could not determine the effect of the surgical approach used on the incidence of dislocation but found malposition of the acetabular component in more than half of the dislocations. Conversely, a number of authors were unable to find any association between the position of the acetabular component and the risk of dislocation[16-19] and considered that the importance of the angle of abduction of the acetabular component as a risk factor was overstated.[16] Most of the earlier studies were based upon small numbers of patients only.[14] Furthermore, most of the authors did not evaluate their methods for measurement of the position of the acetabular component. The results of the different studies can be approximately compared with each other because of the various definitions of anteversion which were used.[20] Other authors did not use standardised or well-documented radiological material, thereby preventing accurate measurements of the angulation of the acetabular component.[8]

Surgical navigation systems have been developed for THR in order to allow more precise placement than may be obtained by traditional surgery.[21,22] For this reason, guidelines for the

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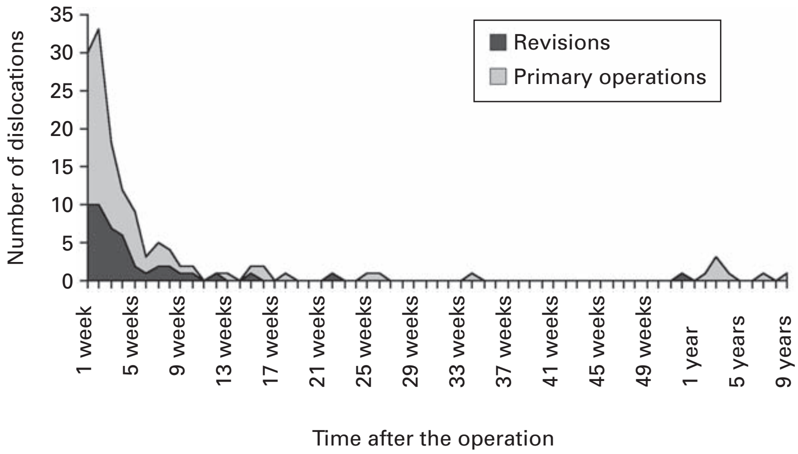

Fig. 1

Graph showing the number of dislocations (n = 137) over time. Only seven primary dislocations occurred more than one year after surgery.

best position of the acetabular component need to be established from an adequate database.

We, therefore, examined the radiological position of the acetabular component in a large number of patients with dislocation and used an accurate radiological method to compare them with a control group without dislocation. Our aim was to determine the effect of the position of the acetabular component on the risk of dislocation and to assess the accepted recommendations for its positioning.

Patients and Methods

Dislocation group. We performed a total of 4784 THRs (3781 primary, 1003 revision) in our department between January 1990 and December 2000. Of these, 132 patients (137 THRs) (76 women and 56 men; 91 primary and 46 revision arthroplasties) were seen in our unit because of dislocation. Dislocations in our patients who were treated in other hospitals could not be recorded. However, our hospital is the only one in the region in which social security patients undergo THR. Most dislocations (119, 78%) occurred within 12 weeks of surgery (Fig. 1) and approximately 95% of the patients had been reviewed in the 12th week. The number of unrecorded dislocations would be negligible. The mean age of those patients who had a dislocation was 68 years (37 to 86). All but one of the operations had been performed using a standard anterolateral, transgluteal approach with complete capsulectomy. In one patient, a dorsal approach had been used for oncological reasons and this hip was excluded in the statistical analysis.

The types of acetabular and femoral components which had been used are shown in Table I. In 27 of the revision operations an acetabular reinforcement ring was also used. The size of the femoral head was 28 mm in 117 operations and 32 mm in seven. In 12 patients the size of the femoral head was not stated in the operation note. Only head sizes of 28 or 32 mm were available.

Control group. A control group of 342 patients (182 men and 160 women) was taken from four earlier studies on migration of the acetabular component using Einzel-Bild-Roentgen-Analysis (EBRA).[23-26] These consecutive patients

Table I. Details of the number of implants used in the dislocation group

	Primary	Revisions	Total
Acetabular components			
Cementless			
Duraloc 100 (DePuy, Warsaw, Indiana)	14	-	14
RM Morscher (Robert Mathys Co, Bettlach, Switzerland)	3	1	4
Others	1	-	1
Cemented			
Artos (GmbH, Berlin, Germany)	50	36	86
Müller (Sulzer, Bern, Switzerland)	13	5	18
Link (Link, Hamburg, Germany)	4	-	4
Others	5	4	9
Total	90	46	136
Femoral components			
Cementless			
Cementless Spotorno (Sulzer)	9	-	9
Others	5	-	5
Cemented			
Lubinus Static Physiological II (Link)	68	38	106
MEM (Protek AG, Bern, Switzerland)	-	3	3
Others	8	5	13
Total	90	46	136

were operated on by experienced consultant surgeons and were randomised by age and gender. There were no further inclusion or exclusion criteria. All operations were performed through a transgluteal approach. The types of component which had been used are shown in Table II. A head size of 28 mm was used in all cases.

No patient in the control group had a dislocation.

Radiological analysis. Three months after surgery a standardised anteroposterior radiograph was performed with the legs internally rotated. In nine patients in the dislocation group no post-operative radiograph was available for analysis. Therefore, the orientation of the acetabular component was studied in 127 hips with dislocation and compared with the data for the 342 patients in the control group.

Complying with Murray's definition of anteversion,[20] the EBRA method was used to determine both the radiological

Table II. Details of the number of implants used in the control group

	Number
Acetabular components	
Cementless	
PCA (Howmedica, Rutherford, New Jersey)	110
RM Robert Mathys (Robert Mathys Co)	115
Duraloc 100	68
Cemented	
Weber Metasul (Sulzer)	25
Weber PE (Sulzer)	24
Total	342
Femoral components	
Cementless	
PCA	110
MEM	115
CLS	59
Cemented	
Weber CF-30 (Sulzer)	49
Lubinus SP II	9
Total	342

anteversion and the angle of abduction of the acetabular component. EBRA was originally designed to measure migration and wear in consecutive comparable radiographs. This measurement requires at least two well-controlled radiographs. The 95% confidence limits are 1.0 mm for longitudinal and 0.8 mm for transverse migration.[23] EBRA reconstructs the spatial situation at exposure. In order to calculate the pelvic position at exposure, the pelvic contours on the radiograph must be marked with defined grid lines. The projection of the spherical cup is an ellipse, which must be marked with seven reference points, defining two semiaxes of the ellipse. EBRA then calculates the spatial position of the centre of the cup in relation to the plane of the radiograph with respect to the film-focus distance and the focus position. For each radiograph, the anteversion angle was computed into a data file. In an earlier study, Stöckl et al[27] tested the accuracy of measurement of anteversion of the acetabular component on a single radiograph by EBRA. A series of radiographs was taken of a pelvic model to simulate different anteversion angles. Three observers independently measured all radiographs. The results suggested that EBRA was a valuable tool for the measurement of anteversion in single radiographs to an accuracy of < 2°.

Our patients with dislocations were divided into four subgroups: 1) those with a primary THR and anterior dislocation; 2) those with a primary THR and posterior dislocation; 3) those with revision surgery and anterior dislocation; and 4) those with revision surgery and posterior dislocation.

Fifty-one of the primary operations and all 46 revisions were performed by experienced consultant surgeons and 39 primary THRs were undertaken by registrars. The 51 patients with primary osteoarthritis of the hip and a post-operative dislocation were divided into six subgroups according to the direction of the dislocation and the experience of the surgeon. The position of the acetabular component was compared with the control group.

Statistical analysis. This was performed using SPSS 11.0 software (SPSS Inc, Chicago, Illinois). Quantitative variables were described by the mean and SD. The mean values of all the subgroups were compared with the control group (Mann-Whitney U test). Variances were compared using the Levene test. The chi-squared test was used to investigate the independence of two nominal variables, such as the comparison of the rates of dislocation of primary diagnoses. The odds ratio was used to calculate the relative risk of dislocation in relation to the position of the acetabular component. Values of $p < 0.05$ were regarded as significant.

Results

Incidence. The incidence of dislocation was 2.4% for primary THRs and 4.6% for revisions. This difference was highly significant (chi-squared test, $p < 0.001$). Patients with a primary diagnosis of osteoarthritis showed the lowest rate of dislocation (1.5%) in comparison with other diagnoses such as developmental dysplasia of the hip or necrosis of the femoral head. However, statistical significance could only be verified for patients with tumours (15.8%; $p < 0.001$) or previous fractures of the femoral neck (9.9%; $p < 0.001$).

Position of the acetabular component. The anteversion and abduction angles of all the subgroups were normally distributed. The mean value of the abduction angle of the control group was 44.4° (SD 6.9°). However, because of the prosthetic design and the projection of the acetabular rim on the anteroposterior radiograph, the anteversion angle could only be calculated for 114 of the 342 patients of the control group. Its mean value was 14.5° (SD 4.9°).

For the 127 patients in the dislocation group for whom post-operative radiographs were available, 38 with anterior dislocation after primary THR showed a significantly higher mean abduction angle (47.9° (SD 7.9°); Mann-Whitney U test, $p < 0.05$) and anteversion angle (16.8° (SD 6.5°), $p < 0.05$). The orientation of the acetabular component of the 37 patients with posterior dislocation after primary operations was 42.4° (SD 7.7°) for abduction ($p = 0.3$) and 11.0° (SD 5.5°) for anteversion ($p < 0.01$). In eight dislocations, the direction of the dislocation was unknown and the mean position of the acetabular component did not differ from the control group (Figs 2 and 3).

After revision THR only those patients with a posterior dislocation showed significant differences in the orientation of the acetabular component when compared with the control group (abduction 40°, Mann-Whitney U test, $p < 0.05$; anteversion, 11.8°, $p < 0.05$). Table III gives details of all the results.

There was a consistent relationship between the direction of dislocation and the position of the acetabular component. At 15° of anteversion, the relative frequency of anterior or posterior dislocation was the same. With ante-

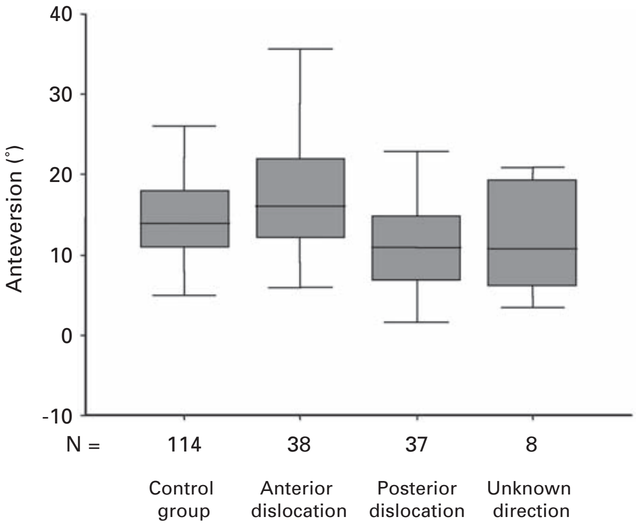

Fig. 2

Descriptive data for anteversion of the acetabular component (mean, interquartile, total range) of the patients with dislocation (anterior, posterior and unknown direction) and the control group. Anteversion was significantly higher for patients with anterior dislocation (mean 17°, Mann-Whitney U test $p < 0.05$) and significantly lower for those with posterior dislocation (mean 11°, $p < 0.01$). The position of the acetabular component for patients with an unknown direction of dislocation did not differ statistically from that of the control group.

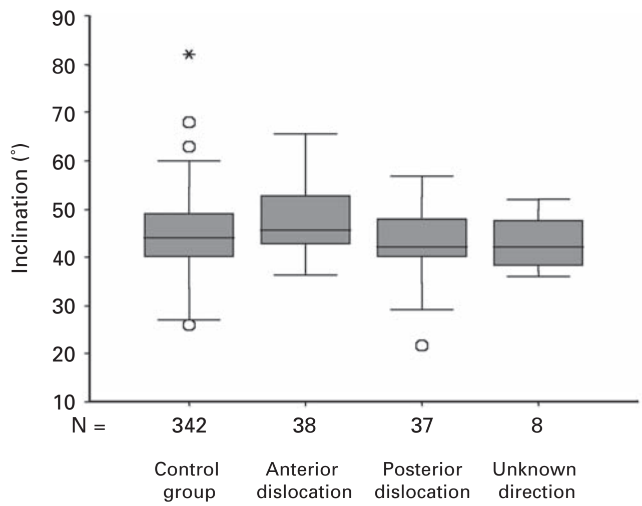

Fig. 3

Descriptive data for abduction of the acetabular component (mean, interquartile, total range) of the patients with dislocation (anterior, posterior and unknown direction) and the control group. The abduction was significantly higher for patients with anterior dislocation (mean 48°, Mann-Whitney U test $p < 0.05$), but was not statistically different for patients with either a posterior (mean 42°, $p = 0.3$) or unknown direction of dislocation.

Table III. The number of measurements and the mean value and SD (°) of anteversion and abduction for the various groups

	Number	Mean	SD	p value
Control group				
Anteversion	114	14.5	4.9	
Abduction	342	44.4	6.9	
Primary THR				
Anterior dislocation				
Anteversion	38	16.8	6.5	< 0.05
Abduction	38	47.9	7.9	< 0.05
Posterior dislocation				
Anteversion	37	11.0	5.5	< 0.01
Abduction	37	42.4	7.7	= 0.3
Unknown direction				
Anteversion	8	12.2	7.1	= 0.3
Abduction	8	43.0	5.9	= 0.5
Revision THR				
Anterior dislocation				
Anteversion	14	12.7	5.9	= 0.5
Abduction	14	46.1	6.5	= 0.2
Posterior dislocation				
Anteversion	22	11.8	6.2	< 0.05
Abduction	22	40.0	6.2	< 0.05
Unknown direction				
Anteversion	8	11.5	7.6	= 0.2
Abduction	8	43.5	9.0	= 0.5

version of less than 4°, all dislocations were posterior, whereas with anteversion of more than 24° all dislocations were anterior. Patients with anteversion of less than 10° had a sixfold higher relative risk (odds ratio) for posterior dislocation than those with anteversion of 15° (SD 5°). Patients with anteversion of more than 20° had a 6.3 times higher relative risk for anterior dislocation (Fig. 4).

In our study, 79% of all hips in the control group were positioned inside the safe zone as defined by Lewinnek et al[14] (Fig. 5). However, the percentage of dislocated hips within the safe zone was significantly lower (60%; chi-squared test, $p < 0.01$). Altering the safe zone to 45° (SD 10°) of abduction and 15° (SD 10°) of anteversion would include 93% of stable and 67% of unstable hips ($p < 0.01$).

Of the 51 patients with primary osteoarthritis and post-operative dislocation 21 had their THR undertaken by experienced surgeons. The mean position of the acetabular component did not differ significantly from that of the control group. By contrast, the mean anteversion of the acetabular component in the nine patients with posterior dislocation operated upon by inexperienced surgeons was significantly smaller than that of the control group (10°; Mann-Whitney U test, $p < 0.05$). Experienced and inexperienced surgeons did not show any significant differences in their variance of the position of the acetabular component.

Recurrent dislocations were also analysed with respect to the position of the acetabular component. However, since the number of patients in each subgroup was too small for good statistical power, further analysis was abandoned.

Treatment of dislocations. Within two months of THR, 81% of the dislocations after primary surgery and 87% of those after revisions had occurred. Only 8% of patients with a primary implant and none of the revision group had their initial dislocation more than one year after the operation (Fig. 1). Of all the patients with dislocation, 63% had

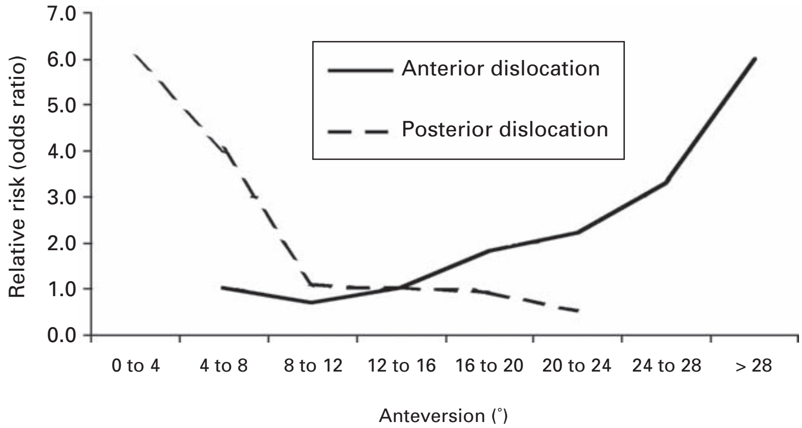

Fig. 4

Influence of version of the acetabular component on the direction of dislocation. There was a constant increase in the relative risk (odds ratio) of anterior dislocation as anteversion increased and *vice versa* for posterior dislocation. No posterior dislocation was recorded above 24° of anteversion and no anterior dislocation below 4° of anteversion.

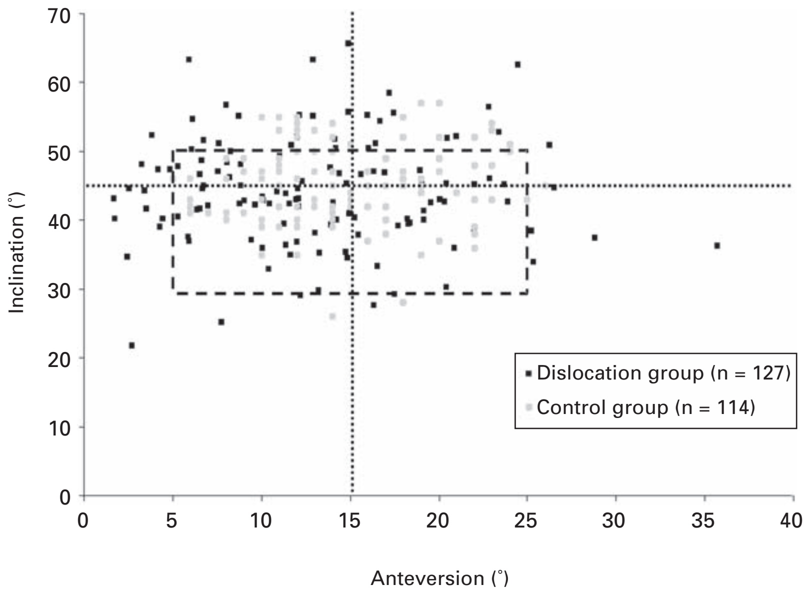

Fig. 5

Values for anteversion and abduction for both the control group and patients with dislocation. The safe range, as defined by Lewinnek et al,[14] is within the dotted rectangle. A significantly higher percentage of control patients (79%) is within the safe range ($p < 0.01$). However, most dislocations are also inside this rectangle (60%).

a further dislocation, 57% after primary operations, and 74% after revision surgery. After primary surgery, 88 (96%) of the 91 dislocated hips were reduced in a closed manner under general anaesthesia. Three required open reduction. Of the 91 hips 52 (57%) had a further dislocation, leading to surgical intervention in 26 (29%). Patients with dislocation after revision surgery had a risk of 52% of requiring operative intervention for stabilisation of their implant.

Discussion

Numerous factors influence the rate of dislocation after THR such as greater age,[28-30] previous surgery to the affected hip,[5,8,15,16,19,31-33] concomitant neurological deficiencies,[5,8,28] excessive alcohol intake[8,16] and nonunion of the greater trochanter.[16,31,32] All cause soft-tissue imbalance and increase the risk of dislocation. Some authors have reported a higher rate of dislocation when using a posterior surgical approach[2,9,34] and Kristiansen et al[10] noted less acetabular version with this approach. Hedlundh et al[35] registered twice the number of dislocations for inexperienced surgeons as compared with their more experienced colleagues, a correlation which was also reported by other authors.[36,37] Fackler and Poss[5] observed a frequent association of dislocation with malposition of the component of which the surgeon was unaware at the time of surgery. This was seen more often among less experienced surgeons. Our data also indicate that the main reason for the higher rate of dislocation of inexperienced surgeons is malpositioning of the cup.

Malposition has long been recognised as an important cause of dislocation.[1,2,4,8,10-13] Accurate positioning of the acetabular component at the time of surgery is crucial in preventing post-operative dislocation.[1] Late dislocation has also recently been reported to occur in association with malposition of the acetabular component. Von Knoch et al[38] suggested that an initial malposition is a risk factor for dislocation throughout the life of the prosthesis. When the

Table IV. Overview of the literature investigating the influence of orientation of the cup on the probability of a post-operative dislocation in THR. Many studies show a deficiency in their design.

Author/s	Number of dislocations	Size of control group	Radiological method	Safe range of cup orientation investigated	Differentiation between primary operations and revisions	Differentiation corresponding to the direction of dislocation	Cup orientation related to dislocations
Yuan and Shih[4]	62	None	AutoCAD* computer program	Yes	No	No	Yes
Fackler and Poss[5]	34	50	AP pelvis- and hip-centred radiographs (McLaren[44])	No	No	No	Yes
Ali Khan et al[8]	142	None	Unknown†	Yes	No	No	Yes
Woo and Morrey[9]	38	None	AP and lateral radiographs	Not investigated	No	No	No
Kristiansen et al[10]	21	21	AP and lateral radiographs	Yes	Only primary operations	No	Yes
Ritter[11]	7	None	Unknown†	Not investigated	No	No	Yes
Coventry et al[12]	47	None	AP and lateral radiographs	Not investigated	No	Yes	Yes
Kohn et al[13]	20	None	AP radiographs	Yes	Only primary operations	No	Yes
Lewinnek et al[14]	9	113	AP pelvis-centred radiographs	Yes	No	No	Yes
Dorr et al[15]	39	22	AP radiographs (Lewinnek et al[14])	Yes	No	Yes	Yes
Paterno et al[16]	32	32	AP and lateral radiographs	No	Yes	Yes	No
Pollard et al[17]	7	90	AP and lateral radiographs	No	Only primary operations	No	No
Herrlin et al[18]	15	44	AP and lateral radiographs	Not investigated	No	No	No
Lindberg et al[19]	45	239	AP pelvis- and hip-centred radiographs (McLaren[40])	No	Only primary operations	No	No
Woolson and Rahimtoola[28]	14	284/214	AP and lateral radiographs	No	Only primary operations	No	No
Jolles et al[41]	21	21	AP and lateral radiographs	Not investigated	Only primary operations	No	No
Mian et al[42]	8	15	CT-based	Yes	No	Yes	Yes
Pierchon et al[43]	38	14	CT-based	No	No	No	No
Current study	137	342	EBRA	Yes	Yes	Yes	Yes

* CAD, computer-assisted design
† unknown, not mentioned in article

acetabular component is malpositioned and the hip is protected for six weeks post-operatively, stability can be achieved by capsular healing. However, this stabilising capsule may stretch over time and the frequency of late dislocations may then increase.[1] Soft-tissue imbalance and malposition are thought to be the two main causes of dislocation.[39]

Morrey[2] stated that rotation of the femoral component is difficult, if not impossible, to measure accurately by radiography. In our study, femoral anteversion could not be calculated by EBRA. Nonetheless, several authors have reported that excessive femoral anteversion may lead to dislocation.[3,11] By contrast, McCollum and Gray[1] asserted that orientation of the femoral component is less critical than orientation of the acetabular component. Cover of the head by the acetabular component changes very little with internal and external rotation of the femoral component. Orientation can be checked easily by comparing the angle of the femoral component with the plane of movement of the knee. Fackler and Poss[5] considered that one of the reasons for malposition was related to the high incidence of ipsilateral knee deformities, making judgement of proper femoral version difficult.

The most commonly recognised cause of failure, however, is orientation of the acetabular component.[7] A hip which dislocates because of malposition has a chance of up to 71% of requiring further open surgery.[6] Corrective surgical intervention is approximately 80% successful.[7]

Murray[20] highlighted the importance of differentiating between the various definitions of acetabular orientation. Operative anteversion is measured around a transverse axis, anatomical anteversion around a longitudinal axis, and radiological anteversion around an oblique axis. Lewinnek et al[14] suggested a safe range for the radiological position of the acetabular component with anteversion of 15° (SD 10°) and abduction of 40° (SD 10°) although their data were based upon only nine patients out of 300 operations. If their data were recalculated using the operative definitions of the position of the acetabular component according to Murray, anterior dislocation occurred in 21%

of hips with more than 38° of anteversion. Therefore, Lewinnek et al[14] should have concluded that acetabular components must be implanted with less than 35°, not 25°, of operative anteversion. McCollum and Gray[1] determined that the safest range for the position of the acetabular component, in order to prevent impingement and dislocation, was 30° to 50° of abduction and 20° to 40° of anteversion. Flexion of the cup was evaluated post-operatively on a standing lateral radiograph.[1] However, the measurement of flexion from a lateral position corresponds to the determination of operative anteversion and must be converted before comparison with the results of other authors.[20]

Few studies are based upon large numbers of dislocations. Ali Khan et al[8] undertook a study of 142 patients with a dislocation but as standardised radiographs could not be obtained, radiological measurements of the position of the acetabular component as published by Lewinnek et al,[14] were not performed. Despite this, Ali Khan et al[8] detected that almost half of the components of the patients who had dislocation were implanted either too vertically (> 50°) or too anteverted (> 15°). Paterno et al[16] could not establish an association between either the version or the abduction angle of the acetabular component and the risk of dislocation. Of the 32 dislocated hips in their study, 30 had an abduction angle of the acetabular component which was within the so-called safe range of 30° to 50°. They therefore concluded that the importance of the abduction angle as a risk factor for dislocation may have been overstated in earlier studies. Many of the studies which investigated the relationship between the position of the acetabular component and dislocation showed a deficiency in their design (Table IV). Many were based upon few patients with dislocations, small statistical power,[4,5,9,11-19,28,40-42] lack of control groups,[4,8,9,11-13] no differentiation between primary and revision surgery[4,5,8,9,11,12,14,15,18,41,42] or anterior and posterior dislocations,[4,5,8-11,13,14,17-19,28,40,42] and inaccurate methods of measuring the position of the component. Furthermore, definitions of anteversion and abduction vary and, for this reason, comparison without recalculation of results is difficult. It has been reported that true lateral or cross-table lateral radiographs are inaccurate for measuring anteversion of the acetabulum.[1] In addition, anterior and posterior radiological orientation is a function of the obliquity of the component.[2] On repeated cross-table lateral radiographs, a variation of as much as 20° has been found in the position of the component in the same patient.[1] A review of the literature revealed no accurate method of measuring anteversion of the acetabular component.[43] Simple radiological measurement was unreliable, especially when assessing flexion or anteversion.[43] However, EBRA significantly reduced radiological errors of measurement which can be caused by changes in the position of the pelvis.[23,27]

Our study showed that small alterations of position of the acetabular component can increase the frequency of dislocation.

Dorr et al[15] stated that one of the most common technical errors which resulted in recurrent dislocation was incorrect anteversion of the acetabular component. They suggested that this could be avoided by using anatomical landmarks at the time of surgery. Variations in positioning of the patient on the operating table can lead to inaccurate orientation of the acetabular component at the time of surgery.[2,43] The position of the component during the operative procedure has been noted to vary by 20°, even for well-trained surgeons, lending support to the argument for the use of hip navigation systems.[40] When using a mechanical guide, DiGioia et al[43] observed a significant variation in alignment of the acetabular component from their desired goal of 45° of abduction and 20° of anteversion. This would have led to unacceptable acetabular alignment in 78% of the hips. As a consequence, they suggested the use of a computer-assisted navigation system in order to measure alignment and to monitor the orientation of the pelvis during surgery. CT-based and, more recently, CT-free navigation systems have been developed for the exact placement of components during surgery.[21,22] Despite no earlier clinical study, DiGioia et al[43] highlighted the necessity to position the cup to an accuracy which was better than 10°.

Our study demonstrates that there is not a safe range for the position of the acetabular component. In the large number of patients which we studied, an anteversion of 15° and an abduction of 45° showed the lowest risk for dislocation when using the anterolateral approach. Nevertheless, the stability of a THR is a multifactorial issue. Other factors which were not investigated in our study such as femoral anteversion, the head neck ratio and soft-tissue tension may, on an individual basis, alter the most stable position of the cup.

Supplementary material

A further opinion by Mr Fares Haddad is available with the electronic version of this article on our website at www.jbjs.org.uk

No benefits in any form have been received from a commercial party related directly or indirectly to the subject of this article.

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