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Can we trust combined anteversion and Lewinnek safe zone to avoid hip prosthesis dislocation?

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ABSTRACT

Introduction: Dislocation is one of the most common complications after primary total hip arthroplasty (THA). Combined anteversion (CA) is currently considered one of the most important measures of stability for THA. Thus, the aim of this study is to determine the association between a correct CA after THA and hip prosthesis dislocation, and to analyze the reliability of the Lewinnek safe zone parameters.

Material and methods: This is a non-interventional retrospective study, carried out at a tertiary hospital in Spain. 2489 primary THA in 2147 patients between January 2008 and December 2014 were identified. Clinical, biological and radiographic data, including cup inclination and cup and femoral anteversion, were analyzed of all patients who developed a hip prosthesis dislocation.

Results: Thirty-four patients met the eligibility criteria to be analyzed. In 73.5% (25/34) of cases, acetabular anteversion (AV) was correct, with a mean AV of 15.1° ± 9.4°. Femoral anteversion (FA) was considered correct only in 38.2% (13/34) of the dislocated THA, with a mean FA of 8.4° ± 17.2°. Sixteen of these 34 patients (47.0%) presented a correct CA, with a mean CA of 24.2° ± 21.0°. Nineteen hips (55.8%) were within the Lewinnek safe zone. Moreover, eleven patients (32.3%) developed a dislocation even though components were within the Lewinnek safe zone and presented a correct CA.

Conclusion: Our findings suggest that even when the THA components are positioned within a correct CA and in the Lewinnek safe zone, hip prosthesis dislocations can occur in a not inconsiderable percentage of the cases. Thus, further radiological and clinical analysis should be done to identify potential reasons for hip prosthesis dislocation.

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1. Introduction

Dislocation is one of the most common complications after primary total hip arthroplasty (THA), affecting between 0% and 5% of all cases.[1,2] This complication can cause significant patient morbidity as well as increased costs of health care.[3] According to registry-based studies, dislocation is the leading cause of revision in the first five years after primary THA.[4]

Numerous patient-related risk factors for dislocation have been identified, including age, body mass index (BMI), American Society of Anesthesiologists (ASA) score, alcohol, cerebral dysfunction during hospitalization, and rheumatoid arthritis.[4,5] Similarly, numerous surgeon-dependent factors have also been identified, including the surgical approach, soft-tissue repair, femoral head size and offset, restoration of leg length, and correct acetabular and femoral components positioning.[6,7] Proper positioning of the components is essential to obtain good results.[8] The placement of the acetabular cup has historically been guided by the "safe zone", which was first described by Lewinnek et al.[9] However, several reports have shown that dislocation can still occur even when the acetabular component is properly oriented in the safe zone.[4,10] Combined anteversion (CA) is defined as the sum of the cup and stem anteversion.[11] If the femoral stem anteversion and the acetabular cup anteversion are performed accurately, this should ensure mating of the femoral head in the cup without causing impingement throughout all body positions.[12] Avoiding

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impingement of the cup and stem is important to prevent pain, accelerated wear, and dislocation in patients who undergo THA.[8]

Measurement of the acetabular position alone is insufficient to diagnose the cause of dislocation in all cases.[4,10] For this reason, CA is currently considered the most important measure of stability for THA.[11,12] In this context, the primary aim of this study was to determine the association between a correct CA after THA and hip prosthesis dislocation, and to analyze the reliability of the "Lewinnek safe zone" for predicting dislocation.

2. Material and Methods

A non-interventional retrospective study was performed in our tertiary trauma centre located in Barcelona, Spain. Institutional review board approval was obtained to retrospectively review all patients who had undergone primary THA at our institution and were subsequently diagnosed with a prosthetic dislocation. Patients were identified through our institutional joint registry. Dislocations were defined as any episode that required closed or open reduction of a THA or that required a revision arthroplasty procedure due to a primary diagnosis of dislocation.

2.1. Eligibility criteria

Patients were included to the stadistical analysis if they concurred all the followings inclusion criteria: (1) patients between 55 and 90 years old who have undergone a primary THA for degenerative hip osteoarthritis, (2) THA performed via posterior approach with soft tissue repair, (3) non-traumatic dislocation occurring in the first 3 years after THA, (4) availability of a hip computed tomography (CT) obtained either before or after reduction of the prosthesis.

As standard protocol in our institution, every patient who suffers a hip prosthesis dislocation undergoes to CT scan in order to study the component's orientation and positioning.

Exclusion criteria included: (1) diagnosis of avascular necrosis of femoral head, hip fractures or dysplasia, (2) hip resurfacing arthroplasty, (3) history of alcoholism, rheumatoid arthritis, dementia, or neurological disorder such as Parkinson's disease**.**

2.2. Patients and surgical technique

From January 2008 to December 2014, we identified 2489 hips in 2147 patients who underwent THA at our institution who did not meet the exclusion criterias. 1362 (54.7%) patients were women, and mean age was 68.7 (SD 12.3). Of these 2489 THA, thirty-four patients (1.37%) met all the inclusion criterias and were included in the stadistical analysis.

A total of three acetabular component designs were used in this series, all of which had uncemented fixation. Four different femoral component designs were used (Table 1). The femoral components were inserted in an uncemented and cemented fashion in 83.7% (2083 stems) and 16.3% (406 stems) respectively.

Table 2
Data of patients with a dislocated total hip arthroplasty (N = 34).

Item	Mean (SD)
Operation time in minutes	73.5 (15.8)
Cup size[a]	54.6 (4)
Femoral head size[a]	34.9 (2.2)
Femoral component size	12 (2)
Neck length[a]	44.5 (3.4)
Femoral offset[a]	43.7 (4.9)
Acetabular offset[a]	33.6 (4.6)
Limb length difference[a]	6.2 (6)

N: number; SD: standard deviation.
[a] Values are given in millimeters.

2.3. Follow-up and outcome measures

Patient demographic and clinical data assessment included age at the time of surgery, sex, ASA score, BMI, time between primary surgery and first dislocation episode, amount of episodes of dislocations, need of revision surgery and time of follow-up.

Radiographic analysis included measurement, on CT scan, of cup inclination and measurement of anteversion of cup and femoral stem. CT scan was used because cup measurements are not affected by pelvic positioning and allows angles to be identified more accurately, particularly femoral anteversion.[13] For the measure of femoral stem anteversion a CT scan was done on the distal femoral condyles to determine the long axis of the femur. Correct positioning for implants was defined as follows: 40° ±10° for cup inclination, 15° ±10° for cup anteversion, 5° ±10° for femoral stem anteversion and 30–50° for the correct CA.[9,14] The Lewinnek zone refers to the correct implantation of both acetabular anteversion and inclination.[9] In the current study, the objective for the CA was based on current literature referring that CA is the sum of cup and stem anteversion [cup anteversion + stem anteversion = 20–50°].[11,12,14] We considered 50° to be the upper limit of the safe according the recommendations of the current literature.[12] All measures were done by a single radiologist with expertise in musculoskeletal pathology. Secondary measurements — including leg length discrepancy, horizontal and vertical offset — were also performed (Table 2).

2.4. Statistical analysis

Categorical variables were described with their absolute values and percentages. Quantitative variables were presented by mean

Table 1
Types of cups and femoral stems implanted in the sample.

Type of components	N = 2.489	
Cup System	**Total sample: 2.455 (%)**	**THA dislocation: 34 (%)**
U2 (United Orthopedic Corporation, Hsinchu, Taiwan)	1.731 (70.5)	22 (64.7)
ProCotyl (Wright Medical Ltd, Pulford, United Kingdom)	579 (23.6)	8 (23.5)
Trilogy (Zimmer, Warsaw, Indiana)	145 (5.9)	4 (11.8)
Femoral Stem		
U2 (United Orthopedic Corporation, Hsinchu, Taiwan)	1.671 (68.1)	22 (64.7)
Furlong (JRI Ltd, London, United Kingdom)	184 (7.5)	2 (5.9)
Profemur (Wright Medical Ltd, Pulford, United Kingdom)	300 (12.2)	6 (17.6)
Preserve (Wright Medical Ltd, Pulford, United Kingdom)	300 (12.2)	4 (11.8)

N: number; THA: total hip arthroplasty.

Table 3
Patient demographics and clinical values.

	Total N = 34	Correct CA N = 16	Incorrect CA N = 18	*P* value
Gender				
Male (%)	14 (41.2)	2 (16.7)	12 (55.5)	0.062
Female (%)	20 (58.8)	10 (83.3)	10 (45.5)	
Age (SD)	71.4 (10.6)	70.7 (10.4)	71.7 (10.9)	0.793
BMI (SD)	29.7 (4.2)	30.3 (5.4)	29.4 (3.4)	0.565
ASA score:				
II (%)	17 (50)	4 (33.3)	13 (59.1)	0.151
III (%)	17 (50)	8 (66.7)	9 (40.9)	
Time between THA and first dislocation episode in days (SD)	273 (372)	425 (531)	190 (223)	0.07
Recurrent dislocation				
Yes (%)	25 (73.5)	10 (83.3)	15 (68.2)	0.339
No (%)	9 (26.5)	2 (16.7)	7 (31.8)	
THA revision				
Yes (%)	18 (52.9)	8 (66.6)	10 (45.5)	0.057
No (%)	16 (47.1)	4 (33.4)	12 (55.5)	
Follow up −months (SD)	39 (14.4)	38.7 (14.2)	40.5 (13.8)	0.720

N: number; SD: standard deviation; %: percentage; CA: combined anteversion; BMI: body mass index; ASA: American Society of Anesthesiologists; THA: total hip arthroplasty.

and standard deviation (SD). Categorical variables were compared with Fisher's exact test, while quantitative variables were compared using *T*-tests or Mann-Withney *U*-tests, as appropriate. Differences with *P* values < 0.05 were considered statistically significant. Statistical analysis was performed with the Stata 14.2 version (StataCorp, Texas, USA).

3. Results

Thirty-four patients (20 women and 14 men) were included in the final statistical analysis. Dislocation rate for primary THA for degenerative hip osteoarthritis who were operated via posterior approach with soft tissue repair in this sample was 1.36% (34 of 2489 patients). Mean age at the time of surgery was 71.4 years (SD 10.6 years). Mean interval between surgery and first dislocation episode was 273 days (SD 372), where all patients suffered of a posterior dislocation. Mean follow up after first dislocation episode was 39 months (SD 14.4) (Table 3).

In 24 cases (70.5%), femoral components were inserted in an uncemented fashion. Nine patients (26.5%) presented only a single dislocation episode while the remaining 25 patients (73.5%) experienced recurrent dislocations. None of the patients who presented only one dislocation episode required a THA revision. Reintervention was required in 18 of the 25 cases (72%) with recurrent dislocations.

Mean femoral offset was 43.7 mm (SD 4.9) while mean acetabular offset was 33.6 mm (SD 4.6). Mean neck length was 44.5 mm (SD 34.4) and mean limb length difference was 6.2 mm longer (SD 6) (95% CI, 5−7 mm).

Mean cup inclination, cup anteversion, and femoral stem anteversion were, respectively, 43.5º (SD 8.6), 15.1º (SD 9.4), and 8.4° (SD 17.2) (Figs. 1 and 2). Cup inclination and cup anteversion were within the Lewinnek zone in 76.4% (26 of 34) and 73.5% (25 of 34) of hips, respectively. Femoral stem anteversion was within a correct zone in 38.2% of cases.

Mean CA was 24.2° (SD 21.0) and in 47% of the hips (16 of 34) it was considered to be in the correct range (Fig. 3). In this group of patients with correct CA, time between surgery and first dislocation episode was 2.2 times greater than in group without correct CA, even though statistical significance was not found in this difference ($p = 0.07$).

Nineteen hips (55.8%) were within the Lewinnek safe zone and 11 patients (32.3%) experienced dislocation even though components were within the Lewinnek safe zone and presented a correct CA (Table 4).

4. Discussion

To obtain good results, it is essential to correctly orientate the implants.[8] The main aim of the present study was to determine if a correct CA accurately predicts dislocation in patients who undergo THA. We also sought to determine if the radiographic “safe zone” proposed by Lewinnek et al. accurately predicts dislocation. Our main findings were that 47.0% of dislocation cases (16/34) presented a correct CA and 55.8% of dislocations cases (19/34) were within the Lewinnek safe zone. Importantly, eleven patients (32.3%) developed a dislocation even though the components were located within the Lewinnek safe zone and also presented a correct CA. These findings show that hip prothesis dislocation can occur in an in a not inconsiderable percentage of the cases, even when the components are properly positioned.

The optimal implant orientation is a topic for considerable discussion and has been variously reported, particularly for the cup position.[4,15] In 1978, Lewinnek et al. defined a safe zone for the acetabular component, which was designed to prevent postsurgical dislocations.[9] However, despite the wide acceptance and use of the safe zone in routine clinical practice, dislocations still occur.[10] In our study, we found that most (55.8%) of the dislocated cups occurred within the safe zone for both inclination and anteversion. These findings are consistent with other studies that have found more dislocations within the Lewinnek safe zone than outside of it.[10,16−21] Biedermann et al. found that 60% of cups that became dislocated were located within both safe zones (i.e., the cup inclination and anteversion).[16] Similarly, numerous other authors have reported that the acetabular cups in the dislocated THAs were within the Lewinnek safe zone in most cases, ranging from 54% to 91% of the dislocations.[10,17−21] Our results support the current literature indicating that measurement of the acetabular position alone is not the origin of all causes of dislocation.[4,10,16−21]

According to most recent reports, the most important measure for the stability of a THA is the combined anteversion.[11,12] CA is nature's method of providing stability and describes a position of the acetabular and femoral components in a relatively secure zone to allow an impingement-free range of motion.[8] Consequently, the CA is currently considered the true safe zone for THA, in contrast to the use of a safe zone for the acetabulum alone.[12] In our study, almost half of dislocations (47.0%) presented a correct CA. As we have shown in this study, the stem version was highly variable,

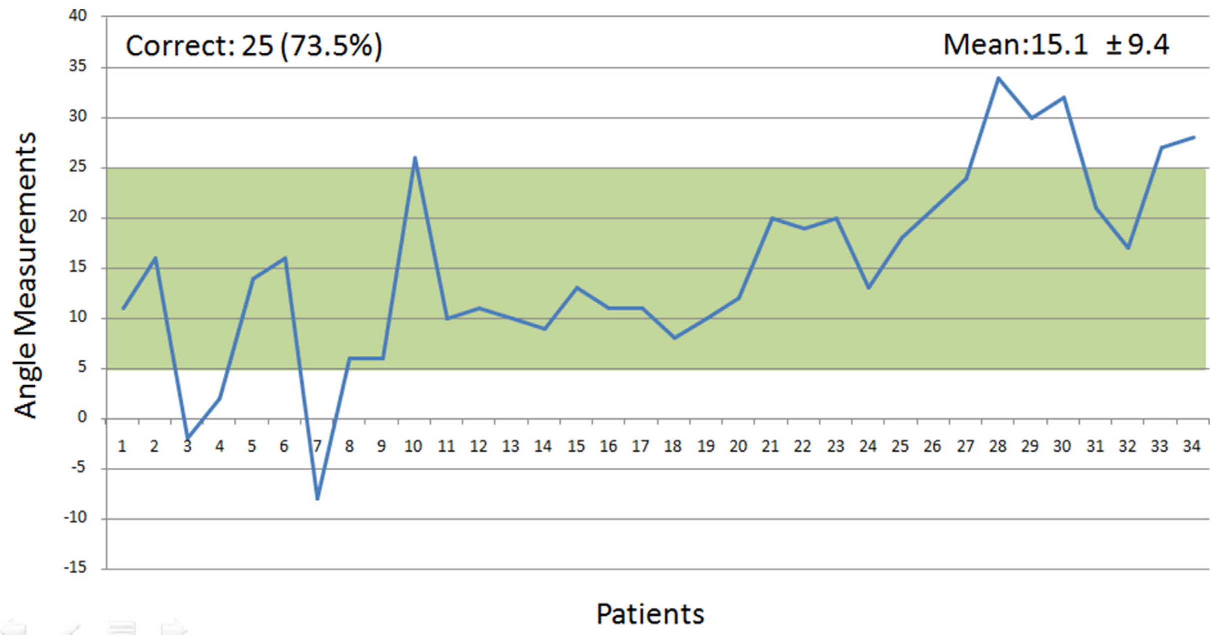

Fig. 1. Diagram depicting the number of patients with a dislocation who had a correct cup anteversion.

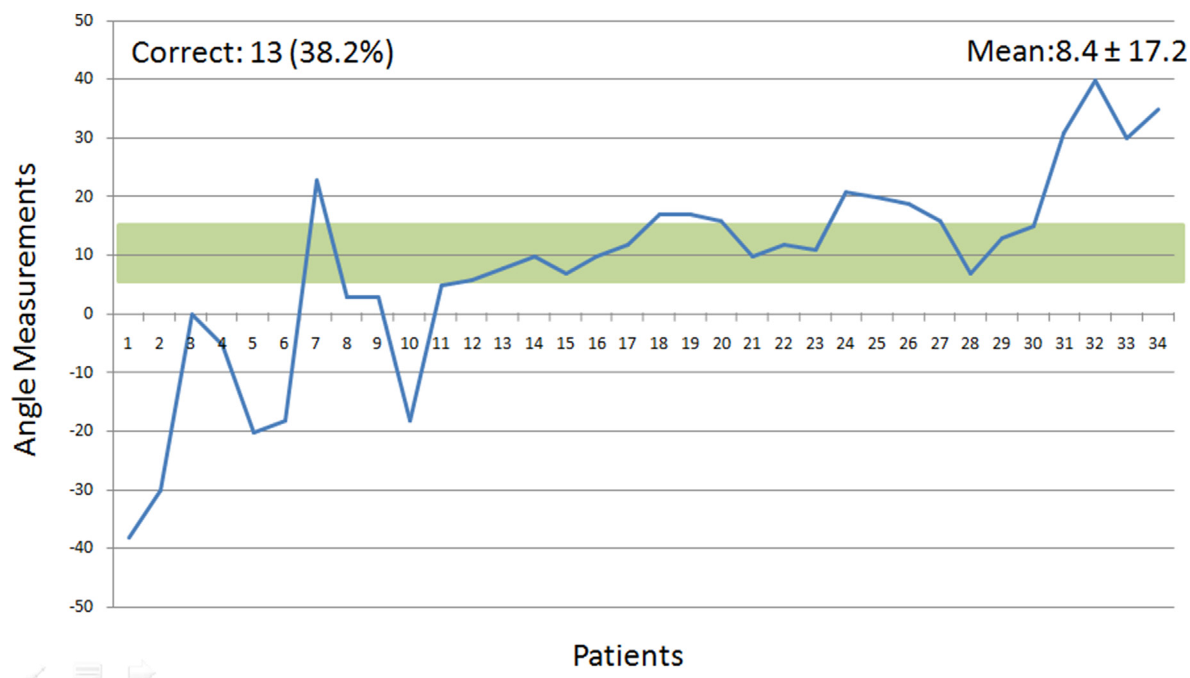

Fig. 2. Diagram depicting the number of patients with a dislocation who had a correct femoral anteversion.

ranging from −30° to 40°, possibly leading to implant malposition with the cup first technique. Cemented stems can be rotated to correct stem anteversion; however, cementless stems of any geometry are limited by native femoral anteversion to achieve the initial stability.[8,11,22] Our results are consistent with previous reports such as that of Maruyama et al. who found a range of stem anteversion, ranging from 17° retroversion to 28° anteversion in cementless femoral stems.[22] Other studies (using, as it was done in this study, post-operative CT scans) have reported a wider range: from 30° retroversion to 45° anteversion in both cemented and cementless stems.[23,24] About the CA technique and measurements, other authors have also evaluated it.[25,26] For instance, Weber et al. evaluated the measurements in 135 patients undergoing cementless THA, finding that prosthetic impingement was inhibited in over 90% of cases when the cup/stem anteversion was within the CA.[25] However, they also found that even when the CA of the cup and stem was located within the target zone of the CA, combined bony and prosthetic impingement still occurred in over 40% of cases. This finding was further confirmed by one case of post-operative dislocation in that sample.[25] Those authors report that

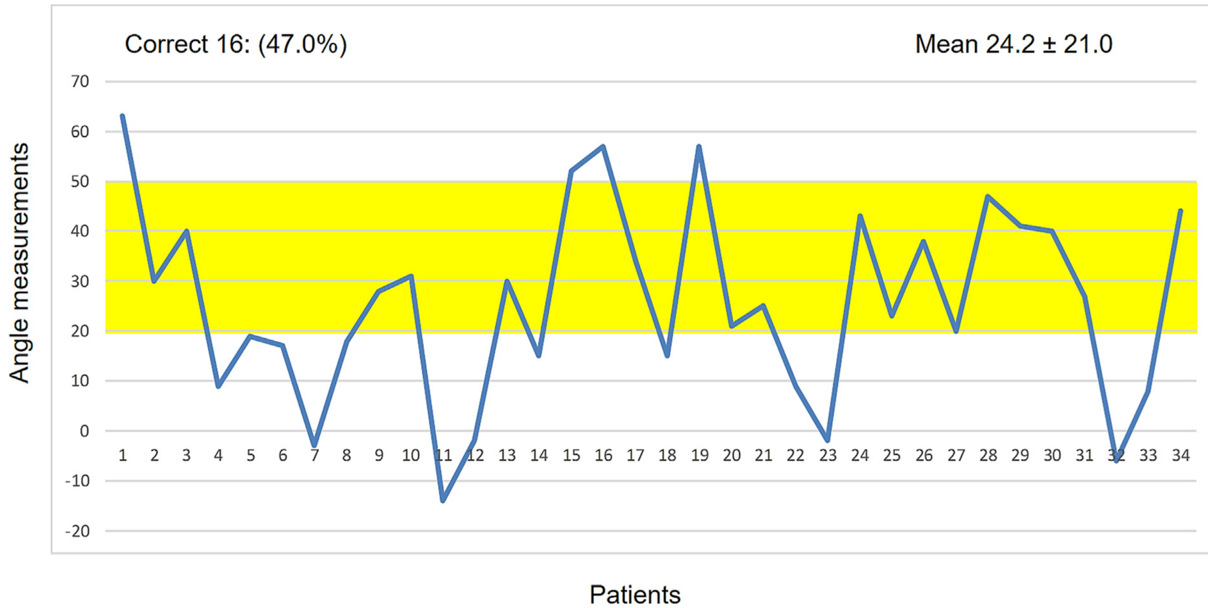

Fig. 3. Diagram depicting the number of patients with a dislocation who had a correct combined anteversion.

Table 4
Radiographic measurements values in dislocated total hip arthroplasty (N = 34).

	Total = 34 (SD)	Safe zone (%)
Cup Inclination[a]	43.5 (8.6)	26 (76.4)
Femoral Anteversion[a]	8.4 (17.2)	13 (38.2)
Acetabular Anteversion[a]	15.1 (9.4)	25 (73.5)
Combined Anteversion[a]	24.2 (21.0)	16 (47.0)
Lewinnek safe zone		19 (55.8)
Lewinnek safe zone + Correct CA		11 (32.3)

SD: standard deviation; %: percentage.
CA: combined anteversion.
[a] Values are given in degrees.

even when the CA is able to detect the prosthetic impingement and therefore serve the purpose of their original design, the failure of CA to detect combined bony and/or prosthetic impingement might be due to the absence of integrating functional aspects of hip joint movement.

In the group with correct CA (16 patients), the time between surgery and the first dislocation episode was 2.6 times greater than in the group without a correct AC (18 patients). However, this difference did not achieved statistical significance. Also, in our study, 11 of the 34 patients who developed a THA dislocation were within the Lewinnek safe zone and had a correct CA. To our knowledge, this is the first study to report THA dislocation even in arthroplasties with a correct cup safe zone position and a correct CA. Given our results and the reports described above, it appears that we need to learn more about the optimal orientation of the prosthetic components. We think that the answer to this question may be found in the close relation between the movement of the spine, pelvis and hip, whose importance was first described by Lazennac et al.[27] Those authors demonstrated that the orientation of the acetabulum is modified during normal activities of daily living. In the standing position, the pelvis tilts forward and thus the acetabular anteversion decreases. During the process of sitting, the pelvis tilts backward and, consequently, acetabular anteversion increases. Lazennac et al. showed that spine-pelvic mobility influences the contact between both prosthetic components and therefore acetabular orientation is a dynamic concept.[27] We agree with the current literature that suggests that the pelvic tilt might have a major influence on the functional outcome after THA and that CA concept does not properly account for this.[25,28] However, since pelvic tilt is a dynamic variable during gait, it is especially challenging to manage the impact of this parameter on functional outcomes.[29]

This study has several limitations. First, multiple surgeons and implant types were involved. Nonetheless, although this could be considered a drawback, it could also be considered as a strength, as it represents a real-life cohort of patients with multiple femoral head sizes and liner options. Second, we used a posterior approach with soft tissue repair in this sample, therefore limiting the applicability of these findings to that approach alone. However, the reason why we selected posterior approach was because it has been associated with higher rates of dislocation, thus presenting the best scenario to examine our research question.[30] Third, we used the linear regression equation provided by current literature in both men and women to achieve a CA of 20–50°.[14] However, some reports recommend a CA between 30° and 40° in men and up to 45° in women.[11,22] Given the limited number of patients in our study, we preferred to use only a single measurement.

In spite of the limitations, our study also has several strenght. To our knowledge, this is the first study to report THA dislocation even in arthroplasties with a correct Lewinnek zone position and a correct CA. Also we found that group with a correct CA showed a quicker dislocation than patient without a correct CA, even though this difference did not achieved statistical significance. Further studies should be completed analyzing the relation between CA and risk of hip prosthesis dislocation, with a greater number of patients and involving patients who have not suffered a dislocation episode.

To conclude, we found that even when the hip arthroplasty components are positioned in a correct combined anteversion and in the correct Lewinnek safe zone, total hip arthroplasty dislocations can occur in a not inconsiderable percentage of the cases. For that reason, further radiological and clinical analysis should be done to identify potential reasons for hip prosthesis dislocation.

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Declaration of competing interest

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