Journal of Clinical Orthopaedics and Trauma 18 (2021) 157–170

Contents lists available at ScienceDirect

Journal of Clinical Orthopaedics and Trauma

journal homepage: www.elsevier.com/locate/jcot

# Decoding the behaviour of extracapsular proximal femur fracture-dislocation - A systematic review of a rare fracture pattern

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ARTICLE INFO

*Article history:*
Received 11 March 2021
Accepted 22 April 2021
Available online 27 April 2021

*Keywords:*
Hip fractures
Hip dislocation
Hip fracture dislocation
Intertrochanteric fracture dislocation
Complex hip injury
Dashboard injury
Intertrochanteric fracture with hip dislocation
Greater trochanteric fracture dislocation
Peri-trochanteric fracture dislocation
Road traffic accidents with hip dislocation
Car hip injuries

ABSTRACT

*Purpose:* Proximal femoral extracapsular fractures with associated ipsilateral hip dislocation is an extremely rare pattern of injury. These fractures may be associated with a spectrum of severity from isolated trochanteric fractures to comminuted intertrochanteric and subtrochanteric fractures with hip dislocation. To date, this pattern of injury is not described in any injury classification system and no clear cut guidelines for the same are available. The aim of this review is to provide an evidence based pooled analysis of the existing literature and develop guidelines that help surgeons tackle this rare injury pattern.

*Methods:* A comprehensive review of the literature was undertaken using the PRISMA. Case reports and series of Extracapsular proximal femoral fracture dislocations published in PubMed, EMBASE, Springer, OvidSP, ScienceDirect, Web of Science and Google scholar between inception of journals to May 2020 were included in the review. A pooled analysis comparing the demography, pattern of the fracture, mode and mechanism of injury with the clinical and radiological outcome and complications was performed.

*Results:* 52 cases from 46 case studies were included in the pooled analysis. There was a near significant association between avascular necrosis and mean time to reduction ($p = 0.0865$). Individuals with compound injury had 10.12 times higher risk of avascular necrosis ($p = 0.009$). No significant association between the pattern of proximal femur fracture and incidence of avascular necrosis ($p = 0.116$, chi-square). There was no significant association between polytrauma and poor clinical outcomes. ($p = 0.231$).

*Conclusions:* Principles of damage control orthopaedics should be followed in unstable patients with this rare fracture dislocation. Percutaneous Schanz screw reduction manoeuvre can be attempted gently with a low threshold to perform an open reduction. Every attempt at salvaging the fractured hip must be performed in young individuals with an arthroplasty standby for comminuted and unreconstructable cases.



## 1. Introduction

Traumatic hip dislocation are known to be associated with fractures of the femoral head and the acetabulum.[1,2] These injuries are common in car accidents where the knee hits against the dashboard, dislocating the femoral head posteriorly, occasionally fracturing the femoral head and posterior wall of acetabulum.[3,4]

There have been rare association of hip dislocation with ipsilateral femoral diaphyseal fractures, with the incidence of 1 in 1,00,000 cases.[5] The association of hip dislocation with extracapsular proximal femur fractures have been further rare. Majority of these cases have been reported as case reports or short case series in the English literature. Being extremely rare, individual case reports may not give clear guidance for the management of this pattern of injury.

In this systematic review, we reviewed the clinical and radiological outcome and complications of 52 patients with this rare fracture dislocation pattern. To our knowledge, this is the largest pooled analysis for this pattern of injury.

## 2. Methods

This review was conducted in accordance to the guidelines by PRISMA.[6] (Fig. 1) A systematic search of the following databases was performed: PubMed, EMBASE, Springer, OvidSP, ScienceDirect,

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https://doi.org/10.1016/j.jcot.2021.04.025
0976-5662/

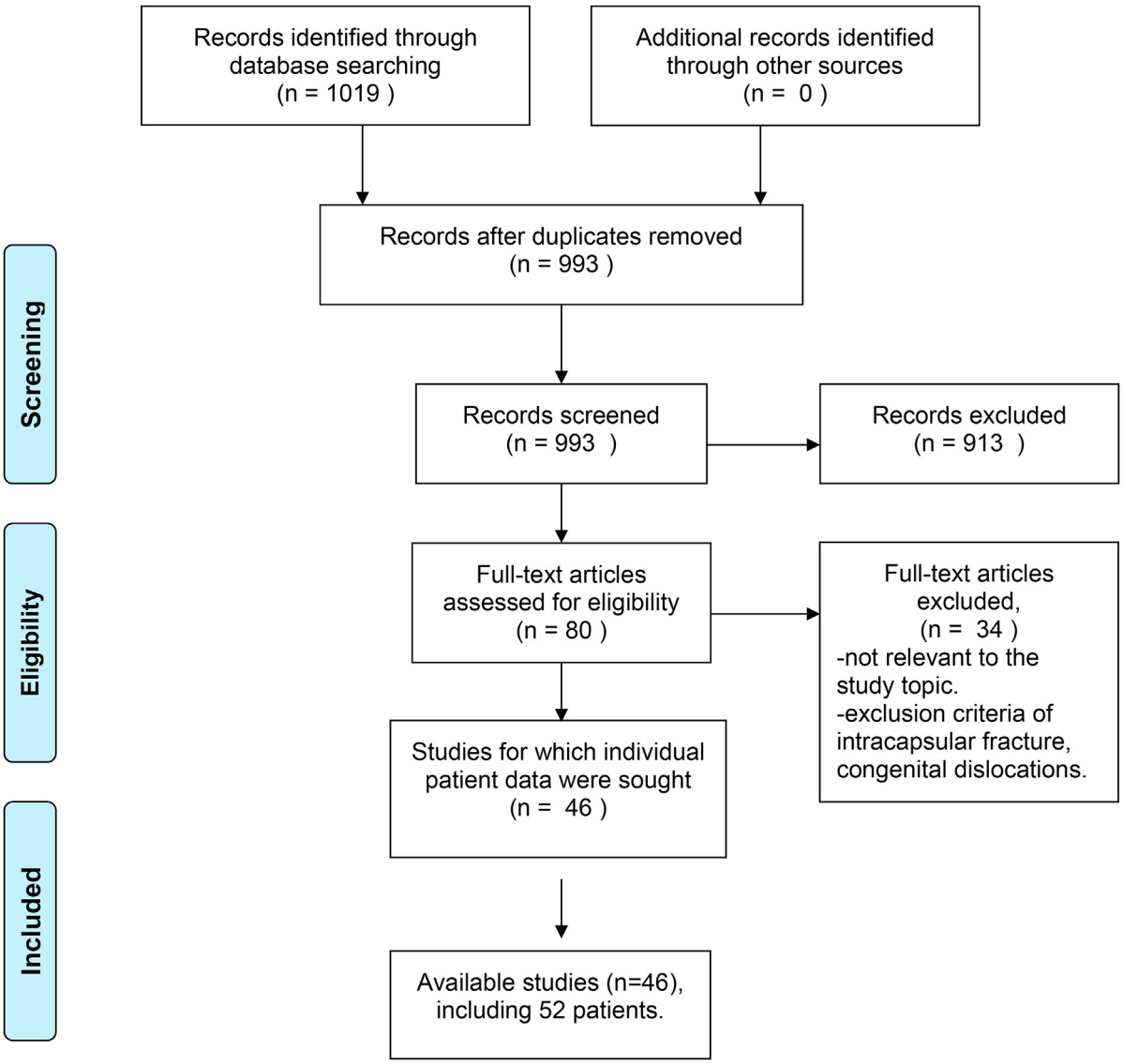


**Fig. 1.** PRISMA flow diagram.

Web of Science and Google scholar.

A search strategy using the Boolean operators like 1) ("fracture dislocation") AND ("femoral head") AND ("intertrochanteric fracture"), 2) ("fracture dislocation") AND ("femoral head") AND ("trochanteric fracture"), 3) ("intertrochanteric fracture" or "trochanteric fracture") AND ("dislocation of hip" or "hip dislocation" or "femoral head dislocation") were used. The primary search was restricted to English language and only humans. The study investigator selected the potentially relevant abstracts and obtained full copies of the articles. Additionally, all the references of the relevant articles were retrieved.

Studies selected were original articles that addressed hip dislocation with trochanteric and peri-trochanteric fractures following trauma with no limitation to age or language. All types of studies-case reports, case series, case control and randomized control trials were considered eligible. Biomechanical and anatomorphological articles were excluded. Date limits were set from inception of the journals to May 2020.

The relevant variables from the selected studies were collected by the author and tabulated. The extracted data included: A) Publication details: year of publication, country of origin, author details. B) Demographic details: Age, gender. C) Injury details: Mode of injury, mechanism of injury. D) Clinical patient profile: general condition, vital status, neurovascular involvement. E) Investigations: Radiographic images, Computed Tomography (CT) scans F) Fracture details: Pattern of fracture, Classification, Associated Femoral head and acetabular fractures. G) Treatment details: Time to reduction, mode of reduction, intra-operative findings, Surgical position and approach, Use of Implants, H) Clinical follow-up and rehabilitation and outcome. F) Complications. Availability of individual case data in the pooled analysis is depicted in (Table 1).

### 2.1. Statistical analysis

The methodological quality of the studies was assessed using the STROBE statement (Table 2), and an assessment tool proposed by Murad et al. designed for case reports and case series (Table 3). Categorical data was represented as proportions and the continuous data was represented as mean, median and standard deviations. Cross table analysis was used for the computation of risk

**Table 1**
Availability of data for the total number of patients (n = 52).

| Clinical variable | % for whom data available | Number | Total (n) |
|---|---|---|---|
| Year of publication | 100 | 52 | 52 |
| Mode of injury | 96.15384615 | 50 | 52 |
| Country of study origin | 100 | 52 | 52 |
| Age | 96.15384615 | 50 | 52 |
| Gender | 96.15384615 | 50 | 52 |
| General condition and vitals | 71.15384615 | 37 | 52 |
| Side of dislocation | 94.23076923 | 49 | 52 |
| Direction of dislocation | 96.15384615 | 50 | 52 |
| Proximal femur fracture pattern | 100 | 52 | 52 |
| Intra-operative assessment of injury | 38.46153846 | 20 | 52 |
| Method of hip reduction/replacement | 96.15384615 | 50 | 52 |
| Time from injury to treatment | 94.23076923 | 49 | 52 |
| Clinical outcome | 76.92307692 | 40 | 52 |
| Radiological outcome | 94.23076923 | 49 | 52 |
| Description of the complications | 96.15384615 | 50 | 52 |

**Table 2**
Assessment of methodological quality of 46 studies- STROBE statement.

| Sr. No. | Assessment of the methodological quality of the 46 studies according to the checklists of the STROBE Statement | Yes | No | Unclear | NA |
|---|---|---|---|---|---|
| 1 | (a) Indicate the study's design with a commonly used term in the title or the abstract | 46 | 0 | 0 | 0 |
| | (b) Provide in the abstract an informative and balanced summary of what was done and what was found | 46 | 0 | 0 | 0 |
| 2 | Explain the scientific background and rationale for the investigation being reported | 0 | 0 | 0 | 46 |
| 3 | State specific objectives, including any prespecified hypotheses | 0 | 0 | 0 | 46 |
| 4 | Present key elements of study design early in the paper | 0 | 0 | 0 | 46 |
| 5 | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow0up, and data collection | 44 | 2 | 0 | 0 |
| 6 | (a) Give the eligibility criteria, and the sources and methods of selection of participants | 0 | 0 | 0 | 46 |
| | (b) For matched studies, give matching criteria and the number of controls per case | 0 | 0 | 0 | 46 |
| 7 | Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable | 46 | 0 | 0 | 0 |
| 8 | For each variable of interest give sources of data and details of methods of assessment (measurement) | 46 | 0 | 0 | 0 |
| 9 | Describe any efforts to address potential sources of bias | 0 | 0 | 0 | 46 |
| 10 | Explain how the study size was arrived at | 0 | 0 | 0 | 46 |
| 11 | Explain how quantitative variables were handled in the analyses | 0 | 0 | 0 | 46 |
| 12 | (a) Describe all statistical methods, including those used to control for confounding | 0 | 0 | 0 | 46 |
| | (b) Describe any methods used to examine subgroups and interactions | 0 | 0 | 0 | 46 |
| | (c) Explain how missing data were addressed | 0 | 0 | 0 | 46 |
| | (d) if applicable, describe analytic methods taking account of sampling strategy | 0 | 0 | 0 | 46 |
| | (e) Describe any sensitivity analyses | 0 | 0 | 0 | 46 |
| 13 | (a) Report the numbers of individuals at each stage of the study | 0 | 0 | 0 | 46 |
| | (b) Give reasons for nonparticipation at each stage | 0 | 0 | 0 | 46 |
| | (c) Consider use of a flow diagram | 0 | 0 | 0 | 46 |
| 14 | (a) Give characteristics of study participants (eg, demographic, clinical, social) and information on exposures | 46 | 0 | 0 | 0 |
| | and potential confounders | 0 | 46 | 0 | 0 |
| | (b) Indicate the number of participants with missing data for each variable of interest | 46 | 0 | 0 | 0 |
| 15 | Report numbers of outcome events or summary measures | 44 | 2 | 0 | 0 |
| 16 | (a) Give unadjusted estimates and, if applicable, confounder0adjusted estimates and their precision | 0 | 0 | 0 | 46 |
| | (b)Report category boundaries when continuous variables were categorized | 0 | 0 | 0 | 46 |
| | (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period | 0 | 0 | 0 | 46 |
| 17 | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses | 0 | 0 | 0 | 46 |
| 18 | Summarise key results with reference to study objectives | 46 | 0 | 0 | 0 |
| 19 | Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias | 0 | 0 | 0 | 46 |
| 20 | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence | 0 | 0 | 0 | 46 |
| 21 | Discuss the generalisability (external validity) of the study results | 0 | 0 | 0 | 46 |
| 22 | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based | 0 | 0 | 0 | 46 |

factor odds for avascular necrosis and heterotrophic ossification. Descriptive statistics were employed where possible. Statistical analysis was performed using IBM SPSS statistics (version 20; Chicago, Ill).

## 3. Results

1019 articles were identified after the primary literature search. The titles and abstracts of the articles were reviewed by the author and 80 relevant articles were identified after the removal of duplicates. After reviewing the full text of these articles and all its references, 46 articles describing 52 cases were selected including 2 articles in Korean,[7,8] 1 in Japanese[9] and 1 in French[10] language. Majority of these cases (12) were reported from India,[11–21] followed by U.S.A (10).[22–27] (Fig. 2).

### 3.1. Patient demographics

Among the 52 reported cases, the median age was 33 years (range from 7 to 74 years) and the mean age was 34.6 years

**Table 3**
Quality assessment of studies.

| Sr No. | Author | Selection | Ascertainment | | Causality | | | | Reporting |
|---|---|---|---|---|---|---|---|---|---|
| | | Does the patient(s) represent(s) the whole experience of the investigator (center) or is the selection method unclear to the extent that other patients with similar presentation may not have been reported? | Was the exposure adequately ascertained? | Was the outcome adequately ascertained? | Were other alternative causes that may explain the observation ruled out? | Was there a challenge/ challenge phenomenon? | Was there a dose eresponse effect? | Was follow-up long enough for outcomes to occur? | Is the case(s) described with sufficient details to allow other investigators to replicate the research or to allow practitioners make inferences related to their own practice? |
| 1 | Arnold K[63] | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | T.F Riggs[26] | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 3 | Fina[24] | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 4 | Barquet[64] | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | Sadler[25] | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 6 | Korovessis[33] | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 7 | Hamzaoglu[65] | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 8 | Maruoka[36] | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 9 | Rafai[10] | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 10 | Garcia Mata[66] | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 11 | Mostafa[67] | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 12 | Moon Do-hyun[7] | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 13 | Maini[12] | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 14 | R. Singh[18] | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 15 | M.Khan[27] | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 16 | R.Agarwal[19] | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 17 | A. Singh[68] | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 18 | Tokashiki[9] | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 19 | Martin[54] | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 20 | Alexa[69] | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 21 | Almosalmy[38] | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 22 | Park[8] | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 23 | Muzaffar[17] | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 24 | Yousefi[57] | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 25 | P.Zhen[41] | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 26 | Radulescu[70] | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 27 | Sinha[20] | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 28 | Kuhn[23] | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 29 | Jangir[71] | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 30 | Jamshidi[15] | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 31 | Anderson[72] | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 32 | Raja[13] | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 33 | Chotai[22] | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 34 | Rehan[14] | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 35 | Majd El Hajj[35] | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 36 | Granahan[37] | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 37 | Atchi[34] | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 38 | Uzun[55] | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 39 | Fageir[40] | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 40 | Chenxian[39] | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 41 | Selvanayagam[16] | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 42 | Cocolos[58] | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 43 | Pascarella[73] | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 44 | Desai[11] | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 45 | Mandavo[74] | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 46 | Khalifa[32] | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |

(SD = 14.89). Among the 50 patients whose gender was reported, 43 were men (86%) and 7 were women (14%). Vital status and general condition was reported in 37 patients, 26 of them being stable and 11 were vitally unstable.

### 3.2. Injury pattern

Thirty two patients had an associated posterior hip dislocation and 18 had anterior dislocation. Among the anterior, 9 were pubic type and 8 were obturator type. Right side was predominantly involved extremity seen in 26 cases. Of the 50 cases, the injury was closed in 40 (80%) and compound in 10 (20%) cases. Majority of the compound injuries had associated anterior hip dislocation (80%). Sciatic nerve involvement was seen in 5 cases (10%) and 2 patients (4.25%) had an associated vascular injury (Table 4).

### 3.3. Mechanism of injury

Road traffic accident was the commonest mode of injury encountered in 33 patients, followed by fall from running vehicle in 4 patients (8%). Among the vehicles, car was involved in 15 (34.09%) of the cases, followed by motorcycle in 4 cases. Head-on-collision was the most commonly reported mechanism of injury (31.25%), followed by single-vehicle accident in 2 and side impact collision in 1 (Table 5) (Fig. 3).

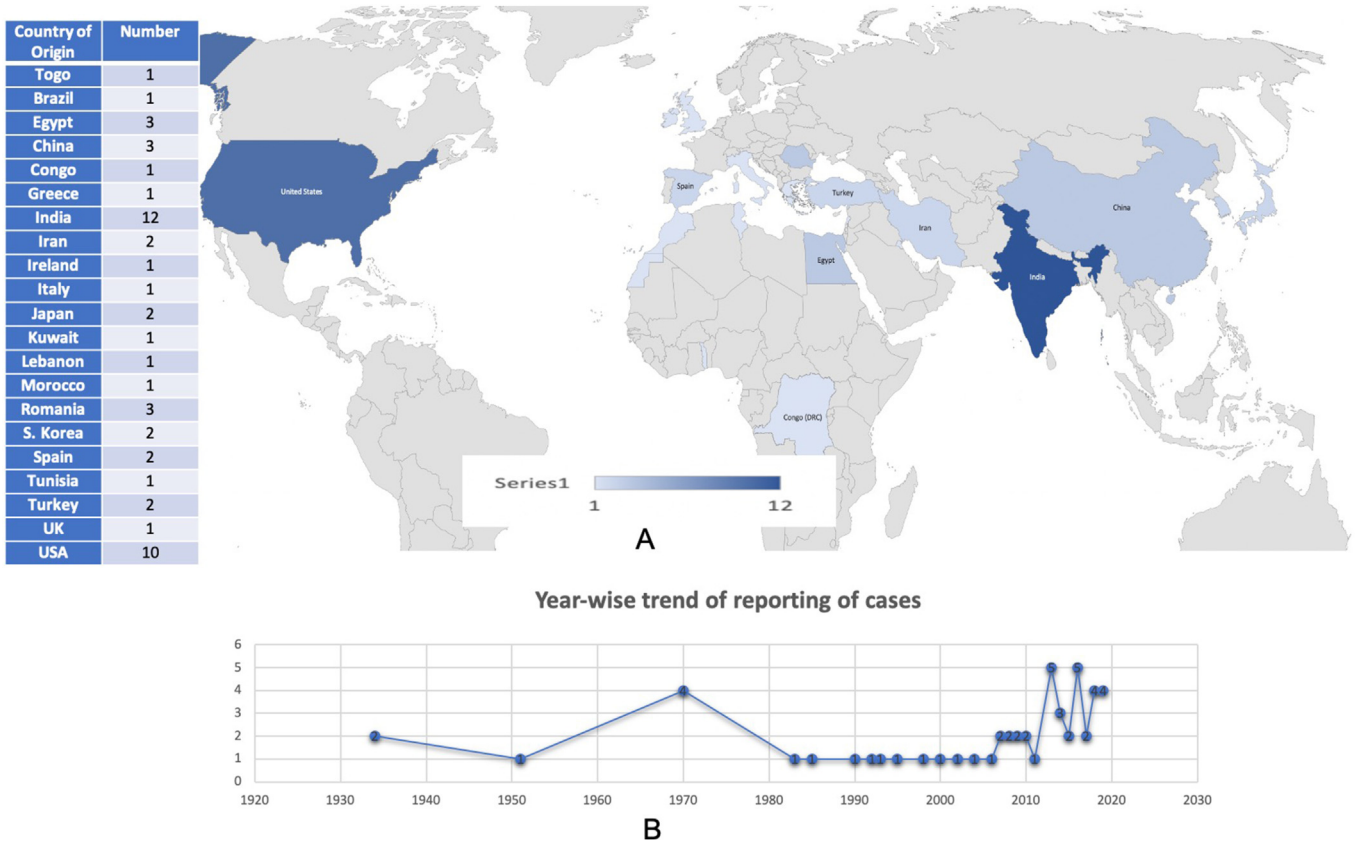


**Fig. 2.** A: Global distribution of reported cases
2B: Year wise trends of reported cases.

**Table 4**
Demographic details and Injury pattern.

| Patient Characteristic | No. of patients (%) |
|---|---|
| Age (y), mean ± SD (n = 50) | 34.87 ± 14.95 |
| **Gender (n=50)** | |
| Male | 43 (86%) |
| Female | 7 (14%) |
| **Clinical Vital status (n=37)** | |
| Vitals Unstable at presentation | 11 (29.72%) |
| Vitals Stable | 26 (70.27%) |
| **Side of Dislocation (n=48)** | |
| Left | 22 (45.83%) |
| Right | 26 (54.16%) |
| **Direction of Dislocation (n=50)** | |
| Anterior: | 18 (36%) |
| Anterior- Not specified | 1 (2%) |
| Pubic | 9 (18%) |
| Obturator | 8 (16%) |
| Posterior | 32 (64%) |
| **Closed/Open Injury (Gustilo Anderson) (n=50)** | |
| Closed | 40 (80%) |
| Closed-Anterior | 10 (20%) |
| Closed-Posterior | 30 (60%) |
| Open | 10 (20%) |
| Open-Anterior | 8 (16%) |
| Open -Posterior | 2 (4%) |
| **Information about Neurological injury (n=50)** | |
| Sciatic palsy | 5 (10%) |
| No palsy | 43 (86%) |
| **Information about Vascular injury (n=47)** | |
| Vascular injury Absent | 45 (95.74%) |
| Vascular injury Present | 2 (4.25%) |
| Dissection of external iliac | 1 |
| Popliteal intimal tear | 1 |

**Table 5**
Mode and mechanism of Injury.

| Mode of trauma (n = 50) | Number of patients (%) |
|---|---|
| Road Traffic accident | 33 (66%) |
| Fall from running vehicle | 4 (8%) |
| Extreme severity not specified | 3 (6%) |
| Impact by vehicle | 3 (6%) |
| Run over by vehicle | 3 (6%) |
| Train crash | 1 (2%) |
| Fall from height | 1 (2%) |
| Fall from stairs | 1 (2%) |
| Mining accident | 1 (2%) |
| **Accidents involving vehicles (n=44)** | Number of patients (%) |
| Car | 15 (34.09%) |
| Motorcycle | 4 (9.09%) |
| Train | 3 (6.81%) |
| Truck | 3 (6.81%) |
| Bus | 2 (4.54%) |
| Roller | 1 (2.27%) |
| Tractor | 1 (2.27%) |
| Tram | 1 (2.27%) |
| **Mechanism of RTA(n=13)** | Number of patients (%) |
| Head on collision | 10 (76.92%) |
| Side impact collision | 1 (7.69%) |
| Single vehicle accident | 2 (15.38%) |

RTA- Road traffic accident.

### 3.4. Fracture morphology

Extracapsular fracture pattern was interpreted from the written text and/or the available radiographic images in all the 52 cases. Intertrochanteric fracture was the commonest fracture pattern associated with hip dislocation in 29 (55.76%) cases, followed by

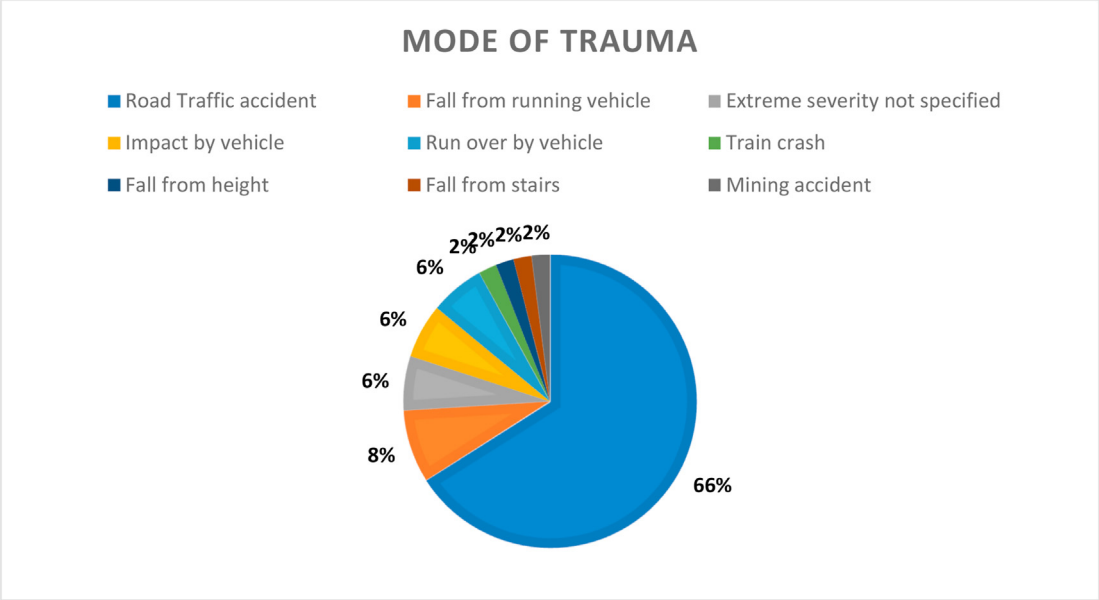


**Fig. 3.** Pie chart of different modes of injury.

isolated greater trochanteric fracture in 14 (26.92%). Forty-three (84.31%) of the 51 reported cases had fracture of the greater trochanter. Radiographs of 17 cases showed posteromedial comminution in the calcar region of the inter-trochanteric fractures. The fracture stability was classified as stable/unstable for the inter-trochanteric and subtrochanteric fracture patterns. 30 (81.08%) of the 37 cases had unstable fracture pattern. Jensen's modification of Evan's classification was used to classify the fracture patterns into 5 types based upon the existing radiographs. Thirty-four fractures were classified, of which type 5 was the commonest pattern seen in 17 (50%) of the 34 cases and type 3 in 10 (29.411%) cases. Nineteen (36.53%) patients had an associated acetabular fracture and 10 had associated femoral head fracture. Posterior wall fracture was the predominant pattern of the acetabular fracture, seen in 9 (47.36%) cases (Table 6).

### 3.5. Treatment

Out of the 52 patients presenting with this rare pattern of injury, 3 patients were treated with primary arthroplasty and 47 with osteosynthesis. Thirty-three (66%) of the 50 reported cases were treated on emergency basis within a period of 1 day and 17 (34%) were treated in the routine operative room theatre after primary stabilization, the mean time to reduction being 3.91±6.13 days (Range-1 to 30 days).

### 3.6. Method of reduction

Closed reduction was attempted in 20 (40%) patients with success in 12 (60%) patients. Three of these were successful with the use of a Schanz screw and 3 with Allis's maneuver. Eight of the attempted cases had failure of closed reduction (CR). Direct open reduction (OR) without CR attempt was done for 30 (60%) cases.

Among the patients with posterior dislocation of the hip, open reduction was performed in 25 cases. Posterolateral approach was the most preferred approach in 12 (42.85%) followed by lateral approach in 11 (39.28%) patients. Anterior approach was used for hip reduction in 2 patients with posterior dislocation. Among the patients with anterior dislocation, open reduction was performed in 7 patients (41.17%), anterior approach being the most preferred approach (Table 7).

### 3.7. Implant of choice

Dynamic hip screw was the most preferred choice of implant for the intertrochanteric fracture group whereas the majority of the isolated greater trochanteric fractures were treated conservatively (Table 8). Acetabular fracture was present in 2 out of the 18 anterior dislocations and 15 of the 32 posterior hip dislocations. Majority of the posterior wall acetabulum and its associated fractures were treated with Open reduction and fixation using buttress plate and screws. One patient with T fracture of acetabulum, treated conservatively went into nonunion.

### 3.8. Outcome and complications

The median follow-up of the patients was 15 months (Range- 6 weeks to 11 years). The clinical outcomes were described in an ordinal scale of poor, fair, good and excellent. Harris hip score was the most commonly used outcome measure. Functional outcomes were classified according to the above scale in 32 (62.7%) cases. The association of functional outcomes with different parameters have been described in the (Table 9).

Of the 5 patients having poor functional outcome at their final follow-up, 4 had evidence of avascular necrosis, 2 had heterotrophic ossification and 1 had an episode of re-dislocation at 5 months post injury. Of the 5 patients with poor outcome, 1 needed a re-surgery for debridement attributed to infection and 1 had a total hip replacement for degenerative joint disease.

No statistical significance was found between individual groups when comparing the functional outcome with the proximal femoral fracture pattern (Jensen's modification of Evan's classification), posteromedial comminution and degree of greater trochanteric comminution, by Kruskall-Wallis test. The Kruskall-Wallis test revealed a significantly difference in the clinical outcomes with the soft tissue injury associated with the fracture dislocation (Grade 3a having poor outcome). No significant difference in outcomes between patients treated within 1 day, 1 week or

**Table 6**
Description of the fracture pattern.

| Pattern of Extracapsular proximal femur fracture (n = 52) | No. of patients (%) |
|---|---|
| Isolated trochanter involvement | 14 (26.92%) |
| Basicervical fracture | 3 (5.76%) |
| Intertrochanteric | 29 (55.76%) |
| Subtrochanteric | 1 (1.92%) |
| Intertrochanteric + Subtrochanteric | 5 (9.61%) |
| **Jensen's modification of Evans classification (n=34)** | **No. of patients (%)** |
| 1 | 1 (2.94%) |
| 2 | 6 (17.64%) |
| 3 | 10 (29.41%) |
| 5 | 17 (50%) |
| **Involvement of Greater trochanter(n=51)** | **No. of patients (%)** |
| No | 8 (15.68%) |
| Yes- Comminuted | 26 (50.98%) |
| Yes-Avulsion | 17 (33.33%) |
| **Posteromedial comminution (n=38)** | **No. of patients (%)** |
| No | 21 (55.26%) |
| Yes | 17 (44.73%) |
| **Fracture stability in intertrochanteric/subtrochanteric fractures (n=37)** | **No. of patients (%)** |
| Stable | 7 (18.91%) |
| Unstable | 30 (81.08%) |
| **Associated involvement of the acetabulum (n=51)** | **No. of patients (%)** |
| No acetabulum fracture | 32 (61.53%) |
| Acetabulum fracture | 19 (36.53%) |
| **Description of acetabulum involvement (n=19)** | **No. of patients (%)** |
| Posterior wall | 9 (47.36%) |
| Posterior wall with associated patterns | 4 (21.05%) |
| Anterior column | 1 (5.26%) |
| Improper description | 5 (26.31%) |
| **Description of femur head involvement(n=48)** | **No. of patients (%)** |
| No femoral head # | 38 (79.16%) |
| Femur head fracture | 10 (20.83%) |
| **Description of femur head fracture (n=10)** | **No. of patients (%)** |
| Comminuted | 3 (30%) |
| Non comminuted | 5 (50%) |
| No detail | 2 (20%) |

**Table 7**
Description of Surgical position and approaches.

| Surgical position | Lateral Position | Supine Position |
|---|---|---|
| Anterior dislocation | 2 | 15 |
| Posterior dislocation | 22 | 7 |
| **Posterior hip dislocation- Surgical approach** | | |
| Postero-Lateral | 12 | |
| Lateral | 11 | |
| Anterior | 2 | |
| Not-mentioned | 3 | |
| **Approach- Anterior hip dislocation** | | |
| Lateral | 4 | |
| Postero-Lateral | 2 | |
| Antero-Lateral | 1 | |
| Anterior | 1 | |

**Table 8**
List of implants used for fixation of proximal femoral fracture dislocation.

| Implant (n = 50) | No. of patients |
|---|---|
| Dynamic Hip Screw | 16 (32%) |
| Conservative after reduction | 8 (16%) |
| Cephalomedullary nail | 4 (8%) |
| Proximal femur plate | 3 (6%) |
| Angled blade plate | 2 (4%) |
| Dynamic condylar screw | 2 (4%) |
| Ex-fixator followed by DHS | 2 (4%) |
| GT tension band wiring | 2 (4%) |
| External fixator | 1 (2%) |
| Reversed distal femur Locking plate | 1 (2%) |
| 2 Cannulated cancellous screws | 1 (2%) |
| McLaughlin nail plate | 1 (2%) |
| Parham band | 1 (2%) |
| Moe plate and screws | 1 (2%) |
| Multiple pin fixation | 1 (2%) |
| Primary arthroplasty | 3 (6%) |
| Arthrodesis | 1 (2%) |

GT- Greater trochanter, DHS- Dynamic hip screw.

beyond 1 week of injury by Kruskall-Wallis test (p = 0.607). (Table 9).

### 3.9. Avascular necrosis

14 (32.55%) out of the 43 reported cases had evidence of avascular necrosis of the femoral head of these cases with the median time to diagnosis being 1 year. Hip and thigh pain was the most common clinical presentation.

There was a significant association between the occurrence of avascular necrosis and the degree of soft tissue injury (p = 0.009, OR = 10.12), mean time to hip reduction (p = 0.0865). There was no association of avascular necrosis with the occurrence of acetabular (p = 1), femoral head fracture (p = 1) and the method of reduction (p = 0.455). Performing anterior capsulotomy for femoral head fixation and joint inspection in a posteriorly dislocated hip, did not significantly increase the incidence of avascular necrosis. No significant association was between avascular necrosis and the type of proximal fracture pattern (chi square, p = 0.116) or the direction of dislocation (Fischer's exact test-p = 0.488). (Table 10).

Twelve out of the 14 patients had reported the time to the radiological diagnosis of avascular necrosis. Majority of these patients (50%) had avascular necrosis diagnosed in the first year, the remaining in the second and the third year (Table 11).

**Table 9**
Association of clinical outcome with different parameters.

| Clinical outcome in Harris Hip score | Excellent | Good | Fair | Poor |
|---|---|---|---|---|
| AVN(n = 10) | 0 | 5 | 1 | 4 |
| HO(n = 3) | 0 | 0 | 1 | 2 |
| Unstable vital status/shock at presentation (n = 6) | 0 | 3 | 1 | 2 |
| Anterior dislocation (n = 13) | 1 | 9 | 0 | 3 |
| Posterior dislocation (n = 19) | 1 | 13 | 3 | 2 |
| Open reduction (n = 23) | 1 | 15 | 3 | 4 |
| Closed Reduction (n = 7) | 1 | 5 | 0 | 1 |
| Compound # DL (n = 6) | 0 | 2 | 0 | 4 |
| Closed # DL (n = 26) | 2 | 20 | 3 | 1 |
| **Soft tissue injury (Gustilo-Anderson classification)** | **Excellent** | **Good** | **Fair** | **Poor** |
| Closed wound | 2 | 20 | 3 | 1 |
| Open Grade unspecified | 0 | 1 | 0 | 0 |
| Open Grade 2 wound | 0 | 1 | 0 | 0 |
| Open Grade 3a wound | 0 | 0 | 0 | 3 |
| Open Grade 3b Wound | 0 | 0 | 0 | 1 |
| Significant, p = 0.007, Kruskall Wallis test for non parametric variable. | | | | |
| Dunn's pairwise test- strong difference between groups with Grade 3a wound and closed injury, p = 0.01 | | | | |
| **Time to Reduction** | **Excellent** | **Good** | **Fair** | **Poor** |
| Group 1- Less than 1 day | 1 | 15 | 1 | 4 |
| Group 2- 1 day to 1 week | 1 | 2 | 1 | 0 |
| Group 3- more than 1 week | 0 | 4 | 1 | 1 |
| **Organ systems involved** | **Excellent** | **Good** | **Fair** | **Poor** |
| Isolated Hip injury | 1 | 0 | 0 | 0 |
| Multiple skeletal fractures | 0 | 6 | 1 | 1 |
| 2 Organ system involvement | 0 | 2 | 0 | 1 |
| Polytrauma | 0 | 2 | 1 | 2 |
| Details unavailable | 1 | 12 | 1 | 1 |
| | **Fair/Poor** | **Excellent/Good** | **p value** | |
| >2 Organ system involvement | 4 | 4 | 0.231 | |
| Trauma restricted to skeletal system | 2 | 7 | | |
| Mean time to reduction (days) | 5.62 ± 7.87 | 3.47 ± 4.69 | p = 0.3606 (independent *t*-test) | |

AVN-avascular necrosis, HO- heterotrophic ossification, DL-dislocation.

### 3.10. Heterotrophic ossification

Heterotrophic ossification was observed in 6 (13.04%) out of the 46 reported cases.

There was a strong association between the occurrence of heterotrophic ossification and the presence of head and/or chest injury (p = 0.0017, Fischer's exact test) with an odd's ratio of 28.33.

For posteriorly dislocated hips, performing an anterior capsulotomy was associated with a 17.5 times higher risk of developing heterotrophic ossification (p = 0.014). There was no significant difference in the occurrence of heterotrophic ossification in relation to the direction of dislocation (p = 0.64), mode of reduction (p = 0.10) and the severity of local soft tissue injury (Gustilo-Anderson classification) (p = 1). (Table 12).

## 4. Discussion

To the best of our knowledge, this is the first review of the published literature, to identify the mode, mechanism, pathoanatomy and prognostic factors determining the outcome in the patients with hip dislocation with extra-capsular proximal femur fractures. Our analysis was conducted from 46 case studies published from the inception of the journals to May 2020, predominantly from English literature.

In contrast to fracture of the femoral neck which occur in elderly osteoporotic individuals, traumatic hip dislocations are a result of high velocity injuries and occasionally sports.[28] Similar to the contemporary literature for hip dislocations,[29,30] road traffic accident (66%) was the most common mode of injury for this pattern of injury.

Head on collision was a major mechanism of injury in majority of these patients (76.92%). In a head-on-collision, the force due to the sudden deceleration of the vehicle is frequently transmitted throughout the lower extremity.

The two patterns of greater trochanteric involvement indicated two differing mechanisms of injury. Comminution of the greater trochanter is most likely as a result of direct trauma to the area of the greater trochanter before or after the dislocation. Avulsion of the trochanteric fragment may be a result of the violent external rotatory force.

It is apparent that the greater trochanteric fracture precedes the dislocation as the stabilizing forces of the greater trochanteric muscular sleeve would not allow an easy dislocation. The capsular disruption is seen in all the cases. Union of the greater trochanteric apophysis in 5 cases of anterior dislocation treated conservatively after reduction indicates the possible intactness of the muscular sleeve of the Gluteus Medius and Vastus lateralis with the trochanter, thus repositioning the trochanter to its anatomical position after hip reduction. The possible mechanism of injury in such cases is a thus a violent rotatory movement with or without direct injury to the greater trochanter (Fig. 4A–D). Comminuted fracture of the greater trochanter may be associated with direct injury to the lateral aspect of the hip.

The occurrence of intertrochanteric fracture-dislocation occurs as a continuation to the typical dashboard injury. The axial force along the flexed and neutrally abducted limb forces the femoral head posteriorly with or without an associated posterior wall fracture.[31] If the lower extremity abducts with the continuation of deceleration force, the dislocated head impinges under the posterior lip of acetabulum and the abduction-external rotation torque leads to fracture of the inter-trochanteric and subtrochanteric region. The twisting force is thus responsible for and oblique fracture

**Table 10**
Predictors of avascular necrosis.

| | AVN | No AVN | p value (Fischer's exact test) |
|---|---|---|---|
| Compound trauma (n = 8) | 6 | 2 | p = 0.009 |
| Closed trauma (n = 35) | 8 | 27 | OR = 10.125 |
| Closed reduction (n = 10) | 2 | 8 | p = 0.455 |
| Open reduction (n = 33) | 12 | 21 | OR = 2.28 |
| Acetabulum fracture (n = 14) | 5 | 9 | p = 1 |
| No acetabulum fracture (n = 29) | 9 | 20 | OR = 1.234 |
| Femur head fracture (n = 10) | 3 | 7 | p = 1 |
| No femur head fracture (n = 33) | 11 | 22 | OR = 0.8571 |
| Anterior dislocation (n = 14) | 6 | 8 | p = 0.488 |
| Posterior dislocation (n = 29) | 8 | 21 | |
| Surface implant (n = 27) | 5 | 22 | p = 1 |
| Intramedullary implant (n = 4) | 1 | 3 | |
| Anterior capsulotomy for posterior dislocation (n = 3) | 2 | 1 | p = 0.143 |
| Posterior capsulotomy for posterior dislocation (n = 21) | 4 | 17 | OR = 8.5 |
| **Mean time to reduction** | 6.57 ± 9.41 days | 3.03 ± 3.88 days | p = 0.0865 (Independent *t*-test) |
| | **AVN** | **NO AVN** | **P value, Chi-square** |
| **Evan's classification** | | | |
| 1 | 0 | 1 | p = 0.325, df = 4, n = 43, chi square |
| 2 | 3 | 3 | |
| 3 | 1 | 8 | |
| 4 | 0 | 0 | |
| 5 | 3 | 11 | |
| **Pattern of Proximal femoral fracture** | | | |
| Basicervical neck | 2 | 1 | p = 0.116, df = 4, Chi square |
| Intertrochanteric | 5 | 20 | |
| Intertrochanteric + Subtrochanteric | 1 | 3 | |
| Isolated trochanteric fracture | 6 | 4 | |
| Subtrochanteric fracture | 0 | 1 | |

AVN-avascular necrosis, OR- Odds ratio.

**Table 11**
Time to radiological diagnosis of avascular necrosis.

| Time to radiological diagnosis of avascular necrosis | |
|---|---|
| First 3 months | 3 |
| 3–6 months | 1 |
| 6months - 1 year | 2 |
| 2 nd year | 2 |
| 3rd year | 2 |
| Unspecified | 4 |

line at the cancellous inter-trochanteric region. It is evident that dislocation of the hip occurs before the fracture as the continuity of the femoral neck is essential to transmit the dislocating force (Fig. 5A–C).

### 4.1. Reduction techniques

Maneuvers like Allis as in the reduction of conventional hip dislocation and Percutaneous techniques with the use of Schanz screw under fluoroscopic guidance were the two most commonly used techniques for closed reduction.

Closed reduction techniques using simple maneuvers were successful in predominantly isolated greater trochanteric fractures due to the continuity of the femoral shaft, neck and the femoral head.[15,16,32–37] The technique was also successful in a case of comminuted intertrochanteric fracture and in a case of undisplaced inter-trochanteric fracture. Closed reduction with traditional maneuvers were predominantly unsuccessful in intertrochanteric and subtrochanteric fractures (66.66%).[22,25,38–41]

There have been three cases with successful closed reduction of intertrochanteric and subtrochanteric fracture dislocations with the use of percutaneous Schanz screw under fluoroscopic guidance.[18,21,23] A successful and relatively atraumatic closed reduction can aid in early reduction of the dislocated hip without any significant added insult to the soft tissue envelope around the hip. The Schanz pin is inserted into the proximal head neck fragment under fluoroscopic guidance and gently de-rotated to reduce the head into the acetabulum (Fig. 6A–C). Multiple attempts of failed closed reduction are contra-indicated.[42] An inverted torn acetabular labrum, incarcerated intra-articular fragment or buttonholing of the capsule should be suspected in absence of the classical clunk and a concentric hip reduction. In our study, 2 patients had a failure of closed reduction due to head buttonholed from a defect in the joint capsule, which needed release during the open reduction (Fig. 7A and B). One patient had a loose osteo-cartilaginous head fragment incarcerated into the joint hindering a concentric reduction.

Button-holing of the femoral head from the capsular and intermuscular defects can be an important impediment to closed reduction. An intra-operative observation by Sadler et al. in a case of anterior hip fracture dislocation found the femoral head herniating through a defect in the anteromedial joint capsule.[25] The anterior joint capsule is reinforced by strong iliofemoral and pubofemoral ligaments. These ligaments are loose in the position of

**Table 12**
Predictors of Heterotrophic ossification.

| | HO Yes (n = 6) | No HO (n = 40) | p value (Fischer's exact test) |
|---|---|---|---|
| HI present | 3 | 3 | p = −0.011 |
| HI absent | 2 | 38 | OR = 19 |
| CI present | 5 | 1 | p = 0.001 |
| CI absent | 5 | 34 | OR = 34 |
| HI ± CI | 5 | 6 | p = 0.001 |
| No HI/CI | 1 | 34 | OR = 28.33 |
| | | | phi +0.58 |
| Anterior dislocation | 1 | 14 | p = 0.6472 |
| Posterior dislocation | 5 | 26 | |
| Closed injury | 5 | 32 | p = 1 |
| Compound Injury | 1 | 8 | |
| Closed Reduction | 3 | 7 | p = 0.106 |
| Open reduction/Arthroplasty | 3 | 33 | OR = 4.71 for closed reduction |

HI= Head injury, CI= Chest injury, OR- Odds ratio, HO= Heterotrophic ossification.

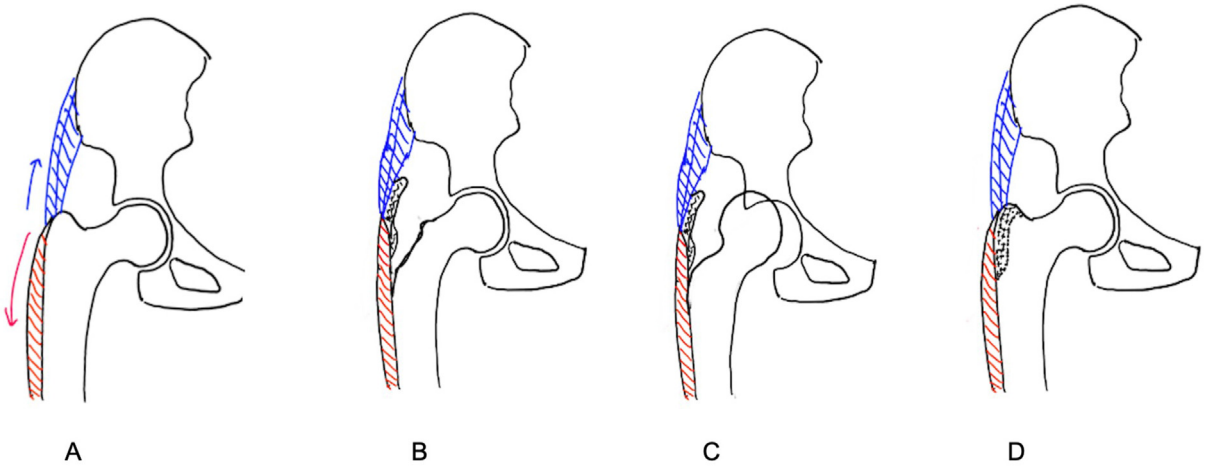


**Fig. 4.** 4A: Gluteus Medius and vastus lateralis attached to the greater trochanter.
4B: Fracture avulsion of the greater trochanter due to violent rotatory force.
4C: Dislocation of the femoral head with capsular tear.
4D: Restoration of the fracture on closed reduction due to the balanced pull of Gluteus Medius and vastus lateralis.

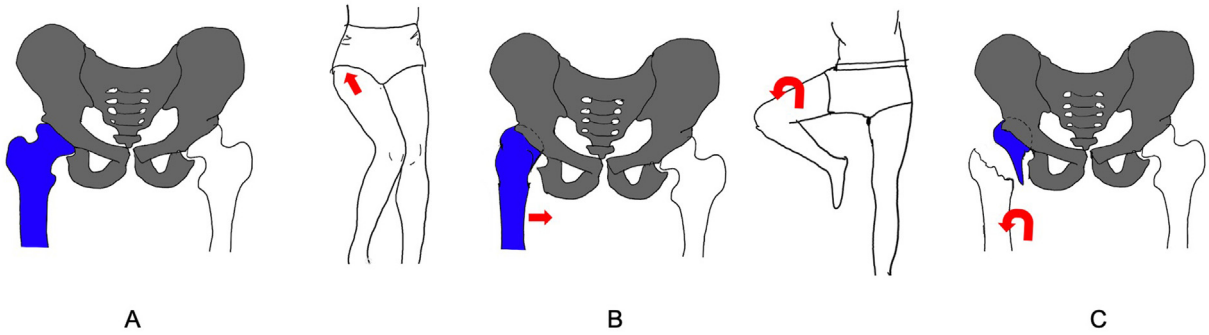


**Fig. 5.** 5A: Intact hip joint.
5B: Stage 1 of injury with dislocation of hip with hip in flexion and neutral/adduction.
5C: Stage 2 of injury with hip in flexion, abduction and external rotation with impingement and intertrochanteric fracture.

hip flexion.[43] Besides, the flexion, abduction and external rotation force can injure these ligaments favoring the dislocation through the weak zone in the capsule, between the iliofemoral and pubofemoral ligaments. The author believes that this form of femoral head buttonholing can be suspected in cases of failed closed reduction with obturator type of dislocation and can be

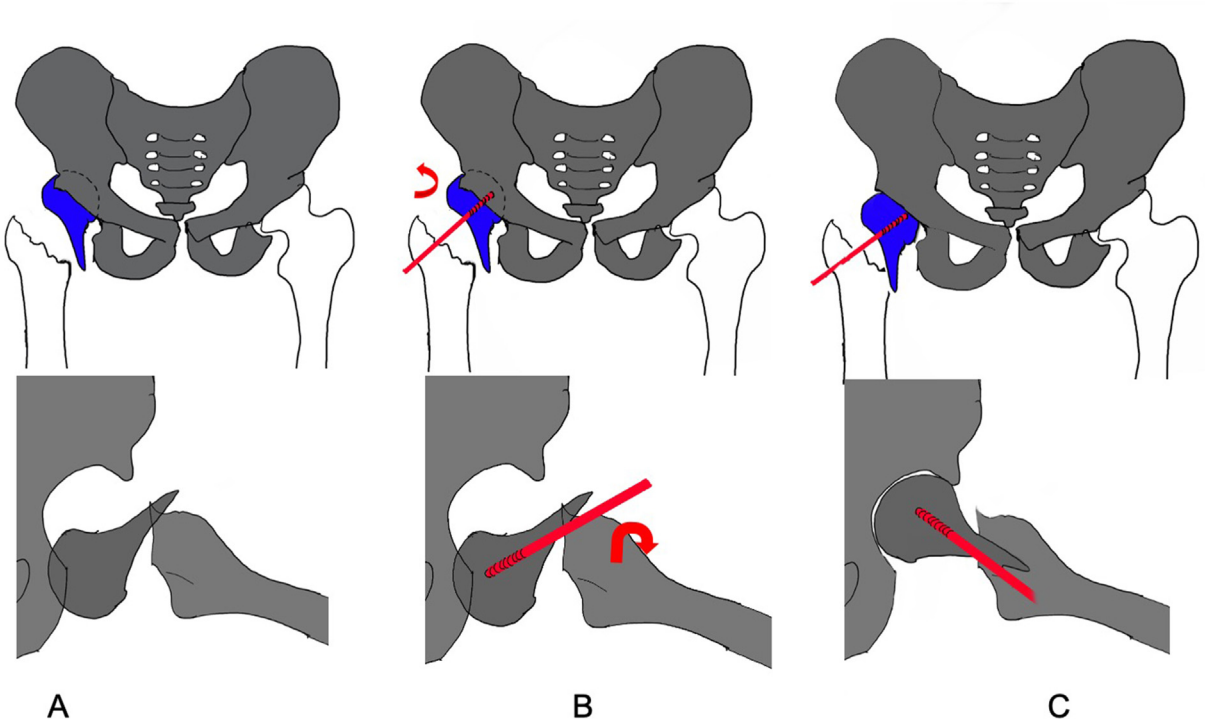


**Fig. 6.** 6A: Intertrochanteric fracture with posterior dislocation.
6B: Schanz pin inserted in the femoral head under fluoroscopic guidance.
6C: Gentle rotational maneuver to relocate the femoral head into the acetabulum.

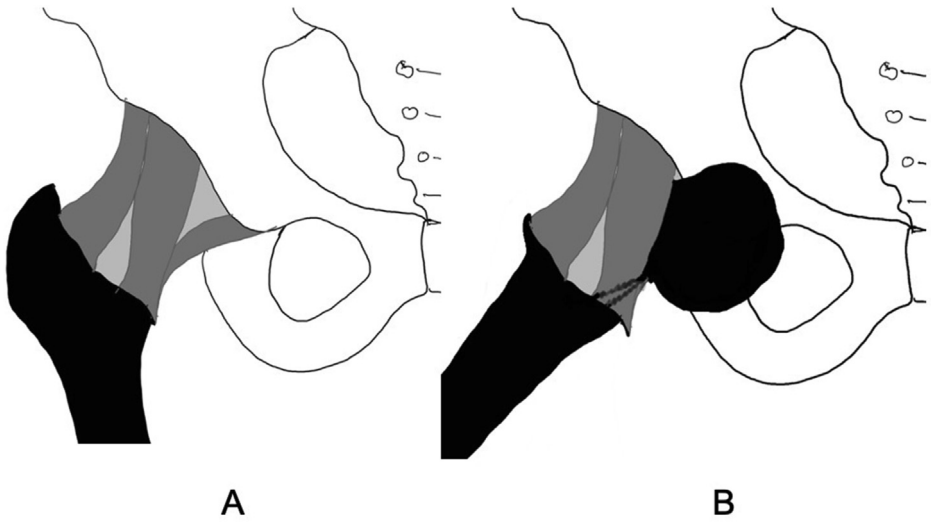


**Fig. 7.** 7A: Intact hip joint with extracapsular ligamentous re-inforcement.
7B: Femoral head buttonholing from the capsular defect.

treated by extending the capsular defect and manual reduction.[25]

### 4.2. Complications: Avascular necrosis

Isolated per-trochanteric fractures have an increased risk of avascular necrosis in presence of risk-factors like increasing age,[44] atherosclerosis,[45] high energy trauma,[44] fracture comminution,[46] proximal fracture line near the base of the femoral neck, major fracture displacement, excessive time interval between fracture and reduction of fracture,[47,48] forceful manoeuvres of reduction and fixation, valgus reduction and fixation of the fracture, damage to the vascularity by the insertion of the femoral nail in the piriformis fossa.[45]

From the results of our pooled analysis, the severity of soft tissue injury and the timing of reduction were the two important parameters associated with the occurrence of avascular necrosis. However, unlike the classical studies in elderly per-trochanteric fractures, the pattern of fracture and degree of comminution did not have any significant association with avascular necrosis.

Anterior approaches for open reduction of posteriorly dislocated hips have traditionally been contraindicated owing to the embarrassment of the existing compromised blood supply.[49,50] In our

**Table 13**
List of 52 cases with relevant parameters.

| Author | Age | Sex | Side | Direction | Vitals | O/C | FP | A# | RM | TTR (d) | AVN | HO | Outcome | Union |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Arnold K[63] | 14 | M | – | – | – | – | GT | – | – | – | – | – | – | – |
| Arnold K[63] | – | – | – | – | – | – | GT | – | – | – | – | – | – | – |
| T.F Riggs[26] | 59 | F | L | P | – | C | IT | PW | OR | 14 | Yes | – | Good | Yes |
| Fina[24] | 40 | M | R | P | – | C | IT | No | OR | 30 | Yes | – | Arthrodesis | Yes |
| Fina[24] | 57 | M | – | P | – | C | IT | PW | OR | 4 | Yes | – | Fair | Yes |
| Fina[24] | 60 | F | R | P | – | C | IT | No | OR | 12 | No | – | Good | Yes |
| Fina[24] | 34 | M | L | P | – | C | IT+ST | PW | OR | 13 | No | – | Good | Yes |
| Barquet[64] | 25 | M | R | P | US | C | IT | No | OR | 5 | No | – | – | Yes |
| Sadler[25] | 27 | M | R | AO | S | C | B | No | OR | 1 | Yes | – | Good | Yes |
| Korovessis[33] | 22 | M | L | AO | S | C | GT | No | CR | 1 | No | – | Excellent | Yes |
| Hamzaoglu[65] | 34 | M | R | P | S | O-Gr III B | GT | PWA | OR | 1 | Yes | – | Poor | Yes |
| Maruoka[36] | 28 | M | R | AP | – | C | GT | No | CR | 1 | No | – | Good | Yes |
| Rafai[10] | 9 | M | L | A | – | O | GT | No | OR | 1 | Yes | – | Good | Yes |
| Garcia Mata[66] | 10 | M | L | AP | US | O-Gr IIIA | GT | No | OR | 1 | Yes | – | Poor | NO |
| Mostafa[67] | 32 | M | L | P | US | C | IT | No | OR | 3 | No | – | Good | Yes |
| Moon Do-hyun[7] | 58 | F | L | P | S | C | IT | No | OR | 7 | No | – | Fair | Yes |
| Maini[12] | 25 | M | L | P | S | C | B | No | OR | 1 | Yes | – | Good | Yes |
| R. Singh[18] | 35 | M | R | AO | S | C | IT | No | CR | 1 | No | – | Good | Yes |
| M.Khan[27] | 40 | M | R | P | S | C | IT+ST | AC | CR | 1 | No | Yes | No disability | Yes |
| R.Agarwal[19] | 40 | M | L | P | S | C | IT+ST | No | OR | 1 | No | – | Painless movement | Yes |
| A. Singh[68] | 55 | M | R | AO | – | O-Grade II | ST | No | CR | 1 | No | – | Good | Yes |
| Tokashiki[52] | 74 | M | R | P | – | C | IT | PW | OR | 1 | Yes | – | Implant failure | Yes |
| Martin[54] | 27 | M | R | P | US | C | IT | No | OR | 15 | No | Yes | Fair | Yes |
| Alexa[69] | 41 | M | R | P | S | C | IT | PW | OR | 2 | No | – | – | – |
| Almosalmy[38] | 28 | M | L | P | US | C | IT | PW | OR | 1 | No | – | Good | Yes |
| Park[8] | 38 | M | L | P | US | C | IT | No | OR | 21 | Yes | Yes | Poor | Yes |
| Muzaffar[17] | 35 | M | R | AP | US | O-Gr IIIA | IT | A? | OR | 1 | DEATH | DEATH | Death | – |
| Yousefi[57] | 43 | M | R | P | S | C | IT | PW | OR | 1 | No | – | Good | Yes |
| P.Zhen[41] | 59 | M | L | P | S | C | IT | PW | A.plasty | 1 | – | – | Good | NA |
| Radulescu[70] | 44 | M | L | AP | S | C | IT | No | OR | 1 | No | – | Good | Yes |
| Sinha[20] | 45 | M | L | P | – | C | IT | PWA | OR | 1 | No | – | Good | Yes |
| Kuhn[23] | – | – | – | P | US | C | IT+ST | No | CR | 1 | – | – | – | – |
| Jangir[71] | 25 | M | L | P | S | C | B | PW | OR | 1 | No | – | Good | Yes |
| Jamshidi[15] | 26 | M | R | P | – | C | IT | PWA | CR | 1 | No | Yes | Partial movement limitation | Yes |
| Anderson[72] | 46 | M | L | AP | S | O-Gr IIIA | GT | No | OR | 1 | No | – | Poor | Yes |
| Raja[13] | 60 | F | L | AP | S | C | GT | No | A.plasty | – | – | – | Good | NA |
| Chotai[22] | 25 | M | L | P | S | C | IT | No | OR | 1 | No | – | – | Yes |
| Rehan[14] | 36 | F | R | P | S | C | IT | No | OR | 1 | No | – | Fair | Yes |
| Majd El Hajj[35] | 24 | M | R | AO | S | C | IT | No | CR | 1 | No | – | Good | Yes |
| Rehan[14] | 26 | M | R | P | S | C | IT | No | OR | 5 | No | – | Good | Yes |
| Granahan[37] | 31 | M | R | AP | – | C | GT | No | CR | 1 | – | – | – | Yes |
| Atchi[34] | 23 | M | L | AP | US | O-Gr IIIA | GT | No | CR | 1 | Yes | – | – | Yes |
| Uzun[55] | 20 | M | L | P | US | C | IT | PWA | OR | 3 | No | Yes | Partial movement limitation | Yes |
| Fageir[40] | 31 | M | R | P | S | C | IT | No | OR | 1 | No | – | Good | Yes |
| Chenxian[39] | 29 | M | R | P | S | C | IT | No | OR | 3 | No | – | Excellent | Yes |
| Chenxian[39] | 38 | F | R | P | US | C | IT+ST | PW | OR | 14 | Yes | – | Good | Yes |
| Selvanayagam [16] | 28 | M | R | AP | S | C | GT | No | CR | 1 | No | – | Good | Yes |
| Cocolos[58] | 49 | M | L | P | S | O-Grade I | IT | No | OR | 1 | – | – | – | – |
| Pascarella[73] | 38 | F | R | AO | – | C | IT | A? | A.Plasty | – | – | – | – | – |
| Desai[11] | 19 | M | R | P | S | C | IT | No | OR | 2 | No | – | Abductor lurch | Yes |
| Mandavo[74] | 7 | M | L | AO | S | O-Gr IIIA | GT | No | OR | 1 | Yes | – | – | Yes |
| Khalifa[32] | 13 | M | R | AO | S | O-Gr IIIA | GT | No | CR | 1 | Yes | Yes | Poor | Yes |

M-Male, F-Female, L-Left, R-Right, A-Anterior, AP-Anterior pubic, AO-Anterior obturator, P-Posterior, US-Unstable vitals, S-Stable vitals, O- Open injury, C-Closed injury, FP-Fracture pattern, GT-Isolated Greater trochanteric fracture, IT-Inter-trochanteric fracture, B-Basicervical fracture, ST-Subtrochanteric fracture, A#-Acetabular fracture, PW-Posterior wall fracture, PWA- Posterior wall with associated fracture types, AC-Anterior column, A?-acetabulum fracture not specified, RM- Method of reduction, TTR (d)- Time to reduction in days, AVN-avascular necrosis, HO-heterotrophic ossification, A.plasty- Arthroplasty.

study, 2 out of 3 cases (66.66%) of posterior dislocations treated by anterior open reductions developed avascular necrosis.[8,26] The choice of implant, surface or intramedullary did not influence the occurrence of avascular necrosis in these patients. Barquet et al. in a systematic review supported this finding where avascular necrosis in inter-trochanteric fractures was not found to co-relate with the type of implant and the position of the screw.[51]

### 4.3. Complication: Heterotrophic ossification

Heterotrophic ossification, an unregulated differentiation of muscle tissues into endochondral bone, occurs commonly in association with traumatic injury to the brain and spinal cord.[52] High injury severity score (ISS), surgical intervention, severe muscle damage, and bony fractures are the other factors associated with heterotrophic ossification.[53] Similar to the contemporary literature, our study revealed strong association between heterotrophic ossification and head-chest injury.[8,15,27,32,54,55] However, the association between the same with the direction of dislocation and the degree of soft tissue injury or intervention was not significant.

### 4.4. Complication: Sciatic nerve palsy

Stretch or compression of the nerve by the dislocated femoral head is found to be a common underlying mechanism behind sciatic nerve palsy. A study of 105 patients with femoral head

dislocations by Hillyard et al.[56] concluded a direct association between time to hip reduction and the degree of sciatic motor nerve injury. In our pooled study, sciatic nerve injury was found in 5 patients (2.08%) which when explored were found to be intact.[7,20,38,57,58]

### 4.5. Clinical outcomes

The clinical outcomes associated with hip dislocations are multifactorial. Time to hip reduction has been traditionally considered to be a risk to avascular necrosis and poor outcome. A study by Sahin et al. showed better results with reduction achieved in the first 12 h after the initial injury.[59] Studies by Letournel and Judet found no differences in the occurrence of avascular necrosis in patients whose reduction was performed in the first 6h, 7h–24h or 2–3 days.[60] Study by Bhandari et al. did not find any significant association between time to reduction and poor outcomes.[30] In the present pooled review, the association between poor or fair outcome and time to reduction was not statistically significant ($p = 0.3606$). This could be partly attributed to the extra-capsular nature of the fracture with relative preservation of retinacular blood supply and the younger age group of the patients (Table 11).

Statistically significant association was found between the compound nature (Grade 3b) of the injury and poorer outcomes Similar results were found in conventional cases of hip dislocations as reported by Grundy and Lamberti.[61,62]

Case details of pooled analysis is summarise in Table 13.

### 4.6. Strength and limitations of the study

A comprehensive search and analysis of the world literature with no limitation of language and year, is one of the strengths of this study. The incomplete documentation of information, preventing the achievement of definitive conclusions was one of the limitations of the study.

Sound evidence-based recommendation are difficult to be generated considering the paucity of the existing literature on this topic. However, the recommendations from this review can provide evidence-based guidance for managing this rare fracture pattern.

## 5. Conclusions

Association of hip dislocation with Extracapsular proximal femur fractures is extremely rare. Principles of damage control orthopaedics should be followed in such a scenario considering the co-relation between time to reduction and avascular necrosis. Compound injuries and involvement of neurovascular structures should be considered as emergency indications for immediate intervention. Gentle manipulation, in isolated trochanteric fractures and devices like Schanz screw in associated intertrochanteric fracture dislocations can be used to attempt closed reduction. There should be a low threshold for open reduction of such fractures as repeated attempts of closed reduction can be detrimental. Sciatic nerve palsy is usually transient in nature and almost always recovers. Considering the young age of the majority of patients, every attempt must be made to salvage a fractured hip, keeping equipment for arthroplasty standby in borderline and highly comminuted un-reconstructable cases.

## Author statement

Keyur Desai: Conceptualization, Methodology, Software, Data curation, Writing – original draft, Visualization, Writing – review & editing

## Declaration of competing interest

No conflict of interest to disclose.

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