



Use of computerized axial tomography to determine correct alignment of prosthetic components in primary hip arthroplasty: A single-center observational study.

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Abstract

Introduction: The correct position and alignment of prosthetic hip components are essential for optimal short-term and long-term results. Among the factors that influence biomechanics are femoral and acetabular anteversion, which reduce the risk of dislocations. To avoid dislocation, the objective was to determine the angles of femoral and acetabular anteversion of the prosthetic components after hip arthroplasty via tomography.

Methods: This is a descriptive, cross-sectional study of the Traumatology and Orthopedics Service of the Alcívar Clinic from 2022 to 2023.

Results: Twenty-one patients presented average acetabular anteversion angles of $14^\circ \pm 8$ (6-22), 15° in men and 12° in women; average femoral anteversion angles of $18^\circ \pm 10$ (8-28), 18° in men and 20° in women; average combined anteversion angles of $33^\circ \pm 14$ (21-47); and 33° for males and females. Among the five early dislocations and two late dislocations, four posterior dislocations ($<21^\circ$) and three anterior dislocations ($> 47^\circ$) were functional according to the modified Harris scale, with results ranging from excellent to good (80–95%).

Conclusions: Tomography is a valuable and reliable tool for determining the correct alignment of prosthetic components in the hip in patients undergoing CTA. Early dislocations are not directly related to acetabular or femoral anteversion; multifactorial causes must be considered.

Keywords:

Prosthesis, Biomechanics, Femoral Anteversion, Acetabular Anteversion, Luxation.

Abbreviations

TCA: Total hip arthroplasty.

AV: true anteversion.

CT: Computerized axial tomography.

Supplementary information

No supplementary materials are declared.

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Authors' contributions

Manuel Enrique Betancourt Castillo: Conceptualization, data curation, formal analysis, acquisition of funds, research, writing - original draft.

Hugo Ernesto Villarroel Rovere: Conceptualization, data curation, acquisition of funds, project management, supervision.

Carlos Jacinto Valle Ochoa: Conceptualization, formal analysis, methodology. All the authors read and approved the final version of the manuscript.

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Availability of data and materials

The datasets used and analyzed during the present study are available from the corresponding author upon reasonable request.

Introduction

Correct alignment of prosthetic components is crucial to achieving successful clinical results and avoiding long-term complications. Misalignment can cause premature component wear [1], prosthesis dislocation, joint instability, and persistent pain [2].

Accurate measurement and correct placement of the femoral and acetabular anteversion components are essential to optimize the long-term results of total hip arthroplasty (THA). Various techniques, such as radiographic evaluation and surgical guides, determine and adjust anteversion angles during surgery.

Since conventional radiological and clinical measurement systems can be imprecise, it is possible to employ a simple, easy, and reliable method to measure the acetabular and femoral torsion angles, considered the leading anatomical indicators of clinical trauma. Computerized axial tomography (CT) has emerged as an invaluable tool in the pre- and postoperative evaluation of THA. CT provides detailed, three-dimensional images of the hip, allowing an accurate assessment of bone anatomy and the alignment of prosthetic components [3].

Anteversion of the femoral neck, also known as femoral torsion or version, refers to the relative rotation (torsion) between the axis of the bone and the femoral neck [4]. Typically, when viewed from above, the femoral neck projects approximately 15 degrees forward relative to a medial-lateral axis that passes through the femoral condyles. An approximate 15-degree anteversion angle allows for optimal alignment and joint congruence. A torsion greater than 15 degrees is called excessive anteversion. In contrast, torsion less than 15 degrees (approaching 0 degrees) is called retroversion [5]. Any alteration affects the biomechanics and anatomy of the hip and is associated with differences in gait, causing clinical problems, including osteoarthritis and epiphysiolysis of the femoral head [6].

Another risk factor for hip prosthesis dislocation is combined anteversion, which is defined as the sum of the acetabular version and the femoral version; after multivariate analysis, it was determined between $<40^\circ$ and $>60^\circ$; low or low femoral anteversion combined with low femoral and acetabular dislocations was associated with posterior dislocations; and high or combined femoral and acetabular anteversion with anterior dislocations [7].

The dislocation rate of prosthetic materials varies between 2% and 10%, and 28% in revision total hip arthroplasty [8]. The etiology of dislocation is one of the most frequent early postsurgical complications of hip arthroplasty. In

early dislocation, it is essential to check the surgical technique, soft tissue tension, lack of repair of the surgical approach, or patient noncompliance; in late dislocation, poor orientation, which can cause instability, possible eccentric wear, and dislocation, is essential. Multiple factors, such as cognitive status and neuromuscular disorders (dementia, cerebral palsy, Parkinson's disease, and cognitive dysfunction), age greater than 75 years (sarcopenia), previous surgeries (substantial soft tissue trauma and lack of trochanteric union), lack patient education and compliance with precautions [8-11].

To maintain sagittal balance, the lumbar spine, pelvis, and hip joint interactions require proper balance and alignment. Physiological aging, associated with a loss of lumbar lordosis and increased pelvic retroversion, involves a modification in the position of the lower extremities, with an anteversion of the acetabulum, hip extension, and knee flexion in an attempt to rebalance the sagittal profile. Retroverted pelvises put the hip replacement at risk of anterior dislocation when standing. Conversely, anteverted or low-incidence pelvises can put the THA at risk of posterior dislocation when sitting [12-16].

The hip prosthetic components have adequate femoral and acetabular anteversion to ensure good stability and joint function. The different strategies and clinical considerations used to place the elements in the THA correctly should be considered. No studies in our environment have determined the typical ranges of acetabular and femoral anteversion.

This study aimed to determine via tomography an adequate range of acetabular and femoral anteversion to achieve stability while avoiding the dislocation of prosthetic components.

Materials and methods

Study design

The present study is observational and cross-sectional. The source is retrospective.

Stage

The study was conducted in the Traumatology and Orthopedics service of the Alcívar Hospital in Guayaquil, Ecuador, from June 1, 2022, to August 31, 2023.

Participants

Patients who had undergone total hip arthroplasty at the Traumatology and Orthopedics Service of the Alcívar Hospital from June 2022–August 2023 were included, as high-quality CT images of the lower extremities and who had adequate clinical follow-up and complete data were available. Patients who had undergone partial hip arthroplasty (Thomson), patients who could not tolerate CT due to medical conditions

that prevented the study, or patients with insufficient or incomplete image quality of the lower extremities, which prevented an accurate evaluation, were excluded from the alignment of the hip prosthetic components. Patients with incomplete data were excluded from the analysis.

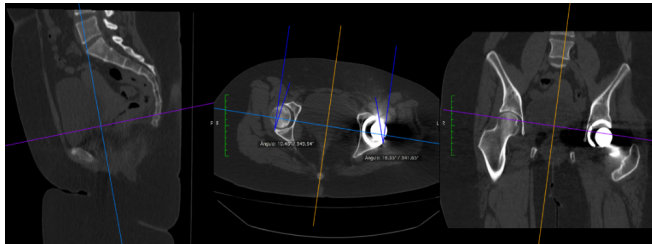
Variables

The variables used were age, sex, description of anteversion, percentage of dislocations, and functionality.

Data sources/measurements

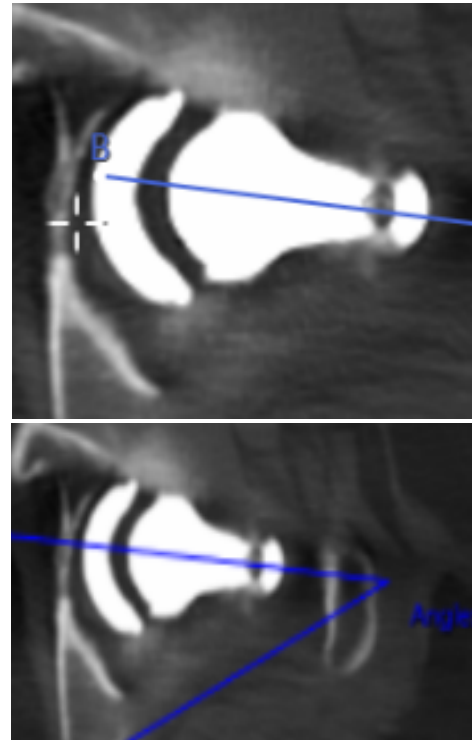
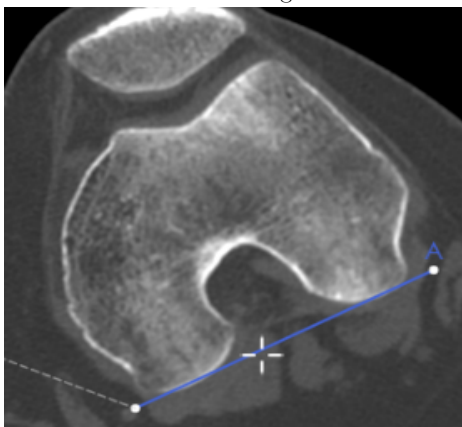
The source was indirect; an electronic form was filled out from the history data. A 128-slice Phillips Incisive CT PRO was used. Patients are examined in the supine position for the study of rotational alignment. When the hip is scanned in the axial, coronal, and sagittal planes, the images are transferred to a DICOM image processing and visualization system.

Figure 1. Acetabular anteversion angle measurement protocol according to Dr. Carlos Valle. (Correction of pelvic tilt by anthropometric angulation (PS-SP line)).



Multiplanar reconstruction for acetabular anteversion angle measurement with pelvic tilt correction.

Figure 2. Femoral anteversion angle measurement.



Measurement of the femoral anteversion posterior border of the femoral condyles and the tangential line of the femoral neck.

Specialized software tools were used to measure the position and alignment of the prosthetic components, and parameters such as acetabular anteversion and femoral anteversion were measured.

The anteversion angle measurement protocol [16]. Pelvic tilt correction by anthropometric angulation (PS-SP line) (Figure 1).

1. Multiplanar reconstruction of images obtained from pelvis and hip axial cuts.
2. Correction of the reconstructed planes' medial, transverse, and sagittal axes.
3. Correction of the inclination of the sagittal axis via correction of the pelvic inclination angle, with an anthropometric angulation value (PS-SP line) of 64 degrees in men and 68 degrees in women. The sagittal axis image shows the promontory and symphysis pubis.
3. Coronal axis correction involves tilting the horizontal and vertical axes in an image that shows the bilateral femoral head.
4. The axial axis was corrected by tilting the horizontal and vertical axes in an image that shows the bilateral femur head.
5. The acetabular anteversion angle between the line corresponding to the sagittal plane and the line drawn tangential

to the anterior and posterior edges of the acetabulum was calculated.

6. To calculate femoral anteversion, the center of the femoral neck is identified in the axial plane, and the line tangential to the posterior border of the femoral condyles is used (Figure 2).

To assess hip functionality in the postoperative period, the modified Harris scale was used through a questionnaire administered to the patient to determine pain and joint function. The activities considered assessing functionality were walking (limp, support, distance tolerated), climbing stairs, putting on socks and shoes, and the ability to sit and use public transport. By evaluating these parameters, a maximum score of 100 points is obtained. A score between 90 and 100 is considered an excellent result; a score between 80 and 89 is good; a score between 70 and 79 is acceptable; and a score less than 70 is a bad result [17].

Biases

To avoid interviewer, information, and memory biases, the principal investigator always maintained the data with a guide and records approved in the research protocol. Observation and selection bias were avoided by applying the participant selection criteria. Two researchers independently analyzed each record in duplicate, and the variables were recorded in the database once their agreement was verified.

Study size

The sample is nonprobabilistic for all the cases available in the service.

Quantitative variables

Descriptive statistics were used. The results are expressed as frequencies and percentages.

Statistical analysis

Noninferential statistics were used. For descriptive analysis, frequencies and percentages are presented. The statistical package used was IBM Corp. (released 2013). IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.

Results

Participants

Twenty-one patients were included in the study.

Main characteristics of the study group

The study included 21 patients with total hip replacement with different service brands, such as Simed and Braum. In the present study, 13 men (62%) and eight women (38%) were included, and the average age was 60 years and was

distributed across the different age groups (Table 1). Most of the patients (81%) underwent surgery due to coxarthrosis III and IV, according to the Kellgren–Lawrence classification. Nineteen percent of these fractures were femoral neck fractures; the latter were considered risk factors for prosthetic dislocations (Table 2).

Table 1. Study population

Category:	Variable	N=21	%
Sex	Men	13	62%
	Women	8	38%
Age	40-59-year-old	9	43%
	60-79-year-old	10	48%
	>80-year-old	2	9%

The anteversions obtained individually were indicated in the universal study sample. Dislocation was identified in 5 patients who underwent operations in our medical home, and two patients, predominantly men, who underwent operations for hip arthroplasty in another medical home were included.

Table 2. Main clinical characteristics of the population.

Category:	Variable	N=21	% or average
Etiology	Coxarthrosis	17	81%
	Fracture	4	19%
Combined anteversion	<21°	3	14%
	21-47°	13	62%
	>47°	5	24%
Acetabular anteversion	Men	15°	14.0° ± 8
	Women	12°	
Femoral anteversion	Men	18°	18.0° ± 10
	Women	20°	
Combined anteversion	Men	33°	33.0° ± 14
	Women	33°	

When the data were analyzed, the values were outside the typical ranges of femoral or acetabular anteversion, but no patient presented with dislocations to date.

Average values of the acetabular and femoral anteversion angles

An average range of acetabular anteversion of 14° was obtained: 15° for males and 12° for females. The global average is 14.5° ± 8 (6-22). The femoral anteversion angle averaged 18° in men and 20° in women. The global average is 19.0° ± 10 (8-28). The average combined anteversion angle was 33° ± 14 (21-47) for men and women.

Identification of dislocations and risk factors

Among the 21 patients whose data were statistically significant, three patients (14%) with combined values less than 21° had a high risk of posterior dislocation, 13 patients (62%) had normal parameters of 21–47°, and 5 (24%) patients with combined anteversion greater than 47° had a greater risk of anterior dislocation. Four of the seven dislocated patients were dislocated posteriorly, and three were dislocated anteriorly. There were five early dislocations (A, B, C, D, E) and two late dislocations (F, G), the latter with a surgical history in another health center, of which 4 were posterior dislocations, with combined anteversion of less than 21 degrees and three dislocations anterior (C, E - F) combined anteversion greater than 47 degrees, three patients (A, B, F) had a previous diagnosis of femoral or acetabular neck fracture, four patients had coxarthrosis, and four patients C, D, F, G underwent surgery for revision arthroplasty of the femoral or acetabular component, loosening of the femoral component, and a revision was performed by cementing the femoral component (C) due to subsidence of the femoral stem (D), with wear of the polyethylene insert (F -G). All patients who underwent open and closed reduction had no complications after this second intervention (Table 3 and Table 4. A registry of representative cases is presented in Figure 3, Figure 4, Figure 5, and Figure 6.

Table 3. Anteversions acetabular, femoral and combined in the study population.

No .	Age	Sex	Acetabular anteversion	Femoral anteversion	Combined anteversion
1	61	M	18.4	11.49	29.89
2	41	M	29.0	26.0	55.0
3	67	M	13.0	21.0	34.0
4	66	F	23.15	13.3	36.45
5	50	M	10.5	19.9	30.4
6	54	F	15.8	16.3	32.1
7	45	M	25.1	13.1	38.2
8	42	M	20.0	31.8	51.88
9*	62	F	5.14	15.6	20.74
10*	82	M	4.4	6.0	10.4
11*	56	M	17.7	10.7	28.4
12	50	M	3.07	10.11	13.18
13	67	F	13.9	14.5	28.4
14	64	M	10.04	16.9	26.94
15*	66	F	28.0	23.9	51.9
16	66	F	36	35.5	39.1
17	22	F	17.0	33.0	50.0
18	76	M	125	8.4	20.9
19*	80	M	10.6	29.1	39.7
20*	71	M	17.3	33.7	51
21*	56	F	2.78	4.79	7.6

* Patients with dislocations.

Table 4. Percentage of dislocations and identification of possible risk factors.

#	Sex	Age	ATC cause	Time (Weeks)	Acetabular Anteversion	Femoral Anteversion	Combined anteversion	Reduction
A	Man	56	Fracture	1	17.7	10.7	28.4	Bloodless
B	Female	62	Fracture	2	5.1	15.6	20.74	Bloodless
C	Man	80	Osteoarthritis	1	10.6	29.1	39.7	Bloody
D	Man	82	Osteoarthritis	3	4.4	6	10.4	Bloody
E	Female	66	Osteoarthritis	4	28	23.9	51.9	Bloodless
F	Man	71	Fracture	10 years	17.3	35.7	51.0	Bloody
G	Female	56	Osteoarthritis	9 years	2.78	4.79	7.6	Bloody

Figure 3. Physical examination of a representative case A.

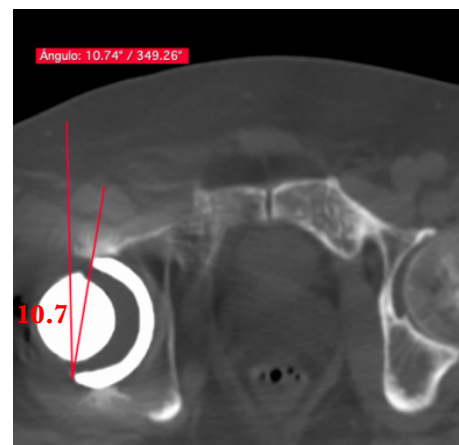
A



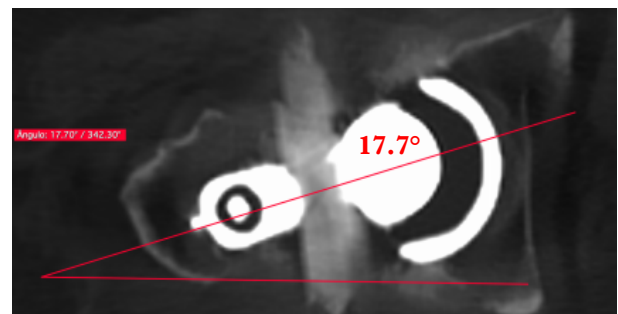
B



C



D



E

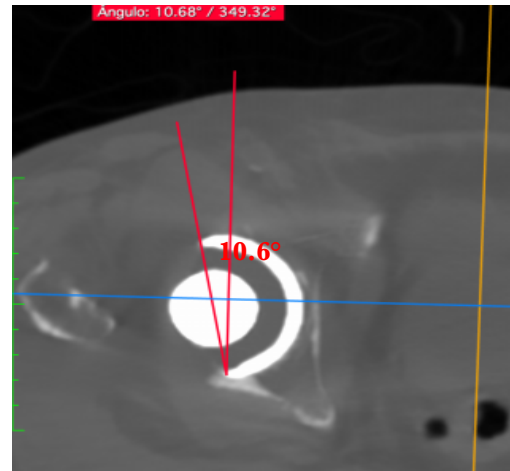
- A. A 56-year-old man with a history of femoral neck fracture.
- B. 1 year ago, he was treated with a DHS plate.
- C. Eight days prior, a right hip prosthesis was placed, abducted, and internally rotated, with posterior dislocation.
- D. Closed reduction was performed, and the acetabular anteversion range was normal (10.74 degrees).
- E. Femoral anteversion range (17.7 degrees). Combined Anteversion (28.4 degrees).

Figure 4. Physical examination of a representative case C.

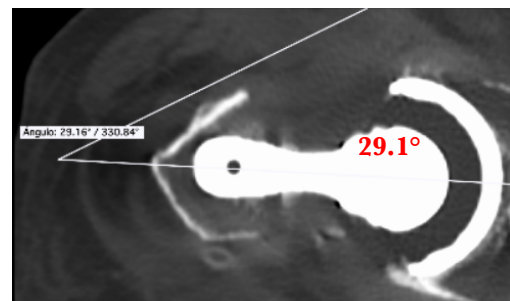
A



B



C

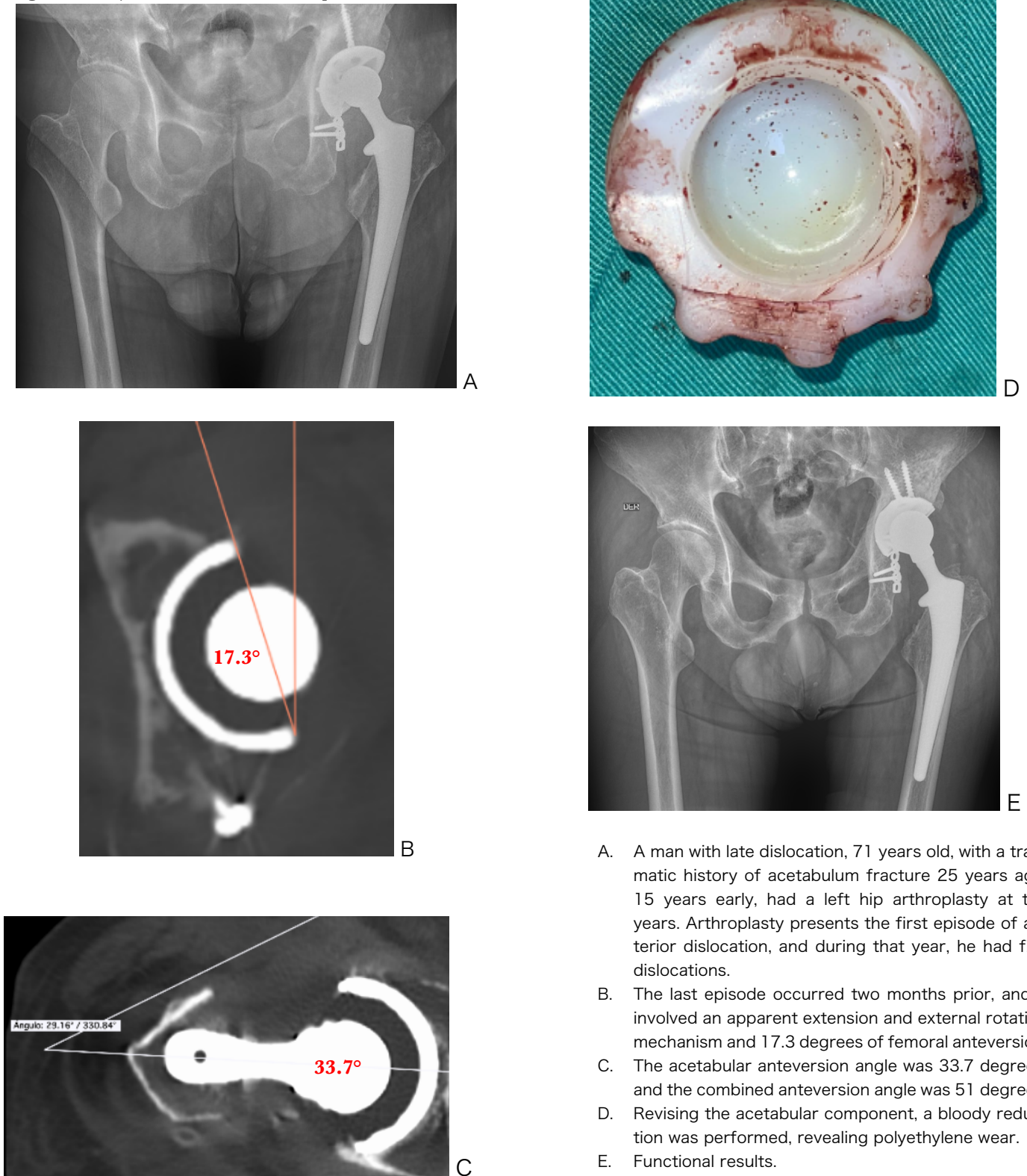


D



E

- A. Man with early dislocation, 80-year-old, history of right hip arthroplasty (12/27/2022) due to type IV coxarthrosis.
- B. Seven days later, he presented anterior dislocation accompanied by pain of 8/10.
- C. The lower right limb was externally rotated and shortened, with femoral anteversion values of 10.6 degrees.
- D. In imaging studies, the acetabular anteversion is 29.1 degrees and a combined 39.7 degrees. There is evidence of subsidence of the femoral component, and a bloody reduction with cementation of the femoral component is performed.

Figure 5. Physical examination of a representative case F.

- A. A man with late dislocation, 71 years old, with a traumatic history of acetabulum fracture 25 years ago, 15 years early, had a left hip arthroplasty at ten years. Arthroplasty presents the first episode of anterior dislocation, and during that year, he had five dislocations.
- B. The last episode occurred two months prior, and it involved an apparent extension and external rotation mechanism and 17.3 degrees of femoral anteversion.
- C. The acetabular anteversion angle was 33.7 degrees, and the combined anteversion angle was 51 degrees.
- D. Revising the acetabular component, a bloody reduction was performed, revealing polyethylene wear.
- E. Functional results.

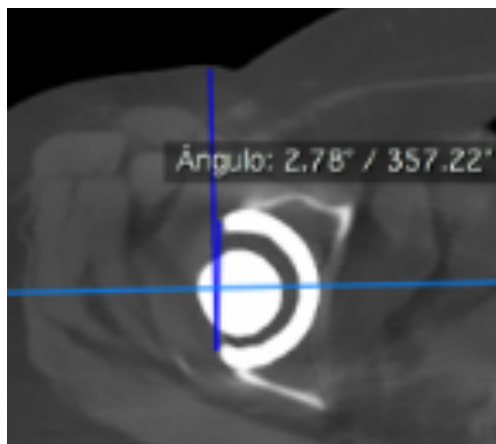
Figure 6. Physical examination of a representative patient (G).



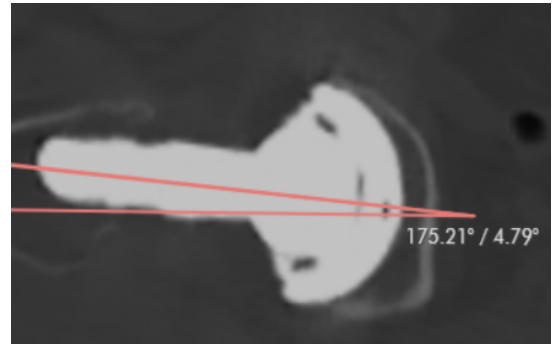
A



B



C



D

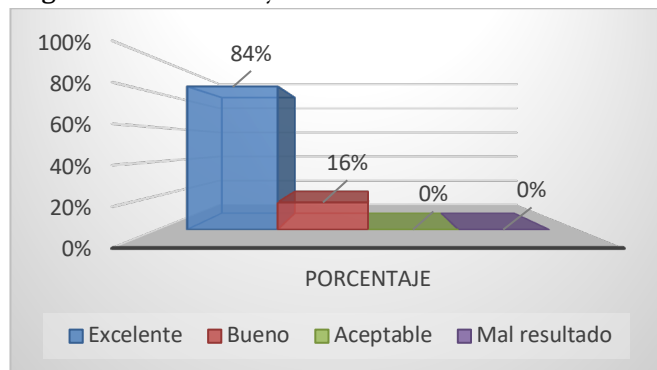


E

- A. Woman with late dislocation, 56-year-old, history of right hip arthroplasty 12 years ago. Nine years early after arthroplasty, she presented the first episode of dislocation.
- B. Last year, she presented four dislocations, the last one a month ago.
- C. The images show an acetabular anteversion of 2.78 degrees.
- D. Femoral anteversion was 4.79 degrees.
- E. Open reduction is performed with revision of the acetabular component.

Functionality assessment was performed with the modified Harris scale, with favorable results ranging from excellent to good (Figure 7).

Figure 7. Functionality with the modified Harris scale.



Discussion

In total hip arthroplasty, the size and position of the prosthetic material influence the postoperative results, anteversion or retroversion, whether femoral or acetabular, and affect the contact between the femoral, acetabular, and polyethylene inserts, causing mechanical alterations, complications, instability, prosthetic loosening, and dislocations.

CT provides detailed three-dimensional visualization of the hip, allowing a comprehensive assessment of the position and alignment of prosthetic components. Compared with conventional radiographs, this enhanced visualization ability is essential for detecting subtle misalignments that may go unnoticed with other evaluation methods.

Measurement with 3D CT should be the gold standard for measuring the acetabular anteversion angle. A significant difference exists in evaluating the true anteversion angle (AV) by 3D and 2D methods. The difference is caused mainly by the anterior-posterior pelvic tilt. The main disadvantage of the 3D process is the time-consuming nature of CT data segmentation. The mean AV angle was 16.1 (5.9)°, as measured via the 3D method, and 22.0 (6.0)°, as measured via the 2D method [18].

Few studies have considered the correction of the pelvic tilt before the measurement of acetabular anteversion because the anterior pelvic tilt decreases anteversion; otherwise, the posterior pelvic tilt increases [12]. A study was carried out at our institution [16] in a patient without hip arthroplasty, where average acetabular anteversion was determined to be 19.3° for men and 20.4° for women. In this study, pelvic correction was performed before measurement, in contrast to our

research on acetabular anteversion in men, which was 13.22° and 15.22° in women. However, it is vitally important to consider femoral anteversion.

A study was conducted in the Chinese population [19] with 466 patients (353 men and 113 women). They reported that the mean femoral angle was 10.62° and that the degree of acetabular anteversion was 18.79°. Importantly, patients younger than 60 had a significantly greater angle but a considerably lower degree of acetabular anteversion than those older than 60. Furthermore, this study revealed that women had significantly greater values of the femoral and acetabular versions than men did. In our study, the average value of femoral anteversion was 19.4°, and the average value of acetabular anteversion was 13.96°. The average age was 60 years, with higher values for females.

Similar results were reported in South Korea [20], which noted that the angles of anteversion by age group tended to decrease, femoral anteversion tended to decline with age in men and women, and acetabular anteversion tended to increase in both men and women. The authors assumed that the cause of increased acetabular anteversion was decreased lordosis of the lumbar spine, which was much more prominent in women with increasing age [20,21]. In our study, anteversion was similar in both sexes.

Another study [22] with 1215 hip arthroplasty patients reported a median femoral anteversion angle of 14.4°, with 12.7° for men and 16.0° for women. Femoral anteversion in men decreased significantly with increasing age. A total of 14% of the patients experienced extreme anteversion (<0° or >30°), similar to the results found in the present study with five dislocations. However, there must be other causes, such as hip replacement care and the age of the patient for the present sarcopenia.

The combined anteversion technique reduced the dislocation rate by a factor of 6 in cementless total hip arthroplasty [23]. The combined anteversion technique used in our study resulted in 79% of our patients having a value of <40 degrees, 21% with a standard range of 40–60° and 5% with a value greater than 60°, with four posterior dislocations and one anterior dislocation, with an average range of 38° ± 9° (range, 12°–55°), [24]; AC 50 ± 10°, [23]. Another study revealed that the optimal total anteversion angle of 40–60° is not a parameter that predicts stability (odds ratio [OR] of 0.40, *P* = 0.144) [25].

The safe zone range of 15° should be abolished because the instability of the TCA seems to be related to the 3D orientation of the complete prosthesis about its circulating

structures, such as the pelvis, femur, and preoperative position [7]; furthermore, it does not allow us to differentiate between stable and unstable CTA implants [25].

In this study, we investigated the use of computerized axial tomography to determine the correct alignment of prosthetic components in the hip in patients undergoing total hip arthroplasty. The results of this study demonstrated that CT is an accurate and reliable tool for evaluating the alignment of prosthetic components as a whole, which is crucial for the long-term success of hip replacement surgery. In addition, we identified the causes of prosthetic dislocations in our study population.

Conclusions

CT is a valuable and reliable tool for determining the correct alignment of prosthetic components in the hip in patients undergoing CTA to achieve adequate alignment and optimal joint congruence, reducing the likelihood of dislocation of prosthetic components. CT with multiplanar reconstruction corrects the pelvic tilt and errors in rotation, achieving a more precise measurement of the acetabular anteversion angle, making it a valuable tool for the postsurgical follow-up of hip arthroplasty. A multifactorial origin should be assessed in patients with hip prosthesis dislocation, and patient education and postsurgical habits influence most postsurgical patients, taking into account the 3D orientation of the prosthesis as a whole. Femoral and acetabular anteversion in combination can be considered risk factors for postoperative hip arthroplasty patients.

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Declarations

Ethics committee approval and consent to participate

The Alcívar Hospital ethics committee approved the study.

Publication consent

The authors have permission to publish tomographic images from the patients who participated in this study.

Conflicts of interest

The authors declare that they have no conflicts of interest.

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