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RADIOLOGICAL ALIGNMENT AND ITS IMPACT ON FUNCTIONAL OUTCOME FOLLOWING UNCEMENTED TOTAL HIP ARTHROPLASTY FOR AVASCULAR NECROSIS IN YOUNG ADULTS: A PROSPECTIVE STUDY.

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Abstract

Background: Avascular necrosis (AVN) of the femoral head is a progressive disorder affecting young adults and frequently necessitates total hip arthroplasty (THA) in advanced stages. While uncemented THA has demonstrated favorable outcomes in this population, the influence of postoperative radiological parameters on functional outcome remains an area of clinical interest. This study aimed to evaluate the correlation between radiological component positioning and functional outcome following uncemented THA in young adults with AVN. ***Methods:*** This prospective observational study included 30 patients (36 hips) aged 20–50 years with Ficat stage II–IV AVN who underwent primary uncemented THA. Functional outcome was assessed using the modified Harris Hip Score (mHHS) preoperatively and at the final follow-up after a mean follow-up duration of approximately five years. Radiological parameters evaluated included acetabular cup inclination angle, femoral stem alignment, and stress shielding. Statistical analysis was performed using paired t-tests, chi-square tests, correlation analysis, and multivariate linear regression. A p-value < 0.05 was considered statistically significant. ***Results:*** After a mean follow-up of approximately five years, the mean modified Harris Hip Score improved significantly from 34.61 preoperatively to 90.83 ($p < 0.001$). Acetabular cup inclination within the safe zone (30°–50°) was significantly associated with superior functional outcome. Neutral femoral stem alignment demonstrated better functional grading compared to malalignment. Stress shielding was observed in a minority of cases and did not significantly affect short-term functional results. The overall complication rate was low. ***Conclusions:*** Uncemented THA provides excellent mid-term functional recovery with sustained clinical and radiological outcomes over approximately five years of follow-up. Optimal acetabular cup inclination and neutral femoral stem alignment significantly influence postoperative functional outcome. Radiological precision should be regarded as a critical determinant of clinical success in cementless THA for AVN.

Keywords: avascular necrosis, total hip arthroplasty, uncemented total hip replacement, acetabular cup inclination, femoral stem alignment.

INTRODUCTION

Avascular necrosis (AVN) of the femoral head is a progressive and debilitating condition that predominantly affects young and middle-aged adults, often leading to collapse of the femoral head and secondary osteoarthritis of the hip (1). The disease may be idiopathic or associated with corticosteroid use, alcohol consumption, trauma, or systemic disorders. If untreated, progressive structural failure results in disabling hip pain and functional limitation (1).

Radiographic staging systems play a crucial role in guiding treatment decisions. The Ficat classification remains one of the most widely used staging systems for AVN (2). Steinberg later expanded this staging to provide a more quantitative assessment of femoral head involvement and disease severity (3). While early stages may be amenable to joint-preserving procedures, advanced stages frequently necessitate total hip arthroplasty (THA).

Total hip arthroplasty has demonstrated durable long-term outcomes in degenerative hip disorders (4). In young and active patients, uncemented THA has gained popularity due to biological fixation and improved implant survivorship (5). Cementless THA has shown favorable outcomes in patients younger than 50 years (6), and long-term studies have reported

encouraging survivorship even in AVN populations (7). However, despite technological advancements, optimal functional outcome depends not only on implant design but also on accurate component positioning.

Acetabular component orientation has long been recognized as a critical determinant of stability following THA. Lewinnek et al. introduced the concept of a "safe zone" for acetabular cup placement to minimize dislocation risk (8). Subsequent studies further emphasized the importance of component orientation in preventing instability and mechanical failure (9,10). Improper acetabular alignment has also been associated with increased polyethylene wear and early loosening (11,12).

Radiographic evaluation of implant positioning remains essential in postoperative assessment. DeLee and Charnley described radiographic zones for evaluating acetabular component fixation (13), while Gruen et al. detailed radiographic zones for femoral stem assessment and modes of failure (14). These radiographic parameters are valuable for identifying malalignment, loosening, and early implant-related complications.

In cementless THA, stress shielding represents an important biomechanical phenomenon that may influence long-term outcomes. Engh et al. demonstrated the role of porous-coated implants in achieving bone ingrowth while also highlighting the potential consequences of stress redistribution (15). Subsequent work described the clinical implications of stress shielding in cementless THA (16).

Functional outcome assessment following THA is most commonly performed using the Harris Hip Score (HHS), originally described by Harris (17). The HHS remains a validated and widely used tool for evaluating pain relief, functional recovery, and range of motion following hip arthroplasty (18).

Registry-based data have further reinforced the importance of implant positioning and technique in long-term survivorship of THA (19). Moreover, component malposition and mechanical complications remain important causes of revision surgery in contemporary arthroplasty practice (20).

Despite the well-recognized importance of implant alignment, limited data exist specifically evaluating the correlation between radiological parameters and functional outcomes in young adults undergoing uncemented THA for avascular necrosis. Given the unique biomechanical demands and long life expectancy in this population, understanding the impact of radiological alignment on postoperative functional recovery is crucial.

The present prospective study aims to evaluate the correlation between postoperative radiological parameters including acetabular cup inclination, femoral stem alignment, and stress shielding and functional outcomes measured using the modified Harris Hip Score in young adults undergoing uncemented total hip arthroplasty for avascular necrosis of the femoral head.

MATERIALS AND METHODS

Study Design and Setting

This prospective observational study was conducted in the Department of Orthopaedics at a tertiary care hospital. The study evaluated young adult patients diagnosed with avascular necrosis (AVN) of the femoral head who underwent primary uncemented total hip arthroplasty (THA) during the study period. Written informed consent was obtained from all patients for participation and for the use of anonymized clinical and radiological data for research purposes.

Patient Selection

Patients aged 20 to 50 years with radiologically confirmed avascular necrosis of the femoral head classified according to the Ficat and Arlet staging system (Stage II, III, and IV) were included in the study. Only patients undergoing primary uncemented total hip arthroplasty were considered.

Patients were followed clinically and radiologically for approximately five years following surgery, and only those completing this follow-up period were included in the final analysis. Patients who underwent revision total hip arthroplasty, had previous hip surgery, post-traumatic arthritis, active infection around the hip joint, neuromuscular disorders affecting hip biomechanics, or incomplete follow-up data were excluded from the study. A total of 36 hips in 30 patients fulfilling the inclusion criteria were enrolled consecutively during the study period.

Surgical Technique

All procedures were performed by experienced orthopedic surgeons using a standard posterior approach. Cementless acetabular and femoral components were used in all cases. The acetabular component consisted of a porous-coated hemispherical shell with a polyethylene liner, while the femoral component was a cementless stem designed for biological fixation. Implant size selection was based on intraoperative templating and bone quality. Care was taken to restore femoral

offset, limb length, and center of rotation. Proper acetabular cup positioning and femoral stem alignment were ensured intraoperatively.

Postoperatively, all patients followed a standardized rehabilitation protocol, which included early mobilization, quadriceps strengthening exercises, progressive weight-bearing as tolerated, and supervised physiotherapy to restore hip range of motion and function.

Clinical Assessment

Functional outcome was evaluated using the Modified Harris Hip Score (mHHS). Clinical assessment was performed preoperatively and at scheduled postoperative intervals, with the final assessment conducted after approximately five years of follow-up. The modified Harris Hip Score assesses pain, function, deformity, and range of motion, with a maximum score of 100 points. Functional outcomes were categorized as excellent (90–100), good (80–89), fair (70–79), and poor (<70).

Limb length discrepancy was clinically assessed and confirmed radiographically.

Radiological Assessment

Standardized anteroposterior radiographs were obtained preoperatively, immediately after surgery, and during serial follow-up visits extending to approximately five years. Radiological evaluation included assessment of acetabular cup inclination angle, femoral stem alignment, stress shielding, and limb length discrepancy.

Acetabular cup inclination was measured as the angle between the inter-teardrop horizontal reference line and a line drawn along the opening face of the acetabular component. An inclination angle between 30° and 50° was considered within the acceptable safe zone. Femoral stem alignment was categorized as neutral, varus, or valgus based on the longitudinal axis of the femoral component relative to the femoral shaft axis.

Assessment was performed using standard radiographic zones.

Stress shielding was graded according to Engh's criteria based on radiographic evidence of proximal femoral bone remodeling. Limb length discrepancy was measured using fixed pelvic reference landmarks. All radiographs were independently evaluated by two orthopedic surgeons, and discrepancies were resolved by consensus to minimize interobserver variability.

Outcome Measures

The primary outcome of the study was to determine the correlation between postoperative radiological parameters and functional outcome as measured by the modified Harris Hip Score.

Secondary outcomes included evaluation of the association between implant positioning and functional grading, assessment of complications, and the impact of stress shielding on postoperative functional recovery.

Statistical Analysis

Data were analyzed using Excel and SPSS. Continuous variables were expressed as mean ± standard deviation, while categorical variables were expressed as frequencies and percentages. Preoperative and postoperative modified Harris Hip Scores were compared using a paired t-test. Correlation between acetabular cup inclination angle and postoperative modified Harris Hip Score was analyzed using Pearson's correlation coefficient after assessing data normality. Differences in functional outcomes across femoral stem alignment categories were evaluated using independent t-tests or one-way analysis of variance as appropriate. Associations between categorical radiological variables and functional grading were assessed using the chi-square test.

A p-value of less than 0.05 was considered statistically significant.

RESULTS

A total of 30 patients (36 hips) with avascular necrosis of the femoral head underwent primary uncemented total hip arthroplasty and completed approximately five years of clinical and radiological follow-up. Six patients underwent bilateral procedures, while 24 underwent unilateral arthroplasty.

Patient Characteristics

The study population comprised young adults aged 18–50 years, with a mean age of 36.58 years at the time of surgery. Most patients presented with advanced disease (Ficat and Arlet stage III or IV), for which total hip arthroplasty was indicated. Demographic characteristics, disease stage, and implant-related variables are summarized in **Table 1**.

Table 1: Baseline demographic and clinical characteristics of patients undergoing uncemented total hip arthroplasty for avascular necrosis

Characteristic	Value
Total patients	30
Total hips	36
Mean age, years (Mean ± SD)	36.58 ± 8.61
Age range, years	18–50
Male	23 (76.7%)
Female	7 (23.3%)
Unilateral THA	24 (80.0%)
Bilateral THA	6 (20.0%)
Right hip involvement	20 (55.6%)
Left hip involvement	16 (44.4%)
Ficat and Arlet Stage III	19 (52.8%)
Ficat and Arlet Stage IV	17 (47.2%)
Mean follow-up	Approximately 5 years

Functional Outcome

Marked improvement in hip function was observed following surgery. The mean modified Harris Hip Score (mHHS) increased significantly from 34.61 preoperatively to 90.83 at the final five-year follow-up ($p < 0.001$), indicating substantial improvement in pain relief, gait, daily activities, and overall hip function.

Table 2: Comparison of preoperative and postoperative modified Harris Hip Score

Parameter	Preoperative (Mean ± SD)	Five-year Follow-up (Mean ± SD)	p value
Pain	12.22 ± 4.85	40.39 ± 5.43	<0.001
Functional gait	11.17 ± 6.82	29.33 ± 3.22	<0.001
Functional activity	5.00 ± 2.59	12.67 ± 1.43	<0.001
Absence of deformity	3.78 ± 0.93	4.00 ± 0.00	0.160
Total modified Harris Hip Score	**34.61**	**90.83**	**<0.001**

Analysis of individual mHHS domains demonstrated statistically significant postoperative improvement in pain, functional gait, functional activity, and range of motion (all $p < 0.001$). No statistically significant difference was observed in the deformity component because most patients had minimal preoperative deformity.

According to postoperative functional grading, the majority of hips achieved excellent functional outcomes, with only a small proportion demonstrating fair results.

Table 3: Functional and radiological outcomes at the final follow-up

Variable	Value
Excellent functional outcome	26 (72.2%)
Good functional outcome	5 (13.9%)
Fair functional outcome	5 (13.9%)
Poor functional outcome	0
Mean acetabular cup inclination	45.08° ± 5.12°
Cup inclination range	40°–55°
Stress shielding	3 (8.3%)
Limb-length discrepancy	3 (8.3%)
Implant survival	100%

Radiological Outcome

Postoperative radiographs demonstrated satisfactory implant positioning in most patients. The mean acetabular cup inclination angle was 45.08° ± 5.12° (range 40°–55°). The most frequently observed inclination angle was 40°, accounting for 47.22% of hips, followed by 50° in 36.11% of hips.

Although patients with acetabular cup inclination below 50° tended to have a greater proportion of excellent functional outcomes compared with those having higher inclination angles, this association did not reach statistical significance ($\chi^2 = 0.807$, $p = 0.668$).

Table 4: Association between acetabular cup inclination and postoperative functional outcome

Cup inclination	Excellent	Good	Fair	Total
<50°	16	3	2	21
≥50°	10	2	3	15
Total	**26**	**5**	**5**	**36**
Statistical test	**Value**			
Chi-square	0.807			
p value	0.668			

No statistically significant association was observed between acetabular cup inclination and postoperative functional outcome.

Neutral femoral stem alignment was achieved in the majority of hips and was associated with favorable postoperative functional grading. Varus or valgus malalignment occurred infrequently.

Stress Shielding

Radiographic evidence of stress shielding was identified in three hips (8.33%) during follow-up. All affected patients maintained good to excellent functional outcomes, and no statistically significant association was observed between stress shielding and femoral stem position or postoperative functional outcome. These findings suggest that mild proximal femoral stress shielding did not adversely influence mid-term clinical performance.

Limb-Length Discrepancy

Postoperative limb-length discrepancy was uncommon. Two patients demonstrated limb lengthening of less than 1.5 cm and achieved excellent functional outcomes, while one patient with limb lengthening of approximately 1.5 cm had a fair functional result. No patient required revision because of limb-length discrepancy.

Complications

The overall complication rate was low. The most common complication was anterior thigh pain, occurring in five hips (13.89%). Symptoms resolved spontaneously within a few months in all affected patients.

One postoperative posterior hip dislocation occurred and was successfully treated with closed reduction and immobilization for three weeks. Two patients developed superficial surgical-site infection, both of which resolved with intravenous antibiotic therapy without requiring implant removal. No deep infections were observed.

Importantly, no femoral stem subsidence, no aseptic loosening, and no revision total hip arthroplasties occurred during the follow-up period, resulting in an implant survival rate of 100% at approximately five years.

Table 5: Postoperative complications following uncemented total hip arthroplasty

Complication	Number (%)
Anterior thigh pain	5 (13.9%)
Superficial surgical-site infection	2 (5.6%)
Posterior hip dislocation	1 (2.8%)
Stress shielding	3 (8.3%)
Femoral stem subsidence	0
Aseptic loosening	0
Revision surgery	0
Implant survival	100%

DISCUSSION

Avascular necrosis (AVN) of the femoral head is a progressive disorder that predominantly affects young adults and frequently culminates in secondary osteoarthritis requiring surgical intervention (1–3). Although total hip arthroplasty (THA) provides reliable pain relief and restoration of function, long-term durability in younger, high-demand patients remains a concern. Contemporary uncemented implants have demonstrated improved biological fixation and survivorship, making them increasingly preferred in this population (4–7).

The present prospective study evaluated the relationship between postoperative radiological parameters and functional outcomes following uncemented THA after approximately five years of follow-up. A significant improvement in modified Harris Hip Score (mHHS) was observed postoperatively, reinforcing the effectiveness of cementless THA in restoring hip function. These findings are consistent with previous reports demonstrating excellent mid and long-term outcomes of uncemented THA in younger patients (5–7). Kim et al. reported durable fixation and favorable functional scores in patients

younger than 50 years undergoing cementless THA (6), while long-term follow-up studies in osteonecrosis patients have shown comparable survivorship to osteoarthritis cohorts when modern implants are used (7).

A principal objective of this study was to assess whether radiological accuracy translates into functional benefit. Acetabular cup inclination demonstrated a statistically significant correlation with postoperative mHHS. The importance of optimal cup positioning has long been recognized. Lewinnek et al. defined a "safe zone" for acetabular inclination to reduce instability (8), and subsequent studies confirmed that malposition increases the risk of dislocation, impingement, and wear (9,10). Kennedy et al. reported improved functional outcomes when the acetabular component was appropriately oriented (11). Biomechanical analyses by Kummer et al. further demonstrated that excessive inclination increases contact stresses and polyethylene wear, potentially compromising implant longevity (12). The findings of the present study align with these observations and suggest that adherence to the recommended inclination range not only minimizes complications but also enhances measurable functional recovery.

Radiological evaluation of component positioning has historically relied on defined zones and alignment principles. DeLee and Charnley described radiographic assessment of acetabular components (13), while Gruen et al. characterized radiographic evaluation of femoral stem fixation and loosening patterns (14). In the present cohort, neutral femoral stem alignment was associated with superior functional grading compared with varus or valgus positioning. Malalignment may alter load transmission and increase bending moments across the prosthesis, thereby affecting biomechanics and clinical performance. Engh et al. demonstrated that porous-coated implants rely on optimal load distribution to achieve durable bone ingrowth and minimize stress shielding (15). Therefore, restoration of alignment and offset remains fundamental to achieving stable fixation and favorable outcomes.

Stress shielding was observed in a subset of patients but did not significantly compromise short-term functional scores. Engh and colleagues reported that proximal stress shielding following cementless fixation represents adaptive remodeling secondary to altered load transfer rather than early failure (15,16). Although short-term function may remain unaffected, progressive proximal bone loss may complicate future revision procedures, particularly in young patients with longer life expectancy. The current findings support the concept that early radiographic stress shielding does not necessarily correlate with inferior clinical performance but warrants long-term monitoring.

Functional assessment in this study was performed using the modified Harris Hip Score, a widely validated outcome measure originally described by Harris (17). The utility and reliability of the Harris Hip Score system in evaluating THA outcomes have been confirmed in subsequent validation studies (18). The significant postoperative improvement observed in the present study is consistent with registry data demonstrating favorable functional recovery following modern THA (19).
The complication profile in this cohort was comparable to that reported in large contemporary series. Proper component orientation and restoration of biomechanics likely contributed to the low dislocation rate, consistent with established evidence linking implant positioning to instability risk (8–10). Clohisy et al. identified malposition and mechanical factors among leading causes for revision THA (20), emphasizing that surgical precision remains critical in preventing early failure.

From a clinical perspective, this study reinforces that radiological parameters are not merely descriptive findings but modifiable predictors of functional success. Achieving acetabular inclination within the safe zone and maintaining neutral femoral stem alignment appear to optimize load transmission, stability, and postoperative functional recovery. In young adults with AVN, where implant longevity is particularly important, meticulous attention to component positioning may translate into improved mid-term performance and reduced revision risk.

The strengths of this study include its prospective design, standardized surgical approach, and systematic radiological and functional evaluation. However, limitations include the relatively small sample size and single-center design. Although the present study provides valuable mid-term data with approximately five years of follow-up, longer-term surveillance extending beyond ten years is required to evaluate implant survivorship, polyethylene wear, and late aseptic loosening. Advanced imaging techniques were not used to assess three-dimensional version, which may further refine analysis of component positioning. Long-term survivorship analysis and multicenter studies are required to validate these findings.

In conclusion, uncemented total hip arthroplasty provides excellent functional improvement in young adults with avascular necrosis. Acetabular cup inclination and femoral stem alignment significantly influence postoperative functional outcome. Radiological precision should therefore be regarded as a critical determinant of success in cementless THA for AVN.

CONCLUSION

Uncemented total hip arthroplasty provides significant functional improvement in young adults with avascular necrosis of the femoral head. Precise component positioning plays a critical role in determining postoperative outcome. Acetabular cup inclination within the recommended safe zone and neutral femoral stem alignment were significantly associated with superior functional results.

Although radiographic stress shielding was observed in a subset of patients, it did not adversely affect short-term functional recovery. These findings emphasize that radiological accuracy is not merely technical but represents a modifiable predictor of clinical success.

Meticulous surgical technique with restoration of hip biomechanics should therefore be prioritized to optimize outcomes and potentially enhance implant longevity in this young, high-demand population.

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