Article

IMPACT OF CAPUT-COLLUM-DIAPHYSEAL ANGLE ON FEMORAL STEM POSITIONING IN SHORT-STEM HIP ARTHROPLASTY PERFORMED WITH AN ANTERIOR MINIMALLY INVASIVE SURGERY

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ABSTRACT

This study examines how variations in the Caput-Collum-Diaphyseal (CCD) angle impact femoral stem alignment in total hip arthroplasty (THA) using short stems in the anterior minimally invasive surgery (AMIS). The objective of this study is to evaluate whether native CCD angles in the varus or the valgus influence the postoperative stem alignment, especially deviations greater than 3°, which may affect clinical outcomes. Patients who underwent THA between July 2021 and July 2023 with primary hip osteoarthritis or avascular necrosis were included. Exclusion criteria were postoperative complications, reoperations, or missing radiographs. Postoperative CCD and stem alignment were measured from radiographs, and statistical analyses were performed to compare these variables using t-tests and Pearson's correlation. Of the 46 hips, 24 were in Group A, and 22 in Group B. Group B showed a better ability to restore the CCD angle ($p < 0.05$). Both groups demonstrated a significant Pearson correlation between native CCD and postoperative stem alignment (Group A: r -0.60;$p < 0.001$ and Group B r: 0.486;$p < 0.05$). The average deviation in stem alignment remained within 3° for both groups. Patients with a varus CCD angle were more likely to have the stem positioned in the varus, while those with a valgus CCD angle showed a slight tendency toward valgus stem alignment. Surgeons should carefully consider preoperative CCD angles to minimize malpositioning during AMIS procedures.

KEYWORDS: *Caput-Collum-Diaphyseal angle, total hip arthroplasty, THA, anterior minimally invasive surgery, AMIS, stem alignment, CCD*

INTRODUCTION

The anterior minimally invasive surgery (AMIS) in hip surgery has gained increasing recognition for its ability to limit soft tissue injury and to improve short-term clinical outcomes. This technique offers significant advantages over traditional approaches, including reduced blood loss, shorter hospital stays, and faster postoperative recovery (1-3).

Proper stem placement is a crucial step and it is influenced by the position of the lower limb, by the higher cortical stress applied to the femur, and by the difficulty in releasing the structures that facilitate the broach insertion (4).

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For this reason, instruments dedicated to the AMIS approach were developed, and the implants were optimized with shorter stems to facilitate their insertion and reduce the removal of bone stock during femoral broaching. However, the uncomfortable positioning and the short stem with the femoral neck or metaphyseal fixation can lead to an increased malpositioning in the varus or the valgus (5, 6). In this context, the native Caput-Collum-Diaphyseal (CCD) angle of the femur is a crucial measurement (7, 8).

The literature emphasizes that no significant clinical or biomechanical effects occur when the stem axis deviates by less than 3° from the femur's native axis (7, 9).

This study aims to analyze how variations in the CCD angle influence the alignment of the femoral stem relative to the femoral axis in the context of the AMIS and the use of short-stem prostheses. The primary objective is to assess whether, based on a femur with varus or valgus CCD, the stem placement deviates more than 3° compared to the anatomical femoral axis (10).

MATERIALS AND METHODS

A retrospective observational study was conducted on all the patients who underwent Total Hip Arthroplasty (THA) through the AMIS approach treated in the Orthopedic Clinic of Perugia from July 2021 to July 2023.

Preoperative pelvic X-rays (both hips, anterior-posterior view, standing erect) were screened to test for THA and to include patients who had a diagnosis of primary osteoarthritis (Kellergen-Lawrence > grade 3) or avascular necrosis of the head of the femur.

Exclusion criteria were patients with low-grade primary osteoarthritis (Kellergen-Lawrence < grade 3), periprosthetic fractures, or patients who developed postoperative complications (infection or aseptic loosening). From a cohort of 81 patients, 44 patients met the inclusion and exclusion criteria, comprising a total of 46 hips.

Surgical technique

All procedures were performed via the AMIS approach, using non-modular, uncemented short-stem prostheses implanted by a single experienced surgeon. The patient was positioned supine on a standard operating table without traction. The surgical site was prepared using a three-step antiseptic scrub with alcohol disinfectant, and sterile draping with an adhesive film was applied.

A 7- to 10-cm incision is made 2 cm latero-distally to the antero-superior iliac spine towards the fibular head; care was taken to isolate the lateral femoral cutaneous nerve (LFCN).

The interval between the sartorius muscle medially and the tensor fascia latae laterally is developed with attention to ligate the anterior circumflex artery to prevent excessive bleeding. The capsule is exposed between the rectus femoris muscle medially and the vastus intermedius muscle laterally. A capsulectomy was performed with identification and later reinsertion.

Trial components and instruments designed for the anterior approach were always used before the final implantation. Intra-operative fluoroscopy was used, but not routinely.

The perioperative and postoperative protocols were standardized across all cases. This included a single-dose antibiotic administration of Cefazoline (2 g IV) given preoperatively, along with weight-bearing as tolerated starting from the first postoperative day. A post-operative radiograph was performed after the weight-bearing on the operated leg was done.

Radiographic evaluations

Radiographic evaluation was performed using only postoperative anteroposterior (AP) pelvic radiographs, as validated by Lu et al. (11). Radiographs were taken with the patient lying flat on the radiography table, with the pelvis and legs in a neutral position. The tube-film distance was set at 110 cm to include both hips, centering the beam on the symphysis. Each radiographic measurement was taken by three of the authors (G.A, L.G, and F.M) in a randomized and blinded fashion. The radiographs were analyzed and measured through the PACS (Impax Enterprise; Agfa, Mortsel, Belgium) program.

To determine the CCD angle, according to Merle et al. (12), as the angle between the femoral neck axis and the femoral shaft axis on the AP radiograph, the hip center of rotation (COR) was defined using a circular instrument that determines the diameter of the femoral head and its center then the anatomical axis of the femoral shaft was determined by using two bisections of the femoral shaft at different locations (Fig. 1). These patients were then divided into two groups based on the native CCD angle from the radiograph of the hip; A normal CCD angle was considered between 120°

and 135° (12-17). The series was divided into Group A, with a varus tendency (CCD ≤ 127°), and Group B (CCD ≥ 128°), with a valgus tendency.

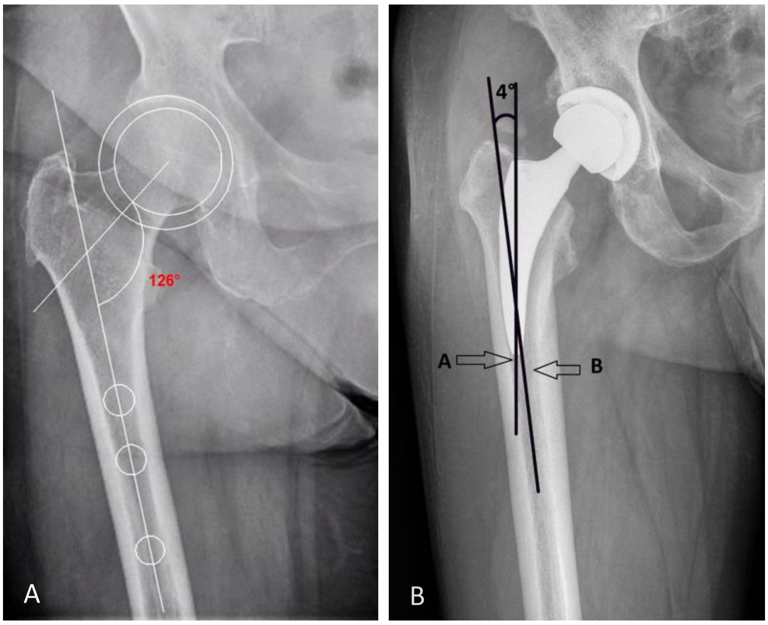

Fig. 1. ***A****): angle measurements of the CCD (caput-collum-diaphyseal);* ***B****): stem alignment angle* ***a****): stem axis;* ***b****): anatomical femoral axis.*

On postoperative radiographs, stem alignment was measured as the difference in degrees between the anatomical femoral shaft and the vertical axis of the stem. Negative values were considered for valgus stems.

Statistics

Statistical analysis was performed using SPSS (IBM Statistics). Native CCD and post-operative CCD were compared through a t-test analysis, and stem alignment was compared with a Pearson's analysis of the native CCD. A statistical confidence level of 95% was selected, and a p-value of < 0.05 was considered statistically significant.

RESULTS

After the radiological measurements, a total of 24 hips were assigned to Group A, and 22 to Group B. Results are shown in Table I.

Radiographic evaluations showed a greater ability to restore the CCD angle in Group B ($p < 0.05$). In comparison, Group A showed less ability to restore the same parameter while maintaining a significant correlation ($p < 0.001$).

Regarding the post-operative stem alignment, Pearson's r in Group A was -0.60 ($p < 0.001$), and in Group B was 0.486 ($p < 0.05$), also showing a significant correlation.

A native varus CCD angle resulted in an average varus stem implant, while a valgus-leaning CCD angle resulted in an average valgus stem implant (Group A: 1.5 in varus; Group B: 1.1 in valgus; $p < 0.001$). In neither group was an average deviation of more than 3° in varus or valgus measured.

Table I. *Results correlated with Native CCD.*

Group	Native CCD	Post-Operative CCD	p Value	Stem alignment	*Pearson's r
A (Varus ≤ 127°) N = 24	120.20 ± 2.5	130.29 ± 4.35	< 0.05	1.5 ± 2.0	-0.60 (p < 0.001)
B (Valgus ≥ 128°) N = 22	133.54 ± 5.0	129.18 ± 3.6	< 0.001	- 1.09 ± 1.77	0.486 (p < 0.05)

DISCUSSION

Proper reconstruction of hip geometry and femoral stem positioning in THA is critical as it affects clinical outcomes, dislocation risk, range of motion, bone impingement, abductor muscle strength, and polyethylene wear (18-20). In the literature, there is high heterogeneity for the cut-off values of varus or valgus stem alignment (9, 21, 22). The main reason for varus stem positioning is still a topic of debate. Reduced surgical exposure in minimally invasive approaches may lead to broaching in a more varus position (23).

Moreover, both Murphy et al. (24) and Luger et al. (10) stated that one of the main reasons for varus stem alignment could be the preoperative CCD angle, showing that low CCD angles and deformities like coxa vara, led to varus implantation.

The results of this study confirm that the native CCD angle of the femur can influence postoperative femoral stem alignment in AMIS approach surgeries using short stems. At the same time, a valgus-leaning CCD appears to influence valgus alignment, although in a less pronounced way.

The group with a preoperative varus-leaning CCD had greater varus stem positioning than those with a higher CCD. A statistically significant correlation analysis confirmed this finding. ($p < 0.001$).

Another aspect that emerged from the study is restoring the postoperative CCD, which is particularly significant in Group B ($p < 0.001$). Again, this suggests that despite a slight tendency for valgus stem alignment, overall positioning is easier to control than in patients with a varus CCD. However, usually in our surgical practice, the absence of collars with an angle below 126° is critical for a tailored stem alignment.

Some authors, however, tend to attribute femoral component malpositioning to the use of straight stems and a steep learning curve (25). In our case, these issues were avoided by including only short stems in the study and selecting patients treated by a single experienced surgeon rather than a group of professionals with varying levels of expertise; Others emphasize the importance of using offset instruments and (26) in our clinical practice, these instruments were routinely employed; however, no comparison with standard instruments was made, which could be a subject of future discussion.

Intraoperative fluoroscopy to evaluate component positioning was not routinely used in the cases included in the study. In the literature, few studies have analyzed this possibility, but they have not shown significant improvements in the final clinical and radiological outcomes (27). Nonetheless, further research could demonstrate that routine fluoroscopy use may significantly reduce implant malpositioning. In our case series, a traction table was never used; however, the literature reports that the outcomes and complications associated with the standard table and traction table are comparable (28, 29).

Some authors, such as Haversath et al. (21), have also identified the critical trochanter angle (CTA) as a predictor of varus stem alignment risk in anterior approach THA. Nevertheless, the literature shows that the CCD angle has a higher sensitivity, with only a marginally lower specificity, in predicting varus stem alignment in short-stem THA, making it a more reliable tool (7).

Several study limitations were addressed. Primarily, the patient inclusion criteria restricted the analysis to patients with primary hip osteoarthritis and avascular necrosis. Thus, caution is necessary when applying these findings to secondary osteoarthritis or other conditions with dysplastic features of the hip joint. Moreover, our study lacks clinical outcome measures or patient-reported outcomes, even though our analysis focused purely on radiographic assessments.

CONCLUSIONS

This study demonstrated how the native CCD angle of the femur significantly influences the postoperative alignment of the stem in THA, which performed an AMIS approach using short stems. Patients with a varus CCD angle were more likely to have the stem positioned in the varus, while those with a valgus CCD angle showed a slight tendency toward valgus stem alignment. Consequently, we hypothesize that a reduced preoperative CCD angle may be a risk factor for varus stem positioning in THA with short stems. Surgeons should pay particular attention to this parameter during preoperative planning for the AMIS approach and maintain the alignment deviation of the threshold 3°.

The data obtained by our study could provide valuable insights for future prospective studies aiming at a more detailed analysis of the femoral morphology and to the femoral stem alignment and its impact on long-term outcomes.

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Institutional Review Board Statement
The study is retrospective, and it follows the Helsinki ethical principles for appropriate medical research.

Conflicts of Interest
The authors declare no conflicts of interest.

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