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REVIEW ARTICLE

Simultaneous ipsilateral floating hip and knee: the double floating extremity—a systematic review and proposal of a treatment algorithm

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Abstract

Purpose To systematically review the currently available existing evidence related to the presentation and management of simultaneous floating hip and knee injuries to identify injury characteristics, treatment strategies, and complications.

Methods Data sources: Relevant articles were identified by searching Medline, PubMed, and Google Scholar databases with no language restrictions. Manual searches of other relevant databases (SciELO and grey literature databases) and reference lists of primary articles found from initial searches were also conducted.

Study selection: All types of study designs published from January 1st, 2000 to October 1st, 2022 involving skeletally mature patients with simultaneous floating hip and knee injuries were included. Data extraction: Basic information and specific injury-related information were collected.

Results Eight case reports were included. No study adequately reported the case with sufficient detail to allow other investigators to make inferences, nor was the result properly calculated, nor was the follow-up considered adequate for adequate functional assessment to occur in 80% of the studies.

Conclusion The exact treatment strategy and the follow-up time are not uniform across the included studies; therefore, they are not sufficient to adequately recommend surgical approach, timing of fixation, and fixation method. Our findings warrant the need for better documentation and reporting information about the mode of treatment of simultaneous floating hip and knee injuries.

Keywords Ipsilateral floating hip and floating knee · Floating hip · Floating knee · Polytrauma

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Introduction

Simultaneous ipsilateral floating hip and floating knee are extremely rare injuries [1]. A 'simultaneous ipsilateral floating hip and floating knee' is defined as a fracture of the pelvis or acetabulum with a concomitant femur and tibia fracture. These are often associated with high-energy trauma mechanism, and more commonly are observed in the younger population. Associated life-threatening injuries to other skeletal and non-skeletal systems are frequent, which pose great challenge even to experienced trauma surgeons [1].

Despite the complexity of this association, simultaneous ipsilateral floating hip and knee injuries do not have well-established treatment guidelines, making this situation even more difficult and stressful for the trauma team. Few case reports have been published in the literature to date, with no clear recommendation regarding mainly the timing and

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sequence of management for each existing skeletal injury. Furthermore, although there is sufficient literature for the treatment of isolated floating knee [2, 3] and floating hip [4, 5] injuries, there is a lack of information on the characteristics of each of these injuries when they occur in association, which can potentially be seen as a cause of increased morbidity and mortality.

Given the importance of this topic and a surprisingly small and highly heterogeneous literature, there is a need for filling this gap by providing a systematic review of existing studies and their perspectives on surgical treatment and complications of simultaneous ipsilateral floating hip and knee injuries. We hypothesized that by addressing these knowledge gaps, we could establish a rational management algorithm based on existing evidence on the management of this combined injury. Therefore, in the herein study, we systematically reviewed the literature documenting simultaneous floating hip and knee injuries to identify injury characteristics, treatment strategies, and complications.

Materials and methods

Study selection, data sources and searches

This study was designed and conducted according to the guide- lines proposed by the Cochrane Handbook for Systematic Reviews of Interventions (https://handbook-5-1.cochrane.org) and it was reported in compliance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement guidelines [6]. As this study is based on previously published studies, ethical evidence and patient consent were not provided.

The study focused on the period after 1999, as it was from this year on that the concept of damage control in Orthopaedics was established in the clinical setting of polytraumatized patients. Therefore, we included all types of study designs in which patients were assessed at a time point, published from January 1st, 2000, to October 1st, 2022, involving skeletally mature patients (> 18 years) with simultaneous floating hip and knee injuries. As the primary focus of this investigation was to identify injury characteristics, treatment strategies, and complications, we excluded studies missing this information, such as reviews, editorials, and letters. We also excluded studies in which patients were lost to follow-up.

Studies included in the review were identified by keyword searches of Medline, PubMed, and Google Scholar databases with no language restrictions. The Medical Subject Heading (MeSH) terms 'floating hip' OR 'floating knee' OR 'ipsilateral floating hip and floating knee', and the combined terms 'floating hip and floating knee AND simultaneous' and 'floating hip and floating knee AND polytrauma' were used. Manual searches of other relevant databases (SciELO and grey literature databases) and reference lists of primary articles found from initial searches were also conducted. Based on the titles and abstracts, the principal investigator (VG) selected the potential eligible studies. All studies were independently assessed by two of the investigators to check whether they met the inclusion criteria. Any disagreement was resolved by discussion involving the other authors for the final decision. Duplicate titles were removed.

Data extraction and quality assessment

After full-text articles were selected, data were independently extracted by two reviewers (KFM and ITC) and crosschecked by a third reviewer (VG). The appraisal tool described by Murad et al. [7], which is based on four domains (selection, verification, causality, and reporting), was adapted to assess the quality of case reports. Basic information was collected including journal, year of publication, author(s), country of the principal investigator, and patient demographics. Specific information was collected including floating hip classification, floating knee classification, individual fracture classification, associated injuries, treatment strategy (surgical approach, timing of fixation, and fixation method), complication rate, type of complication(s), outcome measurement(s), and follow-up. The floating hips were classified according to Liebergall classification [8], the floating knees were classified according to a modified Fraser's classification [9], and each individual fracture of the injury spectrum simultaneous floating hip and knee were classified according to the AO/OTA classification [10]. Open fractures were graded according to Gustilo classification [11]. All relevant information from each article was extracted and inserted in an Excel document.

Data synthesis and analysis

Data were summarized using descriptive statistics, with means and standard deviations for continuous variables and frequencies and percentages for dichotomous variables.

Results

Study characteristics and patient demographics

A total of 2440 references were identified; 1387 duplicates were removed, and 1041 articles were excluded based on title and abstract review. Of the remaining 12 abstracts, 1 article was excluded due to impossibility of having the full text [12]. The remaining 11 articles were reviewed in full; 2 articles were excluded because the patient was lost to follow-up [13, 14], and another article was excluded because

it presented the same case described by other authors previously [15]. Eight articles fit the inclusion criteria and were considered for review, all single case reports (level IV therapeutic evidence) comprising eight patients (seven (87.5%) male and one (12.5%) female) from six countries (India (three (37.5%) cases), Iran (one (12.5%) case), Morocco (one (12.5%) case), Serbia (one (12.5%) case), Turkey (one (12.5%) case), and UK (one (12.5%) case)) [16–23]. The mean (SD) age of patients across studies was 31.9 (SD 17.1) years. All studies were published in English. A PRISMA flow diagram of selected studies is presented in Fig. 1.

All patients sustained a road traffic accident. A total of four (50%) patients had a documented history of acute cardiorespiratory instability at hospital admission, three (37.5%) a history of haemodynamically instability and one (12.5%) an acute respiratory distress syndrome. All patients with a documented history of acute cardiorespiratory instability at hospital admission were male, with a mean (SD) age of 34.7 (SD 17.8) years. Emergency and critical care focuses on resuscitating these patients, including aggressive correction of hypovolemia [16, 19, 22], urgent external fixation of some existing fractures [18, 22], and admittance to the intensive care unit [18]. Comorbidities were reported in one (12.5%) patient, including uncontrolled diabetes and history of seizure disorder [16]. Initial sciatic nerve palsy was reported in 2 (25.0%) patients [16, 19], vascular impairment due to extrinsic occlusion of the popliteal artery was reported in one (12.5%) case [21], and a tibia open fracture was reported in one (12.5%) case [17], and a patella open fracture was reported in one (12.5%) case [19]. Both open fractures were graded as Gustilo grade II. Table 1 includes the basic information of all eight patients.

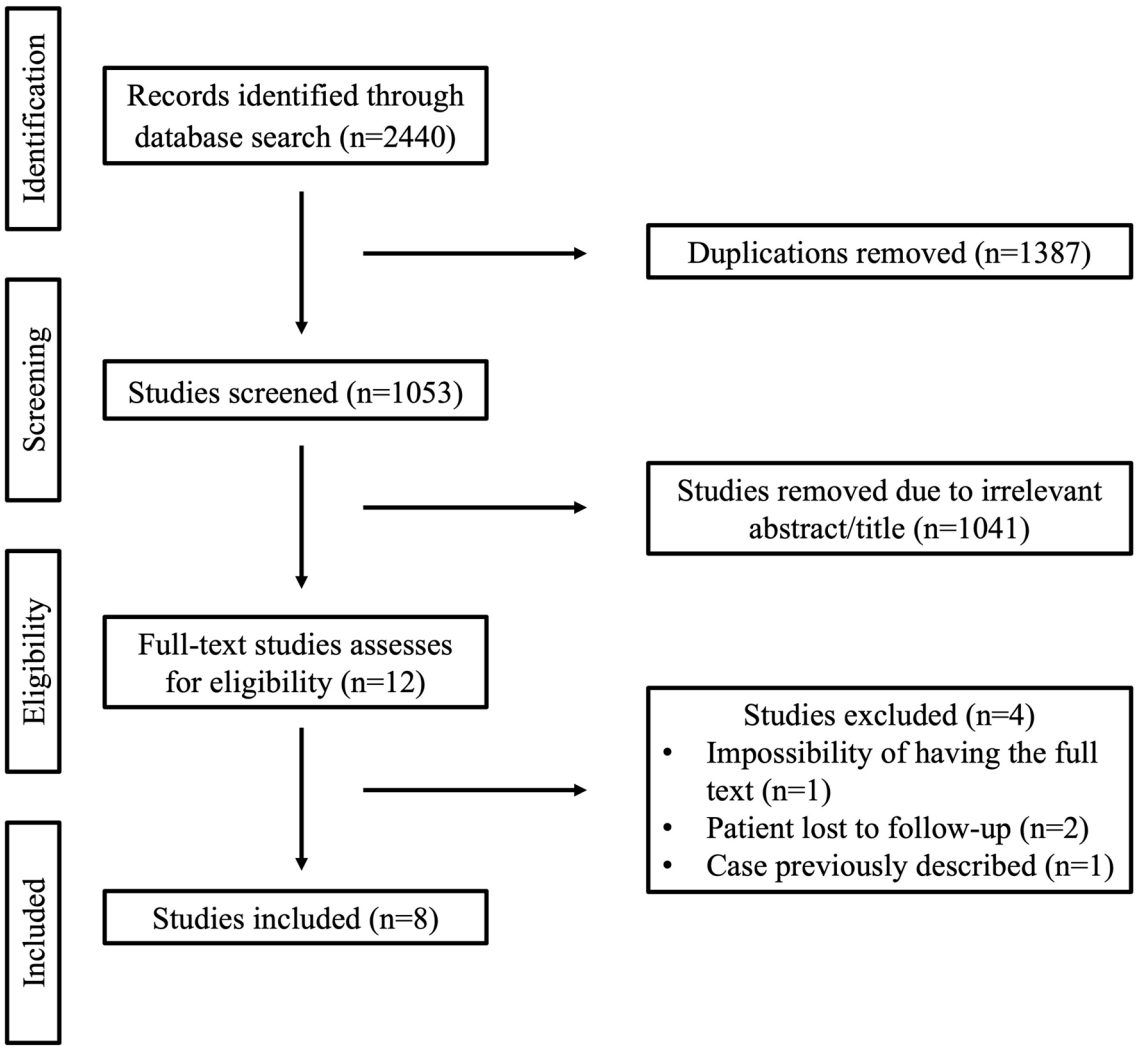

Fig. 1 PRISMA flow diagram

Table 1 Basic information of the eight patients included in the study

Author(s)/Country	Journal/Year of publication	Patient demographics	Injury characterization
Anand et al./India	Trauma Case Rep/2021 [16]	50-year-old male, road traffic accident 24 h before hospital admission, hypovolemic shock (initial haemoglobin 7 g%), gcs 13/15, is 34, left lower limb externally rotated, left foot drop/normal perfusion, uncontrolled diabetes/history of seizure disorder	Comminuted transverse-posterior wall acetabulum fracture Intertrochanteric femur fracture Femur shaft fracture Tibia and fibula shaft fracture
Benabbouha et al./Morocco	Case Rep Orthop/2020 [17]	56-year-old female, Hit by a car traveling about 60 miles per hour, Hemodynamically stable (BP 135/85 mmHg) and conscious, Right lower limb short and deformed in abduction and external rotation, Open wound in the anterior distal 1/3 of the right leg (7 cm with moderate soft tissue injury), Neurovascular intact	Hip dislocation with displaced posterior wall acetabular fracture plus an ipsilateral femoral head fracture Distal femoral shaft fracture Open fracture (Gustilo grade II) of the distal third of the tibia
Dubey et al./India	J Orthop Case Rep/2020 [18]	17-year-old male, road traffic accident, neurovascular intact, acute respiratory distress syndrome (transferred to intensive care unit)	Transverse midshaft femur fracture Distal third tibia fracture Transverse acetabulum fracture Disruption of sacroiliac joint plus contralateral superior and inferior pubic rami fracture
Milenkovic & Mitkovic/Serbia	Case Rep Orthop Res/2021 [19]	55-year-old male, high-velocity road traffic accident, initial management in a general hospital 200 km away / transferred after a few hours, hemodynamically unstable (bp 90/60 mmhg, pulse 125/min, erythrocytes 2.74, haemoglobin, 78, haematocrit 0.24, spo2 94%, and serum lactate 2.5 mmol/l), sciatic nerve palsy / normal perfusion	Hip dislocation with posterior wall acetabulum fracture Femoral neck fracture Femoral shaft fracture Open fracture (Gustilo grade II) of the patella Tibia shaft fracture
Ng et al./UK	Int J Clin Pract/2007 [20]	23-year-old male, road traffic accident (car frontal crash, not wearing a seatbelt), hemodynamically stable (bp 173/115 mmhg, pulse 113), gcs 15/15, grossly swollen and deformed in external rotation left thigh, grossly swollen left ankle, tenderness over the left iliac crest,	Lateral compression pelvic injury Subcapital femur neck fracture Fracture of the proximal third of the femoral shaft Pilon fracture with associated lateral malleolus fracture
Okcu & Yercan/Turkey	Joint Dis Rel Surg/2007 [21]	17-year-old male, Motorcycle struck a car while riding at a speed of 50 mph, Hospital admission after eight hours from the injury (initially managed at a district hospital), Hemodynamically stable, Left lower extremity deformed, Abrasion on the anterior–superior aspect of the left leg, Left foot was cooler compared with the contralateral side (absent dorsalis artery and posterior tibial artery pulse)	Undisplaced fracture of the posterior column of the acetabulum Displaced midshaft fracture of the femur Displaced epiphyseal injury of the proximal tibia Comminuted, displaced shaft fracture of the tibia
Siavashi et al./Iran	J Orthop Spine Trauma/2020 [22]	17-year-old male, motor vehicle accident, hypotensive shock requiring cardiovascular resuscitation, gross deformities in the lower limb (both leg and thigh), with skin abrasions over the thigh and leg, neurovascular intact	Anteroposterior compression pelvic injury T-Type fracture-dislocation of the acetabulum Transverse fracture of the femur Segmental fractures of the left tibia and fibula
Kumar C et al./India	J Orthop Case Rep/2013 [23]	20-year-old male, motorcycle struck a car, pain and deformity in right lower limb/not able to walk, abnormal mobility and crepitus in thigh and leg, haemodynamically stable, neurovascular intact, no head injury	Undisplaced posterior column acetabular fracture Displaced femoral shaft fracture Displaced tibia shaft fracture

Source: SOT-HMMC, 2022

GCS Glasgow Coma Score, *ISS* Injury Severity Score, *BP* blood pressure, *SpO2* oxygen saturation

Injury characteristics and treatment strategies

There were seven acetabular fractures (one transverse plus posterior wall fracture [16], two posterior wall fractures with hip dislocation [17, 19], one pure transverse fracture [18], one T-type fracture [22], and two undisplaced posterior column fractures [21, 23], and three pelvic injuries, two of them associated with an acetabular fracture (one lateral compression injury [18] and one anteroposterior compression injury [22]) and one isolated lateral compression injury [20]. Seven (87.5%) of the eight cases had a femur shaft fracture [16, 19–23], three of them with an associated proximal femur fracture (one intertrochanteric fracture [16] and two neck fractures [19, 20], and one (12.5%) sustained an extraarticular distal femur fracture [17]. Five (62.5%) of the eight cases had a tibia shaft fracture [16, 19, 21–23] and three (37.5%) cases had a distal tibia fracture, two extraarticular [16, 18] and one tibial pilon fracture [20]. One patient had an ipsilateral femoral head fracture [17], one patient had an open comminuted patella fracture [19] and one patient had an epiphyseal proximal tibia fracture [21].

According to the Liebergall classification [8], there were six (75.0%) type A [16, 17, 19, 21–23], one type B [20], and one type C [18] floating hip injuries. According to the modified Fraser classification [9], there were five (62.5%) type I [16–18, 22, 23], two (25.0%) type IIA [20, 21], and one (12.5%) type IIIB [19]. Associated injuries were reported in five (62.5%) of the eight cases. There was no traumatic brain injury with GCS < 8, major thoracic injury (airway obstruction, tension pneumothorax, cardiac tamponade, open pneumothorax, massive haemothorax, and flail chest), or life-threatening blunt or penetrating abdominal trauma. One (12.5%) patient had an extradural haemorrhage and facial fractures [16], two patients had a small pneumothorax [17, 20], two (25.0%) patients had a traumatic sciatic nerve palsy [16, 19], and two (25.0%) patients had other fractures (a fracture of transverse process of L5 vertebra [18] and a fracture of left fifth rib [20]). Three (37.5%) patients had no associated injuries [21–23].

All studies mentioned the treatment strategy they have used. Six (75.0%) of these studies described the surgical approach used for the fixation of at least one of the injuries [16–19, 21, 22], and all studies described the sequence of fixation. The most common reported surgical approaches were the Kocher-Langenbeck approach [16, 17, 19, 22] and the lateral window of the ilioinguinal approach [18, 22], all used for the management of both pelvic and acetabular fractures. Regarding the sequence of fixation, the tibia fracture was fixed first in five (62.5%) cases [17–19, 21, 23], the femur fracture in two (25.0%) cases [16, 20], and the pelvic fracture in one (12.5%) case [22]. Urgent fixation of the tibia fracture was done in three (37.5%) patients, two with an external fixator [17, 18] and one with a plate [21]; the femur fracture was urgently fixed in two (25.0%) cases, one with an external fixator [18] and one with an antegrade cephalomedullary nail [20]; and the pelvic and acetabular injuries were fixed urgently in one case [22].

Intramedullary (IM) nailing of the femur fracture was done in seven (87.5%) patients [16–18, 20–23] and one (12.5%) patient was treated by open reduction and internal fixation (ORIF) of femoral neck and femoral shaft fractures with a self-dynamizing internal fixator [19]. In all patients treated with an IM nail, the anterograde technique was used, however, there is no description regarding reaming of the medullary canal, type of implant, and number of locking bolts. In six (75.0%) studies the type of reduction was mentioned. ORIF was performed in three (37.5%) patients, two managed with an IM nail [17, 20] and one with a plate [19], and closed reduction and internal fixation (CRIF) in three (37.5%) patients, all managed with an IM nail [21–23]. Only one study mentioned the method used for fracture reduction [23]. The quality of fracture reduction was not reported in any study.

IM nailing of the tibia fracture was done in four (50.0%) patients [16, 18, 22, 23], a plate in one (12.5%) patient [21], and an external fixator in three (37.5%) patients [17, 19, 20]. Neither the tibial entry portal used for the IM nail, nor the knee position were reported in any study. Also, there is no description regarding reaming of the medullary canal, type of implant, and number of locking bolts. ORIF was performed in a 17-year-old male patient presenting with absent dorsalis artery and posterior tibial artery pulse at hospital admission due to direct pressure of a posteriorly displaced proximal tibial metaphyseal fracture [21]. ORIF of the tibia shaft fracture with a ten-hole broad dynamic compression plate with two lag screws was done before the urgent surgical exploration of the popliteal artery to facilitate manipulation of the epiphyseal fragment. During surgery, it was noted that the artery was occluded by direct pressure of the posteriorly displaced proximal tibial metaphysis, with no external visible laceration on this vessel. ORIF of the epiphyseal injury of the proximal tibia with K-wires inserted percutaneously from medial and lateral sides, crossing the physis proximal to distal, was performed during the same procedure. Definitive external fixation with standard half-pin fixator was done in two patients [17, 19] and circular external fixator was used in one patient with a tibial pilon fracture [20]. The quality of fracture reduction was not reported in any of the studies.

Urgent closed reduction of the hip dislocation was performed when present [17, 19]. Anterior plating fixation of the sacroiliac (SI) joint with two 3.5-mm reconstruction plates through the lateral window of ilioinguinal approach was done in two (25.0%) patients [18, 22]. Dubey et al. [18] used the same approach along with an anterior superior iliac spine osteotomy for the fixation of the associated anterior column acetabular fracture with a 7.0-mm cannulated

screw. In the same SI joint fixation procedure, Siavashi et al. [22] performed the fixation of the anterior component of the T-type acetabulum fracture using the modified Stoppa approach with a 3.5 mm reconstruction plate, and then fixation of the posterior column of the acetabulum using the Kocher–Langenbeck approach with another 3.5 mm reconstruction plate. Milenkovic and Mitkovic [19] used the Kocher–Langenbeck approach to fix the posterior wall acetabulum fracture with 3.5-mm reconstruction plate. The quality of fracture reduction was not reported in any study. Four (50.0%) patients were managed non-operatively, three sustaining an acetabular fracture [16, 21, 23] and one a pelvic injury [20].

Hospital discharge was mentioned in five (62.5%) studies [16, 17, 19–21], ranging from 7 days to 6 weeks. Details of injury characteristics and treatment strategy are available in Table 2.

Complications and outcome measures

Complications were seen in five (62.5%) patients [16–19, 23], most related to limited range of motion (ROM) of the hip [16] and knee [17, 23]. Heterotopic ossification of the hip occurred in one patient [19] (Brooker grade II [24]), with no limitation in the hip ROM. This patient initially presented complete sciatic nerve paralysis and after 14 months had partial recovery from the neurological injury [19]. One patient had delayed healing of the femur fracture, requiring autogenous bone graft (iliac crest) due to a cortical defect on the medial side, ultimately presenting fracture healing by 5 months [23].

Final follow-up ranged from 6 months to 2 years, with a mean (SD) of 13.7 (6.5) months. Follow-up evaluation was carried out using the Harris Hip Score [16] in one study and a patient-reported outcome measure (PROM) in one study, although the PROM scoring system used was not informed [19]. The other six studies were limited to describing when the fracture healed, the patient's clinical condition, and whether he or she had any residual deformity or dysfunction. Table 3 provides an overview of the type of complication(s), outcome measures, and follow-up.

Quality assessment

Using the appraisal tool described by Murad et al. [7], no study adequately reported the case with sufficient details to allow other investigators to make inferences related to the treatment strategy, especially regarding timing of fixation, surgical approach, and fixation method. In addition, neither the outcome was properly ascertained, nor the follow-up was deemed adequate for outcomes to occur (> 2 years) in six studies.

Discussion

Simultaneous ipsilateral floating hip and knee is a complex and potentially life-threatening injury associated to high-energy trauma, rarely described in the literature. To the best of our knowledge, 11 case reports were published so far, of which only 8 were included in the current study [16–23]. There was a preponderance of male patients ($n = 7$), and the mean age of our sample was 31.9 years, which is similar to that observed in the high-energy trauma victim population [25, 26]. All patients sustained a road traffic accident, and the most common association was an ipsilateral acetabular fracture and extraarticular midshaft femur and tibia fractures. Open fractures were seen in two patients, both classified as Gustilo grade II. Four patients had a documented history of acute cardiorespiratory instability at hospital admission, requiring aggressive correction of hypovolemia and intensive care unit. Again, this is in line with what is seen in the polytraumatized patient [25–27]. As pelvic fractures and femoral shaft fractures are recognized as potentially life-threatening injuries due to significant blood loss, every effort should be made to stop uncontrolled bleeding from these sites [27].

Due to the low prevalence of simultaneous ipsilateral floating hip and knee and the lack of sufficient detail to allow other investigators to make inferences related to the treatment strategy, there is no uniform guideline for the management of the existing injuries, especially regarding timing of fixation, surgical approach, and fixation method. In addition, case reports are known to be a source of bias and are limited by their retrospective, non-blinded, non-randomized study design, which may affect the outcome of the study [28]. Consequently, studies describing the management of both isolated floating hip and floating knee injuries can be a good option for the decision making, and surgeons should be aware of the previously published literature, especially the controversies regarding timing of definitive fracture fixation for skeletal injuries in multiple trauma patients [27, 29].

Floating hip is an uncommon traumatic condition, with a high rate of morbidity and mortality. The acetabular involvement worsens the patient's prognosis, and complications are relatively frequent [4, 5, 8, 30, 31]. Current evidence does not support a sequence of fixation and mostly the general health status of the patient is decisive for choosing amongst treatment options [31]. Müller et al. [30] proposed that definitive treatment should follow the specific recommendations for each of the existing injuries, primarily advocating stabilization of the pelvic ring and then, as early as possible, fixation of the femoral fracture. On the other hand, Liebergall et al. [5, 8] argued that the femur fracture should be stabilized first, as its continuity is

Table 2 Injury characteristics and treatment strategy

Principal investigator (PI)	Floating hip classification	Floating knee classification	Individual fracture classification	Associated injuries	Treatment strategy (surgical approach, timing of fixation, and fixation method)
Vijay Anand	Type A	Type I	Acetabulum: 62B1.2b; Femur: 31A3.1 + 32B2b; Tibia: 42A3b	Extradural haemorrhage Fracture of the nasal bones Right periorbital wall and glass piece foreign bodies in the periorbital wall Traumatic sciatic nerve injury (peroneal division)	Definitive procedure 48 h from the injury (long proximal femoral nailing through posterior approach to the hip / IM tibial nailing—no description if infra or suprapatellar approach)—operating time 180 min Non-operative treatment of the acetabulum Discharged on 10th postoperative day
Abdellatif Benabbouha	Type A	Type I	Acetabulum: 62A1.1; Femur: 32B2c; Tibia: 43A1.3	Small pneumothorax	Urgent closed reduction of the hip dislocation and I&D and stabilization of the open tibia fracture with external fixator Definitive procedure 48 h from the injury (ORIF with antegrade IM femur nail and cerclage wiring / posterior wall acetabulum fracture stabilized with two screws through a Kocher-Langenbeck approach)/ tibia fracture continued with external fixator Discharged after 2 weeks postoperative
Siddharth Dubey	Type C	Type I	Pelvis: 61B2.1c; Acetabulum: 62B1.2; Femur: 32A3b; Tibia: 42A3c	Fracture of transverse process of L5 vertebra	Urgent external fixation of the tibia and femur fractures Definitive procedure 3 weeks from the injury (IM nailing of tibia and femur fractures) and 5 days later (ORIF of pelvis and acetabulum—SI joint with anterior orthogonal 3.5-mm recon plating plus 7.0-mm cannulated screw for the anterior column acetabular fracture through the lateral window of ilioinguinal approach along with ASIS osteotomy)
Sasa S. Milenkovic	Type A	Type IIIB	Acetabulum: 62A1.1; Femur: 31B2.3r / 32A3b; Patella 34C1.1; Tibia: 42A1a	Traumatic sciatic nerve injury (peroneal division)	Definitive procedure 72 h from the injury (unilateral external fixation of the tibia fracture/posterior wall acetabulum fracture stabilized with 3.5-mm recon plate through a posterior approach/partial patellectomy and reinsertion of the patellar ligament to the patella) and 3 days later (ORIF of the femoral neck and femoral shaft fractures with a self-dynamizable internal fixator) Discharged 18 days after admission

Table 2 (continued)

Principal investigator (PI)	Floating hip classification	Floating knee classification	Individual fracture classification	Associated injuries	Treatment strategy (surgical approach, timing of fixation, and fixation method)
A. B. Y. Ng	Type B	Type IIA	Pelvis: 61A2.2; Femur: 31B2.3q / 32A1b; Tibia: 43C1.1q	Fracture of left fifth rib with a small pneumothorax	Urgent ORIF with a long proximal femoral nail for both the proximal and shaft femur fracture with two proximal locking screws Definitive procedure 7 days from the injury (ORIF for the fibula fracture with a five-hole one-third tubular plate along with Ilizarov external frame to the tibial pilon fracture) Pelvic injury managed non-operatively Discharged 6 weeks after admission
Güvenir Okcu	Type A	Type IIA	Acetabulum: 62A2.1; Femur: 32A3b; Tibia: 41t-E/2.1 / 42B3b	None	Urgent surgical exploration (9 h after injury) of the popliteal artery (noted no external visible laceration on the vessel—artery was occluded by direct pressure of the posteriorly displaced proximal tibial metaphysis), ORIF of the tibia shaft fracture with a 10-hole broad dynamic compression plate with 2 lag screws, ORIF of the epiphyseal injury of the proximal tibia with 4 K-wires, inserted percutaneously from medial and lateral sides, crossing the physis proximal to distal, and CRIF of the femoral midshaft fracture with an antegrade, unreamed solid IM nail Acetabular fracture managed non-operatively Discharged 7 days after admission
Babak Siavashi	Type A	Type I	Pelvis: 61B2.3e; Acetabulum: 62B2.2; Femur: 32A3b; Tibia: 42C2j	None	Urgent ORIF of pelvis and acetabulum (SI joint with anterior orthogonal 3.5-mm recon plating through the lateral window of ilioinguinal approach plus 3.5-mm recon plating for the anterior column of the acetabulum through the modified Stoppa approach and 3.5-mm recon plating for the posterior column of the acetabulum through a Kocher-Langenbeck approach), and CRIF of the femur fracture with an antegrade IM nail inserted from the piriformis fossa CRIF of the segmental tibia fracture with an IM nail after 2 days—no description if infra or suprapatellar approach

Table 2 (continued)

Principal investigator (PI)	Floating hip classification	Floating knee classification	Individual fracture classification	Associated injuries	Treatment strategy (surgical approach, timing of fixation, and fixation method)
Yashavantha Kumar C	Type A	Type I	Acetabulum: 62A2.1;Femur: 32A3b; Tibia: 42A3b	None	Definitive procedure 1 day from the injury (CRIF of the tibia with IM nailing—no description if infra or suprapatellar approach—and CRIF using a traction table of the femur fracture with an antegrade IM nail) Acetabular fracture managed non-operatively

Source: SOT-HMMC, 2022

IM intramedullary, *I&D* irrigation and debridement, *SI* sacroiliac, *ORIF* open reduction and internal fixation, *ASIS* anterior superior iliac spine, *recon* reconstruction, *K-wires* Kirschner wires, *CRIF* closed reduction and internal fixation

necessary to put traction during the reduction of an unstable pelvic injury or the identification and removal of intra-articular fragments of the acetabulum. Pavelka et al. [31] observed that primary external fixation of the femur fracture with subsequent conversion to internal osteosynthesis, following the concept of damage control surgery, has no effect on the functional results of femoral or pelvic fracture treatment. However, these authors observed that late definitive fixation of the acetabular fracture makes reduction difficult and results in a worse functional outcome.

Like the floating hip, floating knee injuries are rare and closely related to high-energy trauma mechanisms. Patients with a floating knee are usually victims of multiple traumas and should initially be treated as polytrauma patients [2, 3, 32, 33]. Associated ligamentous and meniscal lesions are common [32], as well as visceral involvement and open fractures [33]. Due to the severity of the injury and the associated lesions, a staged treatment using external fixation has been recommended, although stable patients may undergo immediate reduction and internal fixation [32, 33]. In extraarticular fracture patterns (Fraser type I), the femur should be stabilized first [34]. A single-incision technique for retrograde femoral nail and infrapatellar tibial nail has been shown to reduce the operative time and intraoperative bleeding [35]. There is no clear evidence to support the fixation sequence in the presence of intra-articular extension, although it seems more reasonable to reduce and fix the articular component first, followed by the extraarticular fracture (Fraser type II), or to start with the less complex articular pattern in Fraser type III fractures [34]. ORIF and plate fixation is recommended in the fixation of articular fractures. Muñoz Vives et al. [32] noted that intra-articular involvement complicates treatment and worsens the prognosis for this type of injury.

In the herein study, the tibia fracture was fixed first in five cases, the femur fracture in two cases, and the pelvic fracture in one case. Three patients sustaining an acetabular fracture and one patient sustaining a pelvic injury were managed non-operatively. Although all studies described the sequence of fracture fixation, there was no clear explanation why and how the order of priority was defined. There were six type A, one type B, and one type C floating hip injuries, and five type I, two type IIA, and one type IIIB floating knee injuries. IM nailing was used in seven patients with femur fracture and four patients with tibia fracture. ORIF with a plate was done for a patient with an associated ipsilateral femoral neck and shaft fracture, and for a skeletally immature patient with an associated ipsilateral proximal epiphyseal and tibia shaft fracture. Three patients were managed with definitive external fixation for the tibia fracture, including one patient with a closed pilon fracture treated with a circular frame. Although the management of patients sustaining multiple lower extremity diaphyseal fractures is

Table 3 Complications and outcome measures

Principal investigator (PI)	Type of complication(s)	Outcome measurement(s)	Follow-up
Vijay Anand	Terminal limitation of internal rotation of the left hip	Fractures united by 6 months; Foot drop recovery without residual deficit by 9 months; Harris Hip Score 76.85	2 years
Abdellatif Benabbouha	Limited flexion of the knee at 110 degrees	Acetabular and femur fractures united by 7 months; Tibia fracture united by 10 months	1 year
Siddharth Dubey	Weakness in ankle dorsiflexion, which completely recovered by 3 months	Radiographic bone healing of all fractures at 6 months; patient resumed his normal routine after 1 year	1 year
Sasa S. Milenkovic	Heterotopic ossification (Brooker grade II) in the left hip Partial recovery of the sciatic nerve (peroneal division)	Independently walk without crutches; Hip flexion 100°, abduction 40°, and adduction 15°; Knee flexion 100°; PROM score 14/20; No signs of osteonecrosis or post-traumatic hip osteoarthritis	14 months
A. B. Y. Ng	None	Fully weightbearing and radiological union at 6-month follow-up	6 months
Güvenir Okcu	None	Back to school and to normal activities with no gait abnormality at 5 months; Stable hip and knee joints, with normal range of motion; No leg length discrepancy, rotational and angular malunion; No pain on walking or running	2 years
Babak Siavashi	None	All fractures healed at 6 months; Full range of motion of hip, knee, and ankle joints	6 months
Yashavantha Kumar C	Delayed union of the femur fracture, requiring autogenous bone grafting (iliac crest) due to cortical defect on medial side Restriction of terminal 20 degree of knee flexion	All the fractures united by 5 months; Returned to daily activities; Walking full weight bearing without aid; Good range of motion of hip joint; Able to squat and sit cross-legged; No leg length discrepancy, rotational and angular malunion	1 year

Source: SOT-HMMC, 2022

determined by several factors, including severity and location of extremity injury, the physiological reserve of each patient, and surgeon's preference, training, and resources, Devendra et al. recommend fixing the fractures around the hip and femur first, followed by other lower extremity fractures [25]. Only one patient had the pelvic and acetabulum injuries treated primarily on an urgent basis. ORIF of the SI joint with anterior orthogonal double plating through the lateral window of ilioinguinal approach plus plating fixation of a T-type acetabular fracture through a dual approach was performed in 17-year-old male with hypotensive shock at hospital admission. Based on the available evidence on polytrauma [27, 29, 36, 37], we developed a rational algorithm for the treatment of simultaneous ipsilateral floating hip and

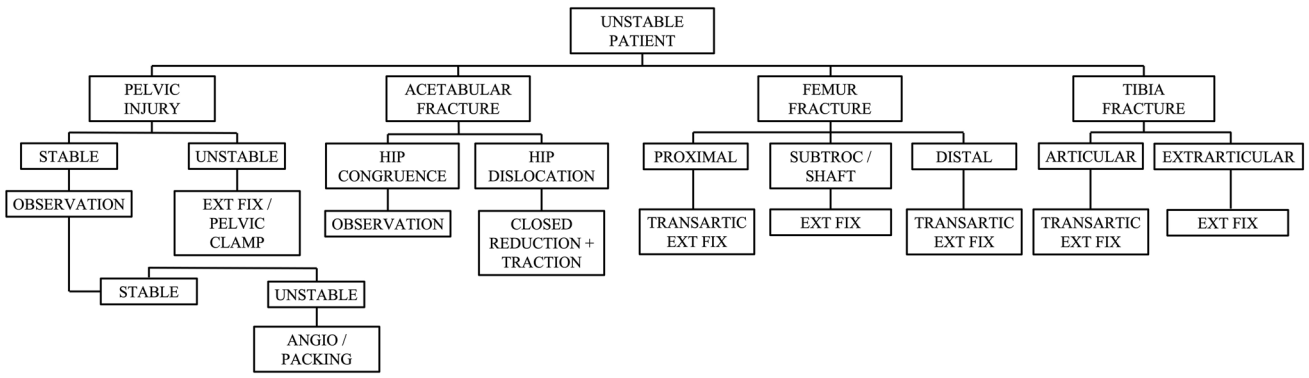

Fig. 2 Proposed algorithm for the treatment of simultaneous ipsilateral floating hip and knee injuries in the unstable patient. [Abbreviations: *Ext Fix* external fixator, *Angio* angiography, *I&D* irrigation and debridement]

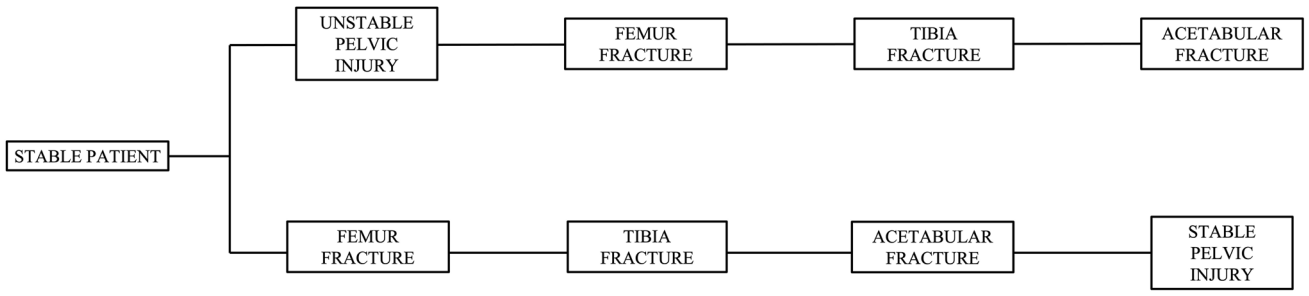

Fig. 3 Proposed algorithm for the treatment of simultaneous ipsilateral floating hip and knee injuries in the stable patient

knee injuries in both the unstable (Fig. 2) and stable (Fig. 3) patient. The proposed algorithm theoretically reduces the risk of unfavourable outcomes in unstable patients presenting life-threatening injuries and potentially reduces the problem of uncertainty in definitive treatment decision making.

Only one study reported on a consistent and reproducible outcome score (Harris Hip Score) [16]. In this study, all fractures united by 6 months and the initial sciatic nerve palsy completely recovered without residual deficit by 9 months. The Harris Hip Score was 76.85 after a 2-year follow-up. Another study used one PROM scoring system, however authors did not inform which patient-reported outcome measure was used [19]. Interestingly that apparently excellent and good functional outcomes were reported in the other cases, even though no objective and/or subjective outcome scoring system was applied [17, 18, 20–23]. The mean final follow-up was 13.7 months, and only two studies had at least 2 years of follow-up [16, 21]. It is possible that either deterioration or improvement of the outcomes can occur with longer follow-up [38, 39], therefore, the outcome reported for all studies with less than 2 years of follow-up may not be sufficient to recommend a treatment strategy. Finally, regarding rehabilitation and postoperative pain management, no study had information about the protocol used. It has been demonstrated that polytrauma patients suffer from different types of pains depending on the nature of the traumatic injury they sustain [40]. In this scenario, the immediate postoperative adoption of a physical therapy protocol and pain management seems to be an integral part following operatively treated pelvic and lower extremity associated fractures.

The main strength of this study is the use of a systematic approach in cases of simultaneous ipsilateral floating hip and knee injuries. In addition, we applied a comprehensive search and a reproducible standardized assessment of the quality of all articles, even knowing that case reports are inherently biased. Using this protocol, we were able to report injury characteristics, treatment strategies, and complications across studies the included studies. Definitive treatment should be planned for the stable patient and programmed staged fixation must be done to avoid patient overload (Fig. 3).

Our study has some limitations, including the relatively low level of evidence of the articles included, all retrospective therapeutic level IV, with a consequent small sample size. This is justified by the rarity of the association of the simultaneous ipsilateral floating hip and knee. Rare diseases and ultra-rare diseases have been defined by a prevalence of ≤ 50 patients and ≤ 1 patient per 100,000 people, respectively [28]. Another limitation is that all included studies lacked relevant clinical or methodological details or were of low quality, thus it was not possible to establish a cause–effect relationship between the severity of the injury and the treatment strategy or between the treatment strategy and the outcome. Nevertheless, surgeons should be aware of the potential life-threatening conditions of this association, suggesting that these patients may be initially managed as polytrauma patients. Given the uncertainty of the adequate fixation strategy, we propose that treatment should be individualized, with staged surgical management of major fractures being preferred, especially in borderline and hemodynamically unstable cases or patients with low physiological reserve, in patients with multiple lower extremity diaphyseal fractures and periarticular fractures. [25, 36]. Clinical evaluation should begin at the prehospital phase and follow through the emergency room to properly assess the severity of the existing injuries. It is important to identify patients at special risk to develop acute complications, especially injuries to the chest, abdomen, and for major fractures [25, 26, 28, 36, 37]. Once again, we reinforce the need to create a definitive treatment plan for these patients as a strategy to reduce potential complications related to the severity of the lesions observed in simultaneous ipsilateral floating hip and knee.

Conclusion

Simultaneous ipsilateral floating hip and knee, the double floating extremity, are extremely rare injuries, often associated with high-energy trauma mechanism. There is a preponderance of young adult male patients. The most common association is an ipsilateral acetabular fracture and extraarticular midshaft femur and tibia fractures. The exact treatment strategy and the follow-up time are not uniform across the included studies; therefore, they are not sufficient to adequately recommend surgical approach, timing of fixation, and fixation method. Our findings warrant the need for better documentation of future cases with more detailed information about the mode of treatment, using appropriate outcome scoring systems, and with a minimum follow-up time of 2 years. We propose a treatment algorithm for the stable and unstable patient sustaining a double floating extremity, characterized by simultaneous ipsilateral floating hip and knee.

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Data availability Not applicable.

Declarations

Conflict of interest The authors declare that there are no conflicts of interest.

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