Dislocation after total hip replacement – *there is no such thing as a safe zone for socket placement with the posterior approach*

Short title: There is no cup safe zone for dislocation in THR

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Abstract

Introduction: Malorientation of the socket contributes to instability after arthroplasty but the optimal orientation of the cup in relation to the pelvis has not been unequivocally described. Large radiological studies are few and problems occur with film standardisation, measurement methodology used and alternative definitions of describing acetabular orientation.

Methods: A cohort of 1578 patients from a single institution is studied where all patient data was collected prospectively. Risk factors for patients undergoing surgery are analysed. Radiological data was compared between a series of non-dislocating hips and dislocating cases matched 2:1 by operation type, age and diagnosis.

Results: The overall dislocation rate for all 1578 cases was 3.29% but the rate varied according to the type of surgery performed. The rate in uncomplicated primary cases was 2.46% which increased to 9.26% for second stage implantation for a two stage procedure for infection. There was no significant difference in the variability of the dislocating and non-dislocating groups for either inclination (p=0.393) or anteversion (p=0.661).

Conclusion: A “safe zone” for socket orientation to avoid dislocation could not be defined. The cause of dislocation is multifactorial, details such as re-establishing the anatomic centre of rotation, balancing soft tissues and avoidance of impingement around the hip are important considerations.

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Keywords: hip dislocation; total hip replacement; bone cement; radiology; socket orientation

Introduction:

Hip dislocation is one of the most common early complications following hip arthroplasty with reported incidences ranging from 0.5 (1) to 9.2% (2). Risk factors are well known (3). In most reported series 60-70% of the dislocations occur within the first 4-6 weeks of surgery (4).

It is generally accepted that component malpositioning, particularly of the acetabular component, influences the risk of dislocation. Kahn et al.(5) reported malorientation of the acetabular component in more than half the 142 cases of dislocation in a series of 6774 hips. Kristiansen (6), in a study of dislocating Stanmore hips, noted the influence of surgical approach, with less acetabular version being observed when the posterior approach was used.

The paper by Lewinnek (7) is the most cited publication concerning dislocation in the literature as the authors define a “safe range” for orientation of the prosthetic socket. Since this paper has become generally accepted as defining optimum socket positioning it is worth studying it in some detail. The authors studied a series of only 300 arthroplasties of which nine (3%) dislocated. Patients with multiple different diagnoses including previous failed surgery are included in the cohort whose operations were carried out by five different surgeons. The authors studied the radiographs of the nine cases that dislocated but only 113 of the 291 hips that did not dislocate since the x-rays could not be retrieved for 178 hips. The total of 122 patients in the study group included the nine dislocations and is therefore not a random sample. The conclusions of the paper are also adversely affected by the fact that six of the nine patients had had prior surgery on the same hip (a factor known to increase dislocation risk (8, 9)), a significantly greater number than in the control group. With regard to anterior dislocations, the three cases that had anterior dislocations were anteverted 25° or more, compared with a value of 15.6° ± 8.5 in the other six dislocators. The control group were reported to have a significantly reduced anteversion angle compared with the group that dislocated anteriorly. The angle of inclination was not significantly different. The authors expected that a decreased anteversion would lead to posterior dislocation but the data available to them did not support this hypothesis and none of the acetabular components in their series was retroverted more than 4°. They infer that whilst excessive posterior version may lead to posterior dislocation, safe orientation of the component will not necessarily prevent such dislocations. They empirically advocated a safe range of orientation of the cup of inclination 40° ± 10° and anteversion 15° ± 10°. That component position alone is not the sole factor in avoiding dislocation is highlighted by the fact that the most experienced surgeon in this publication had a very low dislocation rate (0.5%) but did not position the socket more accurately than the other operating surgeons. It is our contention that the multiple flaws in this paper call into question the whole concept of a "safe zone" for socket positioning advocated by the authors.

In order to confirm the magnitude of the dislocation problem and determine the risk factors for dislocation in our practice, a consecutive cohort of patients who had their hips replaced was studied in detail. X-rays of the dislocating patients were measured and the position and orientation of the cups were compared with a cohort of non-dislocating patients matched 2:1 to the dislocating group by the parameters of operation type, diagnosis and age. The orientation of the implanted cup was of primary interest in the review of these patients.

Patients and Methods:

All patients who had a hip replacement at our institution over a three year period are included in this retrospective review although relevant data were collected prospectively on proformas. Any patients who did not attend a routine appointment were contacted so that no case was lost to follow-op. All patients were specifically asked about the complication of dislocation at each visit so an accurate record of this occurrence could be made.

A total of 1578 total hip arthroplasties were performed; 69.5% were routine primary operations, 4.2% complex primaries and the remainder (26.3%) were revision procedures of varying complexity (Table 1). Generally, more complex cases were carried out by the most senior surgeons. The average age of the cohort was 68.2 (SD 12.7) with a range of 16 – 95 years. The vast majority (96%) of operations were performed through a posterior approach and all of the dislocations occurred in these patients. The majority of hips (72.8%) had a 26mm head, with a further 19.6% a 30mm head. An attempt was made to routinely repair the posterior structures.

Logistic regression using the likelihood ratio method of variable entry was used to determine factors which significantly influenced dislocation.

Pre- and post-operative radiographs of all cases who suffered a dislocation were scanned, scaled and analysed using OrthoView™ (Southampton, Hampshire) software.

Three lines were drawn on the image, one marking the bottom of the ischium on each side, one through corresponding points on the lesser trochanter, and the most superior through the centre of rotation of the hip on each side (Figure 1). Distance HI represents the distance from the bottom of the ischium to the centre of rotation and HT is the distance from the centre of rotation to a point on the proximal femur. The horizontal distance from the teardrop to the centre of rotation (COR) was also measured to allow an assessment of lateralisation of the COR of the hip.

The x-rays of the dislocators were matched 1:2 to x-rays of non-dislocating patients who had their operations during the same review period. The parameters for matching were i) type of surgery, ii) diagnosis and iii) age. The x-rays were sorted into primary and revision cases and an analysis was undertaken to compare measurements taken pre- and post-op on the ipsilateral side. A comparison was also carried out when a normal (anatomic) hip was present on the contralateral side.

For the **ipsilateral comparison** the measurements are therefore of ***change*** in lateralisation of COR, cup height, femoral component height and leg length. The leg length discrepancy in comparison with the other hip was also noted.

The measurements for the **contralateral comparison** allowed comparison of the measurements made on post-operative films with those of a normal contralateral hip (54 cases). These give an indication of how accurately the surgeon recreated the biomechanics of the host hip.

Socket orientation was described by two angles using anatomic definitions developed for the project in the OrthoView Software. Inclination was measured using the radiological definition as described by Murray (10) and anteversion was measured using the anatomic definition of anteversion (10).

Statistical Methods:

Logistic regression using the forward likelihood ratio method of variable entry was used, where the variables with the strongest influence are added to the model first. When there are no more significant variables iteration stops leaving only significant variables in the model. Significance testing was carried out as appropriate for the data type using SPSS for Windows V16 (SPSS Inc, Chicago, Il). Multiple testing was adjusted for using Bonferroni's correction.

Results

There were a total of 51 dislocations. The overall dislocation rate for all 1578 cases was 3.23% but the rate varied according to the type of surgery performed (Table 1). There were significantly more dislocations in revision compared with primary operations ($p = 0.011$) (chi-squared test).

In keeping with other published series, 71% of cases that suffered a dislocation did so within eight weeks of the index procedure (Table 2).

The overall rate of multiple dislocations was 1.3% for the whole series and was predictably higher in the more complex cases. Of the 20 multiple dislocators, nine (45%) had three or more dislocations. Of the total number of dislocating hips 39.2% of them had a further dislocation (Table 3).

The dislocation rate also varied according to the primary diagnosis. For osteoarthritis, the dislocation rate was 2.2% (18/825) overall and 1.5% (12/834) of patients suffered a single dislocation. Patients with inflammatory arthritis had a dislocation rate of 8.8% (3/34) with a similar proportion falling into the single and multiple dislocation groups. The highest dislocation rates were recorded in patients with avascular necrosis following trauma (12.5% - 1/8) or in salvage of a septic joint (12.5% - 1/8). There was a significantly lower rate of single dislocation among primary OA patients compared to those with other diagnoses ($p < 0.001$).

Table 4 records details of patient age, BMI and the occurrence of dislocation. Body Mass Index did not appear to influence the tendency of hip to dislocate after surgery.

Although the rate of dislocation appeared to vary by grade of surgeon as well as complexity of surgery (Table 1), only type of surgery was significant when analysed using a two-way analysis of variance ($p=0.528$ and $p=0.032$ respectively). Differences in dislocation rate in more difficult cases will depend on case mix and the type of socket inserted as well as on other details of the surgical technique employed.

In single stage revision cases (of which 13.9% (50/361) were for instability) the dislocation rate was highest if the femur alone was exchanged compared with revision of the socket alone or both components (Table 5), although this was not statistically significant ($p=0.257$).

Cemented all polyethylene sockets constituted the majority of prostheses inserted (57.6% overall and 82.0% for OA only). The difference in dislocation rate between cemented sockets and uncemented design did not reach significance, either overall or for the OA only group ($p=0.79$ and $p=0.59$ respectively). Since 96% of the cases were performed through a posterior approach no meaningful comparison could be made of alternative surgical exposures of the hip.

Result of regression analysis

Variables included in the analysis were diagnosis, surgery type, surgeon grade, age at operation, surgical approach, psoas release, reduction tightness, head size and external rotator repair.

Using logistic regression for all data, the final model indicates that diagnosis (p=0.011), patient age at operation (p=0.003) and Psoas release (p=0.054) all are significant within the model. For the straightforward primary cases only (25 dislocations), only a diagnosis of inflammatory arthritis proved significant (p=0.021) although diagnosis overall was not significant (p=0.132), as well as head size of 22mm compared with 26mm (p=0.034), but not head size overall (p=0.137).

Radiological findings

Results of measurement of centre of rotation in relation to the pelvis and the femur

Primary ipsilateral data (n=61)

In the analysis of socket and femoral height the primary outcome was the direction of change of the centre of rotation in relation to the pelvis and the femur. Using Bonferroni's correction for multiple testing the significance level of interest is therefore 0.025.

For cup lateralisation, there is no significant difference in direction of change (medial/lateral) for the dislocators and non-dislocator groups (p=0.43). Cephalad/caudal change of centre of rotation, was arbitrarily categorised around zero. There is a significant difference in the direction of change of the centre of rotation. Significantly more cups were inserted in a more proximal position in the dislocator group (p=0.02). For femoral height, there is also a significant difference in the direction of change of the height of the centre of rotation in relation to the femur. The centre of rotation of the femoral head was raised in a significantly greater proportion of the dislocating group (p=0.017). The mean (95% CI) distance cups were raised was 6.5mm (95% CI 4.1 to 8.9) and femurs lengthened was 10.2mm (95% CI 8.2 to 12.1).

The cup height and femoral height figures were then analysed in combination (11) (Table 7). The hip was more likely to dislocate if the centre of rotation was elevated and the femoral component was incompletely seated (p=0.003) (Table 6).

With regard to leg length discrepancy, there was no significant difference between the actual measured figures between the dislocators and non dislocators (p=0.89). There was no difference in the frequencies of those lengthened or shortened between the groups (p=0.76).

Revision ipsilateral data (n=47)

There was no significant difference in either the figures or direction between the groups for any of the parameters considered – cup laterality, cup height, femoral height or leg length discrepancy. The main risk factor for revision procedures is the nature of the operation itself.

Primary contralateral data (n=54)

Lateralisation, cup height and femoral height were compared, and indicate no significant differences between the groups (p-values; 0.26 cup height, 0.49 femoral height and 0.73 lateralisation). There was also no difference in directions for any of these variables (p=0.17 lateralisation, p=0.30 cup height and p=1.0 femoral height). There were no significant differences between measured values for difference in leg length (p=0.91) or in direction (p=0.90).

Revision contralateral data (n=27)

Lateralisation, cup height and femoral height were compared, and indicate no significant differences between the groups (p-values; 0.30 cup height, 0.41 femoral height and 0.71 lateralisation). There was also no difference in directions for any of these variables (p=0.65

lateralisation, p=1.0 cup height and p=0.23 femoral height). Difference in leg length showed no significant difference between groups (0.097) and no difference in direction (p=0.64).

Comparison of socket orientation for the case controlled series

The measurements (Table 7) and boxplots (Figures 2 & 3) for inclination and anteversion for both groups are given.

Normality testing indicated that the inclination data for the dislocators was not distributed Normally. However, due to numbers, the use of parametric testing is justified.

Levene's test for homogeneity of variance indicates that there is no significant difference in the variability of the two groups for either inclination (p=0.39) or anteversion (p=0.66). There is no significant difference between the two groups for inclination (p= 0.83) or anteversion (p= 0.84). There were two extreme outliers for inclination (at 27.8° and 62.7°) in the dislocation group which are known to be at greater risk of dislocation.

The scatterplot for inclination vs. anteversion for dislocators and matched controls (Figure 4) confirms that inclination and anteversion measurements in both groups fell in a similar range of values.

Logistic regression analysis indicated none of the variables were entered into the model and angles for inclination and anteversion combined were not a predictor for dislocation.

There was no difference between the dislocating and non-dislocating matched series with regard inclination and anteversion of the acetabular component. No "safe zone" for socket orientation could be defined when the hip is inserted through a posterior approach.

Discussion: Is there a safe zone for socket positioning?

Several authors have made recommendations for the optimal orientation of the acetabular component. Charnley thought that the component should be inserted in neutral version.(12) Coventry (13) studied 32 cases and suggested 40° abduction and 15° anteversion, McCollum and Gray suggested 30-50° abduction and 20-40° anteversion, (14) whereas Harris,(15) promoted 30° abduction and 20° anteversion. The reference frames and terms used to describe angular position are rarely defined in papers describing surgical technique but surgical practice has evolved citing these papers as evidence for optimal socket position.

Some authors *have* defined the axes or planes to be measured.(7, 14, 16, 17) There is clearly a great range in opinion concerning the safe range of implantation of a socket. It is likely that there are different ranges of safe orientation of the cup depending on the surgical approach to the hip but this has been inadequately recognised in the literature.

Biedermann et al.(18) reported on the orientation of the cup in 127 dislocated hips. In contradistinction to the series reported here, the operations were all carried out through a standard lateral, transgluteal approach with complete capsulectomy and either a 28 or 30mm head was inserted. The radiographic measurements were compared with those of a consecutive series of 342 hips. Unlike our control group they were not a matched series using other risk criteria for dislocation. The authors employed the EBRA (Einzel-Bild-Roentgen-Analysis) system to measure the radiographs.(19) 50% of hips that dislocated were in the “safe zone” defined by Lewinnek,(7) compared with 79% of hips in the control group of non-dislocators. Leichtle et al also found no relationship between acetabular component position and dislocation. (20)

Biedermann reported that only a small alteration in position of the acetabulum inserted through a direct lateral incision can increase the frequency of dislocation. The paper showed that for the direct lateral approach a “safe zone” for socket orientation could not be defined.

In a retrospective analysis of 500 total hip arthroplasties, Rittmeister and Callitsis (21) showed that dislocation was not more frequent when the component had been placed outside the safe zone. Merle et al (22) indicated that reproduction of native anatomy for acetabular inclination would result in inclination much greater than Lewinnek’s “safe zone”, as the native anatomy of the osteoarthritic hip is highly variable.

Conclusion

We describe that for hip replacements performed through a posterior approach there is no "safe-zone" for socket orientation.

We have described that the hip is more likely to dislocate if the cup is implanted high and the femur is inserted into the femur with a raised centre of rotation (p=0.003). Impingement of hard and soft tissues around the hip is more likely to occur if the centre of rotation is abnormal.

Our data indicates that an accurate attempt should be made to recreate the anatomic position of the centre of rotation of the hip and the normal orientation of the acetabular axis. However, even if the socket is aligned adequately the possibility of dislocation cannot be discounted and it is important to ensure that impingement does not lever the head out of the socket at the limits of the envelope of excursion of the hip. Additionally, tendinous structures should not be divided unless absolutely necessary (e.g. iliopsoas tendon), and divided soft tissues should be repaired at the end of the procedure (e.g. posterior capsule and external rotators). The importance of "balancing" the soft tissues is supported by the observation that the dislocation rate is higher in the elderly population and in patients with neurological disorders. If the socket is positioned is an extreme outlier however, then they are known to be at increased risk of dislocation. It could be argued that, within limits, inaccurately positioned sockets may be protected from an increased risk of dislocation by consideration of these other factors and by the surgeon taking whatever measures are required at the time of surgery to ensure that the hip can be manipulated through an adequate envelope of movement without impingement and subluxation taking place. This argument is supported by the fact that inexperienced or low volume surgeons have a higher dislocation rate than experienced operators. (23)

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Conflicts of interest

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References

1. Eftekhar NS. Dislocation and instability complicating low friction arthroplasty of the hip joint. *Clin Orthop Relat Res* 1976:120-5.

2. Ekelund A, Rydell N, Nilsson OS. Total hip arthroplasty in patients 80 years of age and older. *Clin Orthop Relat Res* 1992:101-6.

3. Sanchez-Sotelo J, Berry DJ. Epidemiology of instability after total hip replacement. *Orthop Clin North Am* 2001;32:543-52.

4. von Knoch M, Berry DJ, Harmsen WS, Morrey BF. Late dislocation after total hip arthroplasty. *J Bone Joint Surg [Am]* 2002;84-A:1949-53.

5. Ali Khan MA, Brakenbury PH, Reynolds IS. Dislocation following total hip replacement. *J Bone Joint Surg [Br]* 1981;63-B:214-8.

6. Kristiansen B, Jorgensen L, Holmich P. Dislocation following total hip arthroplasty. *Arch Orthop Trauma Surg* 1985;103:375-7.

7. Lewinnek GE, Lewis JL, Tarr R, Compere CL, Zimmerman JR. Dislocations after total hip-replacement arthroplasties. *J Bone Joint Surg [Am]* 1978;60:217-20.

8. Daines BK, Dennis DA. The importance of acetabular component position in total hip arthroplasty. *Orthop Clin North Am* 2012;43:e23-34.

9. Paterno SA, Lachiewicz PF, Kelley SS. The influence of patient-related factors and the position of the acetabular component on the rate of dislocation after total hip replacement. *J Bone Joint Surg [Am]* 1997;79:1202-10.

10. Murray DW. The definition and measurement of acetabular orientation. *J Bone Joint Surg [Br]* 1993;75:228-32.

11. Jolles BM, Zangger P, Leyvraz PF. Factors predisposing to dislocation after primary total hip arthroplasty: a multivariate analysis. *J Arthroplasty* 2002;17:282-8.

12. Charnley J. *Low Friction Arthroplasty of the Hip: Theory and Practice.* Berlin: Springer; 1979.

13. Coventry MB. Late dislocations in patients with Charnley total hip arthroplasty. *J Bone Joint Surg [Am]* 1985;67:832-41.

14. McCollum DE, Gray WJ. Dislocation after total hip arthroplasty. Causes and prevention. *Clin Orthop Relat Res* 1990:159-70.

15. Harris WH. Advances in surgical technique for total hip replacement: without and with osteotomy of the greater trochanter. *Clin Orthop Relat Res* 1980:188-204.

16. Jaramaz B, Digioia AM, III, Blackwell M, Nikou C. Computer assisted measurement of cup placement in total hip replacement. *Clin Orthop Relat Res* 1998:70-81.

17. Zwartele RE, Brand R, Doets HC. Increased risk of dislocation after primary total hip arthroplasty in inflammatory arthritis: a prospective observational study of 410 hips. *Acta Orthop Scand* 2004;75:684-90.

18. Biedermann R, Tonin A, Krismer M, Rachbauer F, Eibl G, Stockl B. Reducing the risk of dislocation after total hip arthroplasty: the effect of orientation of the acetabular component. *J Bone Joint Surg [Br]* 2005;87:762-9.

19. Stoeckl B, Biedermann R, Auckenthaler T, Bach C, Sununu T, Nogler M. Ante- and retroversion measurements of cups by ebra. [Article]. *J Bone Joint Surg [Br]*;83-B Supplement II:179.

20. Leichtle UG, Leichtle CI, Taslaci F, Reize P, Wunschel M. Dislocation after total hip arthroplasty: risk factors and treatment options. *Acta orthopaedica et traumatologica turcica* 2013;47:96-103.

21. Rittmeister M, Callitsis C. Factors influencing cup orientation in 500 consecutive total hip replacements. *Clin Orthop Relat Res* 2006;445:192-6.

22. Merle C, Grammatopoulos G, Waldstein W, Pegg E, Pandit H, Aldinger PR, Gill HS, Murray DW. Comparison of native anatomy with recommended safe component orientation in total hip arthroplasty for primary osteoarthritis. *J Bone Joint Surg [Am]* 2013;95:e172.

23. Brooks PJ. Dislocation following total hip replacement: causes and cures. *Bone Joint J* 2013;95-B:67-9.

	Routine primary	Complex primary	Single stage revision	2 stage revision	**Totals**
Consultants	361 (2.8%)	36 (5.6%)	229 (4.4%)	37 (10.8%)	**663**
Fellows	647 (2.0%)	29 (3.4%)	126 (4.8%)	16 (6.3%)	**818**
Registrars	85 (3.5%)	2 (0%)	6 (16.7%)	1 (0%)	**94**
SHOs	3 (0%)	0	0	0	**3**
TOTALS:	**1096 (2.4%)**	**67 (4.5%)**	**361 (4.7%)**	**54 (9.3%)**	**1578 (3.23%)**

Table 1: Type of surgery by surgeon grade (dislocation rate).

Surgery type	**within 8 weeks**	**after 8 weeks**
Routine primary	69.2% (18)	30.8% (8)
Complex primary	100.0% (3)	0% (0)
Single stage revision	64.7% (11)	35.3% (6)
2 stage revision	80.0% (4)	20.0% (1)
Total	**71.2% (36)**	**28.8% (15)**

Table 2: Time after operation until dislocation.

Surgery type	**multiple dislocators**	**% dislocators**
Routine primary	1.0% (11/1096)	40.7% (11/26)
Complex primary	1.5% (1/67)	33.3% (1/3)
Single stage revision	1.9% (7/361)	41.2% (7/17)
2 stage revision	1.9% (1/54)	20.0% (1/5)
Total	**1.3% (20/1578)**	**39.2% (20/51)**

Table 3: Rate of multiple dislocations.

All diagnoses	**No cases**	**Mean age (SD; range)**	**BMI (SD)**
Overall	*1578*	*68.2 (12.7; 16-95)*	*27.4 (5.1)*
Multiple dislocation	20	74.4 (10.1; 44-90)	27.4 (5.4)
Single dislocation	31	71.8 (10.3; 53-90)	27.0 (4.7)
No dislocation	1527	68.0 (12.7; 16-95)	27.4 (5.1)
Primary OA			
Overall	*825*	*70.2 (9.3; 39-95)*	*27.9 (5.0)*
Multiple dislocation	6	74.0 (9.5; 66-90)	27.7 (4.7)
Single dislocation	12	70.3 (8.1; 58-83)	26.0 (4.3)
No dislocation	807	70.2 (9.3; 39-95)	27.9 (5.0)

Table 4: Age at surgery, BMI and dislocation.

Single stage revisions	No	Dislocations	Rate (%)
Both components	298	14	4.7
Femur only	34	3	8.8
Socket only	29	0	0.0

Table 5: Components exchanged at revision operation and rate of dislocation.

	Cup not raised, Femur not lengthened	Cup raised **OR** Femur lengthened	Cup raised **AND** Femur lengthened
Dislocators	2	7	16
Non dislocators	13	16	9

Table 6: Change of COR in relation to pelvis and femur.

	Group	N	Mean (SD)	SEM	Range
Inclination	**Dislocator**	48	44.8 (5.2)	0.8	27.8-62.7
	Matched non	91	45.0 (3.8)	0.4	34.8-53.9
Anteversion	**Dislocator**	48	18.9 (9.3)	1.3	3.9-38.5
	Matched non	91	18.6 (9.2)	1.0	-0.1-45.5

Table 7: Inclination and anteversion measurements for dislocators and non-dislocators.

Figure Legends

Figure 1: X-ray illustrating measurements made.

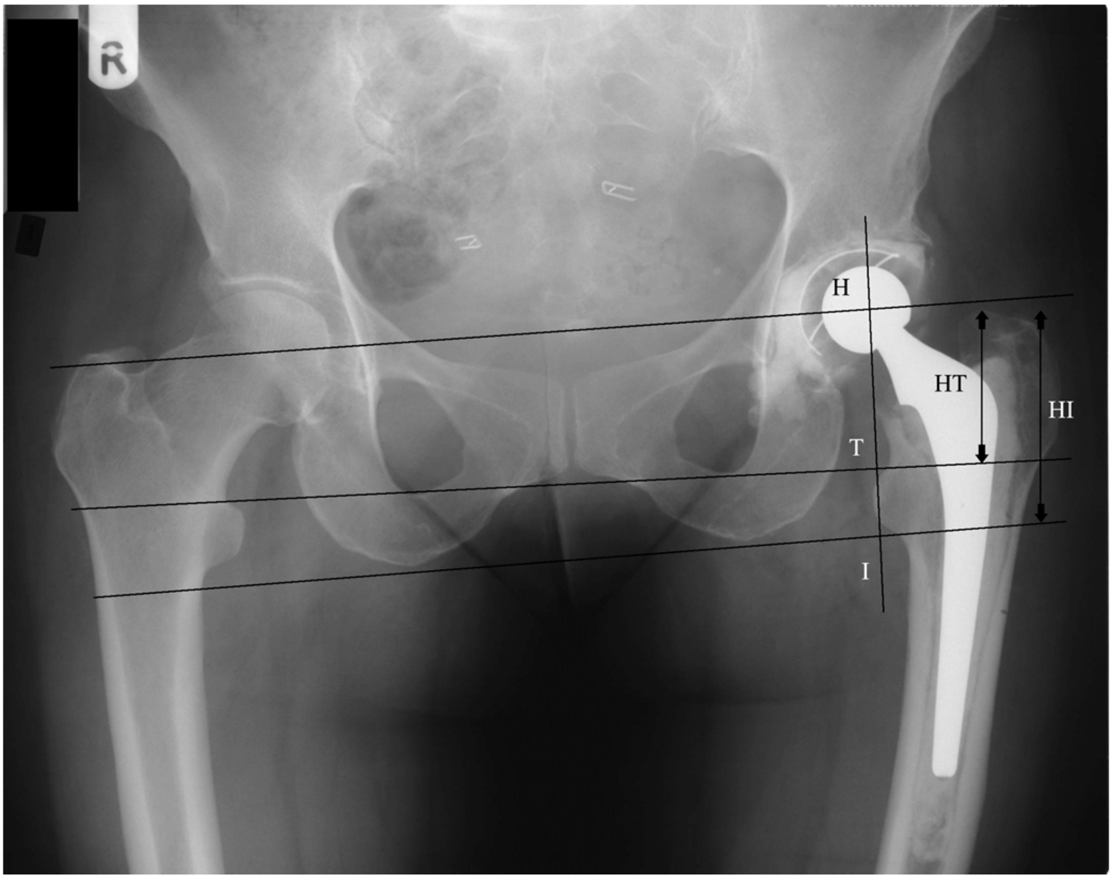


Figure 2: Boxplot for inclination.

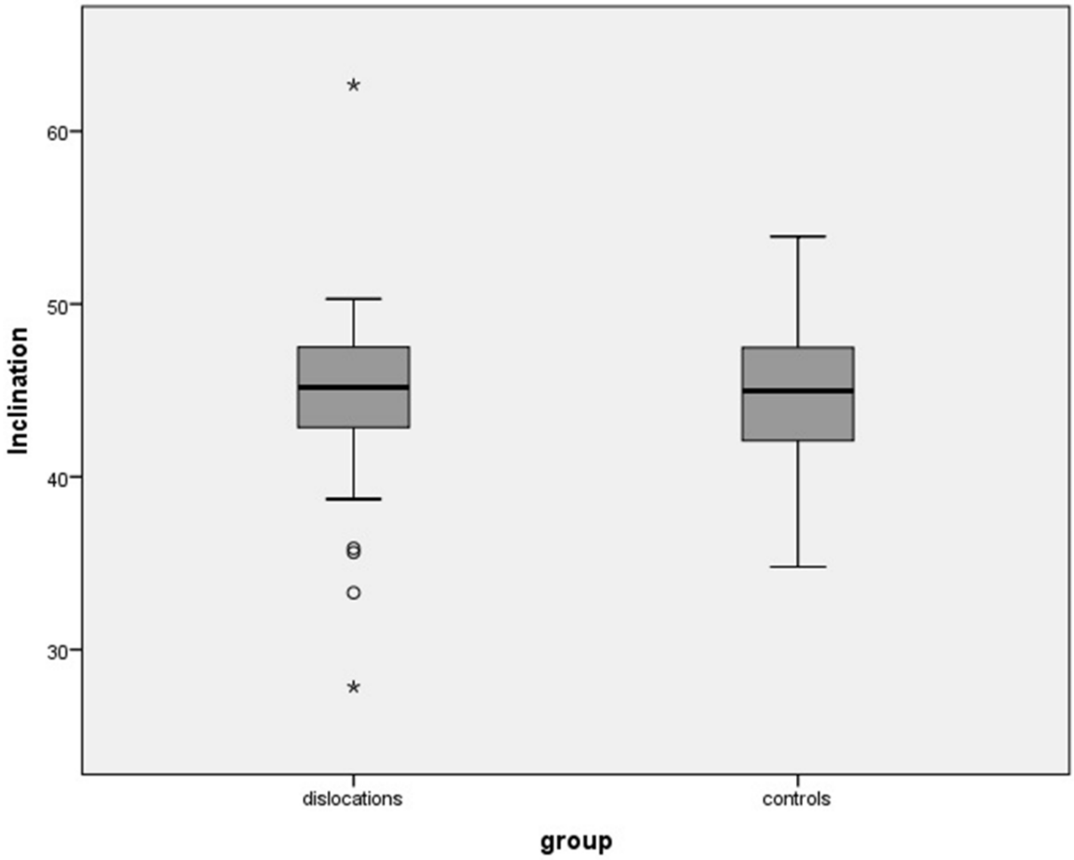
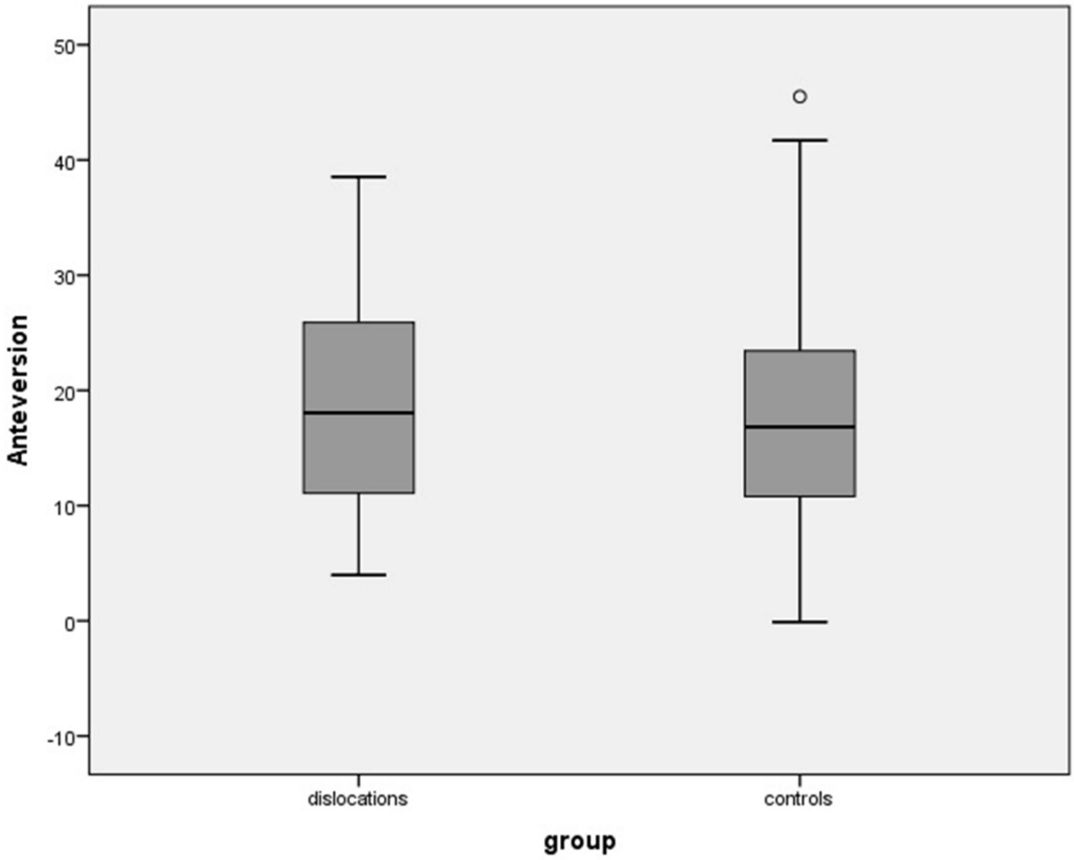


Figure 3: Boxplot for anteversion.



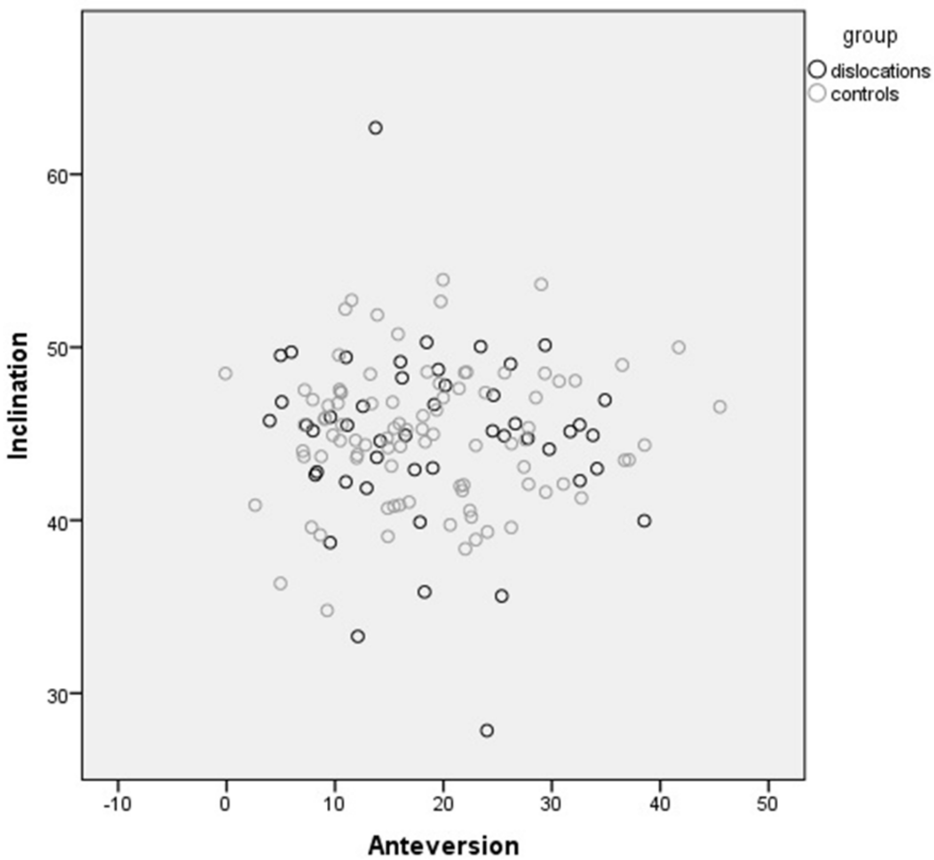


Figure 4: Scatterplot for inclination and anteversion.