Research Article

# Clinical and Radiographic Outcomes of Femoral Head Fractures: Insights from a Single-Center Retrospective Analysis

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## Abstract

**Background:** This study evaluates the radiologic and functional outcomes of femoral head fractures (FHFs), focusing on the correlations between radiologic parameters and postoperative complications.
**Methods:** We conducted a retrospective analysis of 26 Pipkin fractures. Complications and outcomes were documented, with measurements taken for head-neck ratio, surface ratio in multiple planes, and head volume for further analysis.
**Results:** Associated injuries were observed in 65.38% of cases. Osteoarthritis (OA) developed in 61.53%, avascular necrosis (AVN) of the femoral head in 50%, and heterotopic ossification (HO) in 26.92%. According to the Epstein scale, among the 26 patients, seven (26.92%) rated their outcomes as excellent, 11 (42.30%) as good, five (19.23%) as fair, and three (11.53%) as poor. Our findings indicated that head volume ratio, differences in head-neck ratio, and surface ratios in various planes correlated with late complications. Specifically, OA was associated with the sagittal surface ratio ($P = 0.026$) and coronal surface ratio ($P = 0.034$) in type II fractures, while in type IV fractures, it correlated with the axial surface ratio ($P = 0.023$), head volume ($P = 0.020$), and differences in head-neck ratio ($P = 0.017$). HO was linked to head volume ratio ($P = 0.028$) in type II, and to coronal surface ratio ($P = 0.017$) and differences in head-neck ratio ($P < 0.001$) in type IV fractures. AVN correlated with differences in head-neck ratio ($P = 0.041$) in type IV, and with head volume ratio ($P = 0.012$) and sagittal surface ratio ($P = 0.012$) in type II fractures.
**Conclusion:** Head-neck ratio, head volume ratio, and surface ratios are predictive of late complications following FHFs.

*Keywords:* Heterotopic Ossification; Proximal Femoral Fractures; Femur Head Necrosis; Open Fracture Reduction; Total Hip Arthroplasty

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## Background

Femoral head fractures (FHFs) are relatively uncommon yet significant injuries that typically arise from high-energy trauma, accounting for approximately 6% to 16% of posterior hip dislocations (1). These fractures predominantly occur due to mechanisms such as motor vehicle accidents and falls from considerable heights, reflecting the severity of the forces involved (2). The complexity of FHFs is heightened by the fact that associated injuries can be observed in up to 75% of cases, including fractures of the femoral neck and acetabulum, which complicate both diagnosis and management (3).

The classification of FHFs is primarily based on the system established by Pipkin in 1957, which categorizes these injuries into four types. Type I fractures occur below the fovea of the femoral head, while type II fractures extend above it. Type III fractures are characterized by the presence of a femoral neck fracture, and type IV fractures involve an associated acetabular fracture (4). This classification is critical for guiding treatment decisions, as the complexity and location of the fracture significantly influence the surgical approach and potential outcomes (5).

Patients sustaining FHFs often experience poor functional outcomes, with complication rates reported to reach as high as 50% (2). The most common complications include avascular necrosis (AVN) of the femoral head, osteoarthritis (OA), and heterotopic ossification (HO) (3). AVN is particularly concerning, as it can lead to significant morbidity and necessitate further surgical intervention, such as total hip arthroplasty (THA) (6). OA develops as a long-term consequence of joint injury, leading to pain and impaired mobility, while HO can restrict range of motion (ROM) and complicate rehabilitation efforts (7, 8).

Various treatment options are available for FHFs, tailored to the specific fracture type and the presence of associated injuries (1). Surgical interventions may include Smith-Petersen and Kocher-Langenbeck approaches, surgical dislocation, hip arthroscopy, fragment excision, and THA (9). However, despite the diversity of these treatment modalities, clinical outcomes remain inconsistent, with many studies reporting variable prognoses based on fracture type and associated injuries (3, 10). This inconsistency highlights the need for further research to elucidate the factors that influence recovery and complications following FHFs.

This study aims to evaluate the radiologic and functional outcomes of FHFs, focusing on the correlations between specific radiologic parameters and the incidence of complications. By enhancing our understanding of these relationships, we hope to develop improved treatment strategies that can lead to better patient outcomes in this challenging area of orthopedic trauma.

## Methods

***Study Design:*** This study was approved by the Ethics

Committee of Shahid Beheshti University of Medical Sciences, Tehran, Iran, and adhered to the Declaration of Helsinki and its subsequent modifications (IR.SBMU.RETECH.REC.1402.545). We conducted a retrospective study involving patients diagnosed with FHFs who underwent either conservative or surgical management between February 2017 and February 2023. Inclusion criteria required a minimum of one year of clinical and radiologic follow-up. Exclusion criteria encompassed patients with incomplete data and those who failed to attend follow-up appointments.

***Data Collection:*** Demographic data, along with critical variables such as the head-neck ratio, head volume, surface area ratio of the fragments, and early and late postoperative complications, were systematically collected. Additionally, functional outcomes were assessed using the Epstein score and Harris Hip Score (HHS), both of which provide valuable insights into patient mobility and quality of life post-injury (11). At our institution, the preferred surgical approach for FHFs is surgical dislocation (12). However, patients classified as type III with comminuted fractures and those with unsuccessful fixation attempts were managed with THA (13). This approach allows for optimal exposure of the femoral head and facilitates accurate assessment and management of associated injuries.

***Radiologic Assessment:*** Radiologic parameters were meticulously measured using our Picture Archiving and Communication System (PACS). Preoperative, postoperative, and follow-up X-ray evaluations included the assessment of the head-neck ratio, head volume, and fragment surface ratio.

- The head-neck ratio (Figure 1) is defined as the diameter of the best-fit circle of the femoral head divided by the diameter of the femoral neck. This measurement was taken from postoperative radiographs and compared to those obtained at the last follow-up.

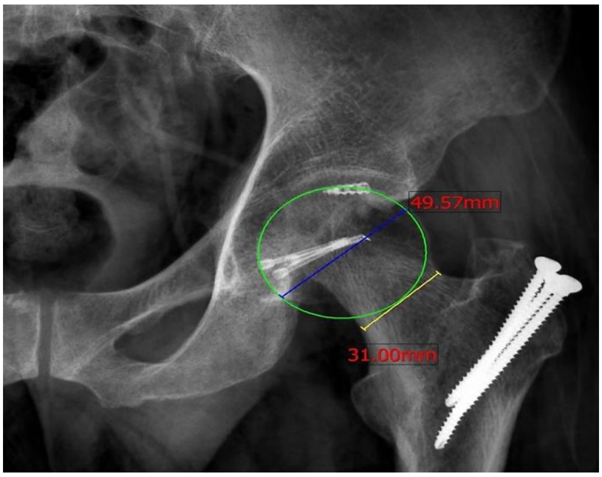


**Figure 1.** Head-neck ratio calculation (The ratio is determined by dividing the length of the blue line by the length of the yellow line)

- The head volume ratio was calculated as the ratio of the last follow-up head volume to the postoperative head volume. This was determined by cubing the last follow-up head diameter and dividing it by the postoperative head diameter.
- The surface area ratio of the fracture fragments was measured using preoperative computed tomography (CT) scans in coronal, sagittal, and axial views. The surface area of the fragment was computed by treating the fragment as a spherical cap, where the surface ratio is defined as the height of the cap divided by twice the diameter of the femoral head (Figure 2).


**Figure 2.** Surface ratio in the coronal plane (The ratio is calculated as the length of the red line divided by twice the length of the green line)

***Assessment of Postoperative Complications:*** Early postoperative complications were assessed, including surgical site infections (SSIs), deep vein thrombosis (DVT), neurovascular impairment, and re-fractures. Late complications were evaluated using previously established criteria: post-traumatic OA was assessed according to the Kellgren and Lawrence classification (14), AVN was classified according to Steinberg et al. classification (15), and HO was graded based on the Brooker classification (16).

***Statistical Analysis:*** Statistical analyses were performed using SPSS software (version 26, IBM Corporation, Armonk, NY, USA). Continuous variables were expressed as means and standard deviations (SD), while categorical variables were reported as frequencies and percentages. Intergroup comparisons for continuous variables were conducted using analysis of variance (ANOVA) or t-tests, while intragroup comparisons for categorical variables utilized the chi-square test. A confidence interval (CI) of 95% was established, with a significance level set at $P < 0.05$.

## Results

A total of 26 patients were enrolled in this study, categorized according to the Pipkin classification as follows: two patients with type I, nine with type II, five with type III, and ten with type IV fractures. Detailed demographic data for these patients are presented in table 1. All patients sustained high-energy trauma, primarily from falls from height and road traffic accidents (RTAs).

Statistical analysis revealed significant differences between groups in terms of Brumback classification ($P = 0.001$) and treatment options ($P = 0.001$). Notably, there were no cases of postoperative neurovascular impairment recorded. Complications included two cases of DVT, one SSI, and one re-fracture. There was no statistically significant difference in Epstein scores between the groups, as summarized in table 2. Regarding revisions, three patients required surgical intervention, all of whom underwent THA.

**Table 1.** Demographic data of the patients

| Parameter | Type I (n = 2) | Type II (n = 9) | Type III (n = 5) | Type IV (n = 10) | P-value |
|---|---|---|---|---|---|
| **Gender** | | | | | 0.580 |
| Men | 2 (100) | 8 (88.9) | 5 (100) | 10 (100) | |
| Women | 0 (0) | 1 (11.1) | 0 (0) | 0 (0) | |
| **Age (year)** | 33.00 ± 2.82 | 35.55 ± 15.78 | 33.20 ± 7.29 | 40.40 ± 6.60 | 0.581 |
| **Mean BMI (kg/m2)** | 29.36 ± 6.48 | 27.85 ± 3.10 | 24.20 ± 4.00 | 26.99 ± 4.22 | 0.330 |
| **Time to close reduction (hour)** | 1.50 ± 0.70 | 1.67 ± 1.32 | 1.00 ± 0.00 | 1.11 ± 0.33 | 0.534 |
| **Trauma type** | | | | | 0.645 |
| FFH | 0 (0) | 0 (0) | 0 (0) | 1 (10.0) | |
| RTA | 2 (100) | 9 (100) | 5 (100) | 9 (90.0) | |
| **Brumback class** | | | | | 0.001* |
| IA | 2 (100) | 9 (100) | 0 (0) | 2 (20.0) | |
| IB | 0 (0) | 0 (0) | 0 (0) | 7 (70.0) | |
| IIB | 0 (0) | 0 (0) | 0 (0) | 1 (10.0) | |
| 3 | 0 (0) | 0 (0) | 5 (100) | 0 (0) | |
| Associated injuries | 1 (50.0) | 3 (33.3) | 5 (100) | 8 (80.0) | 0.348 |
| Preoperative neurovascular compromise | 0 (0) | 2 (22.2) | 1 (20.0) | 0 (0) | 0.404 |
| **Treatment type** | | | | | 0.001* |
| No operation | 1 (50.0) | 0 (0) | 0 (0) | 0 (0) | |
| ORIF | 1 (50.0) | 9 (100) | 1 (20.0) | 10 (100) | |
| THA | 0 (0) | 0 (0) | 4 (80.0) | 0 (0) | |
| **Operation time (minute)** | 120.00 ± 10.00 | 148.33 ± 31.42 | 164.00 ± 99.14 | 176.50 ± 48.87 | 0.643 |
| **Follow-up time (month)** | 16.00 ± 0.00 | 19.88 ± 4.45 | 29.40 ± 24.25 | 23.70 ± 7.37 | 0.428 |

Data are presented as mean ± standard deviation (SD) or number and percent
BMI: Body mass index; FFH: Fall from height; RTA: Road traffic accident; ORIF: Open reduction and internal fixation; THA: Total hip arthroplasty
*: P = 0.001 stands for significant difference.

**Table 2.** Epstein scores among fracture types

| Characteristics | Type I (n = 2) | Type II (n = 9) | Type III (n = 5) | Type IV (n = 10) | P-value |
|---|---|---|---|---|---|
| **Radiological** | | | | | 0.942 |
| Excellent | 1 (50.0) | 3 (33.3) | 1 (20.0) | 2 (20.0) | |
| Good | 1 (50.0) | 4 (44.4) | 2 (40.0) | 4 (40.0) | |
| Fair | 0 (0) | 2 (22.2) | 1 (20.0) | 2 (20.0) | |
| Poor | 0 (0) | 0 (0) | 1 (20.0) | 2 (20.0) | |
| **Clinical** | | | | | 0.735 |
| Excellent | 2 (100) | 6 (66.7) | 3 (60.0) | 6 (60.0) | |
| Good | 0 (0) | 3 (33.3) | 1 (20.0) | 2 (20.0) | |
| Poor | 0 (0) | 0 (0) | 1 (20.0) | 2 (20.0) | |

Data are presented as number and percent

The reasons for revision included two cases of AVN-one in type II and one in type IV - and one case of re-fracture in a type IV patient. There was no significant difference in HHS across the different types (P = 0.427).

***Type I:*** In the type I group, which included two patients classified as IA according to the Brumback classification, one patient presented with an associated bimalleolar fracture of the contralateral ankle. One patient received non-operative treatment, which subsequently led to DVT in the ipsilateral leg, while the other underwent open reduction and internal fixation (ORIF). The mean follow-up duration for this group was 16 months, with no need for revision surgery. The mean HHS at the last follow-up was 95.00 ± 1.00.

***Type II:*** Among the nine patients with type II fractures who underwent ORIF, the mean follow-up period was 19.88 ± 4.45 months. The head-neck ratio decreased by 0.08 ± 0.04%, while the head volume ratio at the last follow-up was 0.88 ± 0.12. Associated injuries were noted in three patients, including pelvic ring injury (anteroposterior compression type 3), bilateral distal radius fractures, chest trauma, posterior cruciate ligament (PCL) avulsion, and contralateral femur fracture. Importantly, there were no early complications in this group. The mean HHS was 91.33 ± 7.90.

ANOVA testing indicated a significant correlation between the surface ratio in the sagittal plane and the incidence of OA (P = 0.026). Additionally, a correlation was found between the surface ratio in the coronal plane and OA (P = 0.034). Analysis of HO revealed that the head volume ratio was significantly correlated with HO (P = 0.028). T-test analysis further indicated that AVN was correlated with the head volume ratio (P = 0.012) and the surface ratio in the sagittal plane (P = 0.032).

***Type III:*** In the type III group, which consisted of five patients, only one underwent ORIF, while the remaining four required THA due to the high degree of comminution (Figure 3). All patients in this group had associated injuries. The patient who initially underwent ORIF later required revision surgery to THA due to AVN. The mean follow-up duration for this group was 29.40 ± 24.25 months, with a mean HHS of 85.60 ± 14.22.

**Figure 3.** A comminuted femoral head and neck fracture (type 3) treated with total hip arthroplasty (THA)

***Type IV:*** The type IV group included ten patients who underwent ORIF. Associated injuries were observed in eight patients, including PCL avulsion, bimalleolar fractures, distal femur fractures, and brachial plexus injury. The head-neck ratio decreased by 0.08 ± 0.07%, with a head volume ratio of 0.83 ± 0.13%. Two patients in this group required revision procedures: one underwent THA due to AVN, while another required THA due to re-fracture of the femoral neck 15 days postoperatively. The mean follow-up duration was 23.70 ± 7.37 months, with a mean HHS of 82.03 ± 17.94.

ANOVA testing revealed significant correlations between OA and the surface ratio in the axial plane (P = 0.023), head volume ratio (P = 0.020), and the difference in head-neck ratio (P = 0.017). Additionally, AVN in this group was correlated with the difference in head-neck ratio (P = 0.041). T-test analysis indicated that HO was correlated with the surface ratio in the coronal plane (P = 0.017) and the difference in head-neck ratio (P < 0.001).

## Discussion

The management of FHF remains a challenging endeavor, primarily due to the lack of comprehensive data on various aspects of these injuries. The primary treatment goals are achieving anatomic reduction, ensuring joint stability, and removing any interposed fragments (1).

Giannoudis et al. conducted a systematic review revealing that regardless of fracture classification or treatment method, outcomes were excellent in 14.3% of cases, good in 39.8%, fair in 19.3%, and poor in 26.5% (17). This aligns with our findings, where we observed a significant incidence of complications alongside varied clinical outcomes. Consistent with Giannoudis et al., our data confirm that the most common mechanisms of injury were traffic accidents and falls from height (17). This highlights the need for targeted preventive measures in high-risk populations.

In a study by Park et al., which examined 52 cases of FHF, 22% of patients developed OA, 5% experienced AVN, and 11.8% suffered from HO (18). The outcomes based on Epstein criteria showed excellent results in 38.4% of cases, good in 36.5%, fair in 19.2%, and poor in 5.7%. Similarly, Del Core et al. reported that 41% of their 22 patients had uncomplicated outcomes, with 18% developing HO and 9% experiencing AVN (19).

In our study, we found associated injuries in 17 out of 26 patients (65.38%), HO in 7 (26.92%), AVN in 13 (50%), OA in 16 (61.53%), and conversion to THA in 3 (11.53%). According to the Epstein scale, seven cases (26.92%) were rated as excellent, 11 (42.30%) as good, five (19.23%) as fair, and three (11.53%) as poor. Although our clinical outcomes are comparable to recent studies, the increased rate of complications may reflect the asymptomatic nature of radiologic findings.

Hosny et al. reported on 18 cases of FHF types I and II, noting that four of six type I cases were rated as excellent and two as good according to the HHS (20). In their type II cases, six were rated as excellent, four as good, one as fair, and one as poor, with only one case of osteonecrosis of the femoral head (ONFH). In contrast, Scolaro et al. studied 69 patients treated via an anterior approach and found that all type III cases failed, with HO occurring in 40% of cases, followed by AVN and OA (21). In our study, four out of five type III patients underwent primary THA, yielding favorable clinical outcomes.

Engel et al. investigated seven patients with type IV FHF treated using the Kocher-Langenbeck approach with a trochanteric flip. They reported that 87.5% suffered from OA and 28.6% from ONFH, with 57.1% requiring conversion to THA (8). In our study of ten type IV cases managed via surgical dislocation, OA was noted in 80% of cases, radiologic ONFH in 40%, and 20% necessitated conversion to arthroplasty. This suggests that surgical dislocation may offer superior outcomes compared to the Kocher-Langenbeck approach for type IV fractures. A decrease in the head-neck ratio has been associated with the development of OA, particularly in younger men (22). In our study, the head-neck ratio decreased by 0.08 ± 0.04% in type II and 0.08 ± 0.07% in type IV. Although there was no statistically significant difference in head-neck ratio reduction between types II and IV ($P = 0.812$), 16 out of 19 cases in these types developed OA. Notably, in type IV, the difference in head-neck ratio was significantly associated with OA ($P = 0.017$).

Regarding HHS and Epstein scores, we found no significant difference between Pipkin types. This contrasts with findings by Menger et al., who reported better outcomes in types I and II compared to types III and IV (23). This discrepancy may stem from our treatment approach for type III fractures, where primary THA was preferred in all but one case. Our analysis revealed that the fragment surface ratio correlated significantly with OA in types II and IV. Additionally, AVN was correlated with the head-neck ratio difference in type IV and the head volume ratio in type II. HO was associated with the surface ratio in type IV and the head-neck ratio difference in type II. These radiologic criteria may prove useful in predicting complications, emphasizing the importance of thorough imaging assessments in clinical practice.

This study is not without limitations. The primary limitation is the small sample size in certain subgroups, which may have affected the statistical power of our analyses. Additionally, the retrospective design of the study presents inherent biases and limits the ability to establish causation.

### *Conclusion*

This study highlights the variability in outcomes and complications of FHF based on Pipkin classification and associated injuries. Complications such as OA, AVN, and HO emphasize the complexity of managing high-energy trauma cases. Our results indicate that while surgical dislocation may offer favorable outcomes for type IV fractures, the increased complication rates warrant careful consideration of treatment strategies tailored to individual patient profiles. The correlation between fragment surface ratios and complications suggests these parameters may aid in predicting outcomes. Despite the study limitations, our findings align with existing literature and underscore the importance of tailored approaches and further research to improve FHF management.

## Conflict of Interest

The authors declare no conflict of interest in this study.

## Acknowledgements

We thank the patients for their consent to participate in the study. Ethical approval was granted by the Ethics Committee of Shahid Beheshti University of Medical Sciences (IR.SBMU.RETECH.REC.1402.545).

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