

General

A review of Risk Factors for Post-traumatic hip and knee osteoarthritis following musculoskeletal injuries other than anterior cruciate ligament rupture.

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Post-traumatic osteoarthritis (PTOA) is a common form of osteoarthritis that might occur after any joint trauma. Most PTOA publications mainly focus on anterior cruciate ligament (ACL) injuries. However, many other traumatic injuries are associated with PTOA, not only for the knee but also for the hip joint. We aim to identify and summarize the existing literature on the musculoskeletal injuries associated with knee and hip PTOA and their risk factors in determining those with a worse prognosis, excluding ACL injuries. Despite the narrative nature of this review, a systematic search for published studies in the last twenty years regarding the most relevant injuries associated with a higher risk of PTOA and associated risk factors for OA was conducted. This review identified the six more relevant injuries associated with knee or hip PTOA. We describe the incidence, risk factors for the injury and risk factors for PTOA of each. Meniscal injury, proximal tibial fracture, patellar dislocation, acetabular, femoral fractures and hip dislocations are all discussed in this review.

INTRODUCTION

Osteoarthritis (OA) is a highly prevalent musculoskeletal disorder with increasing yearly cases. Compared to 2007, OA showed a significant 31.4% increase worldwide.¹ OA is the third-largest contributor to the years lived with disability among the musculoskeletal disorders after back and neck pain, accounting for around 7.1% of this burden.² 10-12% of all osteoarthritis cases are post-traumatic (PTOA).³ OA's first symptoms can appear ten years after injury in patients with PTOA. Patients with PTOA are generally younger than those with idiopathic OA.⁴⁻⁷

Different knee injuries are considered significant risk factors for PTOA.⁷⁻⁹ A meta-analysis, including 20,997 individuals, concluded that a history of knee trauma, mainly Anterior Cruciate Ligament (ACL) rupture, meniscus rupture, and tibial fractures, can increase the chances of having OA more than five times.¹⁰ Similarly, a recent report from a longitudinal cohort in Sweden found that after 19 years of follow up, there was a six-fold increase in the risk of knee OA in subjects that sustained a knee injury com-

pared with those without injury. They and other authors found a higher risk for those with a combined ACL injury and meniscal tears than ACL or meniscal tears alone. Fracture of the upper end of the tibia/patella was the third most crucial mechanism.^{11,12}

Subjects with some occupations, like athletes or military work, are at increased risk of a knee injury and subsequent PTOA. The prevalence of knee osteoarthritis in former athletes was 30% in a meta-analysis including 3100 ex-athletes.¹³ In addition, knee and hip arthroplasties due to OA are greater among former elite male athletes than among age-matched non-athletes controls.^{13,14} Evidence suggests that subjects develop OA faster after a knee injury, which is about 4.2 times more likely compared to those without a history of knee trauma.¹⁵ Most patients with acute ACL tears are younger than 30 when it occurs. The reported incidence of posttraumatic osteoarthritis (PTOA) following ACL injury is 87%, which is very high compared with 19.2% in all adults older than 45 years.¹⁶ However, this number will depend on whether the menisci were excised (87%) or preserved (26%).¹⁷ Other less common injuries might cause OA and more severe functional consequences for the af-

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affected patients. However, the literature is sparse, and there is less research on PTOA due to other traumas than ACL and meniscal lesions. Most research in patients with PTOA has focused on a few types of knee injuries, and limited epidemiologic data is available regarding post-traumatic hip OA. Musculoskeletal injury is considered a predictor of hip OA, with a fivefold increase in risk compared to those without injury.¹⁸ Approximately 2% of all hip OA cases are post-traumatic, but no reliable estimates exist.¹⁹ Despite its importance, there is insufficient literature analysing the injuries causing PTOA of the hip and their associated risk factors.

This work aims to review the existing literature on musculoskeletal injuries associated with post-traumatic hip and knee osteoarthritis and their associated risk factors to determine those with a worse prognosis.

METHODS

A search of studies published regarding the most relevant injuries and risk factors associated with PTOA was conducted using PubMed, Medline, Embase, Cochrane Library, Google Scholar, and by hand-searching through reviews that were considered a searching method for other relevant articles. This narrative review was performed following a systematic search for articles according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guideline for identifying, screening and including articles. Three reviewers (M.C.B., C.L.M. and C.R.M.) searched using the words: “posttraumatic” (or post-traumatic) AND arthritis OR osteoarthritis, AND hip or knee in the Title/Abstract. We selected human studies published in English in the last 20 years (Till January 2022), with full text available, and only adults. Case reports, letters, clinical trials, and editorials were excluded. [Figure 1](#) presents the literature search strategy and exclusion criteria from the articles retrieved in the initial search. We identified and screened 1113 titles and abstracts for post-traumatic knee (834 articles) and post-traumatic hip OA (279).

After removing duplicate records (n=150) and articles concerning ACL injuries (480 articles), four hundred eighty-three abstracts were screened (n=483). Hundred fifty reports were not relevant to the research questions and were excluded. Three observers analysed the remaining 333 remaining articles. We excluded publications that referred to only osteoarthritis without PTOA cases or other factors that would affect the risk of OA after injury ([Figure 1](#)). Our inclusion criteria were: a clear definition of OA, clear identification of posttraumatic osteoarthritis cases and the specific type of injury, including more than 35 patients in clinical studies, and retrospective or prospective studies with a follow up of more than one year. At that stage, 236 articles were excluded. Reference lists of all included studies (n=97) were manually screened for additional articles that met inclusion criteria, adding twenty five more articles. One hundred twenty two articles were included in the review. The three reviewers evaluated each article according to the scientific content, and to classify them were divided into major topics according to the traumatic injuries concerning

PTOA. Meniscal tears, proximal tibial fractures and patellar dislocation for knee PTOA. Acetabular fractures, femoral fractures and hip dislocations were the principal injuries for hip PTOA.

RESULTS

MENISCAL TEARS

Meniscal tears in the presence of ACL injury are as high as 79%, even higher for those with more than eight weeks of trauma.²⁰ Acute injuries occur more frequently in active young patients and chronic degenerative injuries in older patients, where incidental findings of meniscal tears or destruction are common in patients with or without knee pain and OA.^{21,22} Meniscal tears are more prevalent in men than women, with an annual incidence between 0.3 to 0.7 per 1000 inhabitants.^{23–26} A medial or lateral meniscal tear is a common finding in asymptomatic subjects but is more common in patients with symptomatic osteoarthritis.^{21,27} Meniscal damage (grade ≥ 1) and meniscal extrusion are more frequent in knee-OA cases than in controls (54% versus 18%; and 52% versus 29%).²¹ The severity of meniscal damage defines the risk of OA. For a minor meniscal tear versus no meniscal damage, the odds ratio (OR) was 3.0 (95% CI: 1.4–6.4); for more severe meniscal damage versus no damage, the adjusted OR was 7.9 (95% CI 4.4–14).²¹ After 19 years of follow up of meniscal tears, the corresponding risk difference was 10.5% (95% CI 6.4% to 14.7%) compared with uninjured subjects.¹¹

The higher risk for OA is principally seen in patients after meniscectomy, with rates between 24% after four years and 71% after 20 years being higher for total than for partial meniscus repair.^{22,26,28–31} So far, arthroscopic surgery did not demonstrate to be more effective than conservative management in preventing PTOA.^{30,32,33} Female sex, obesity, and age 40 or more are risk factors for PTOA after meniscal injury and repair.^{26,34–36} There are some similarities with the OA risk factors for ACL injuries, perhaps because meniscal tears are commonly associated with ACL ruptures.

PROXIMAL TIBIAL FRACTURES

The tibial plateau fractures (TPFs), also called proximal tibial fractures (PTF), represent 1% of all fractures in all age categories, and 8% of all fractures in individuals over 65.^{37–39} These fractures have an incidence of 0.1–0.13 per 1000 inhabitants and are more common in males than females, principally due to high energy trauma and in women after 70 years secondary to falls.³⁸ For displaced PTFs leading to joint instability, operative treatment is preferred. Open reduction and internal fixation (ORIF) is used to regain normal tibial anatomy, principally for displaced intra-articular tibial plateau fractures.⁴⁰ Although this procedure might restore normal knee function, PTOA is a common complication following PTFs that may lead to total knee replacement as a secondary treatment (TKR).^{39,41,42} Tibial plateau ORIF was associated with an approximately fivefold increased risk of TKA in a cohort of 8,426 patients receiving

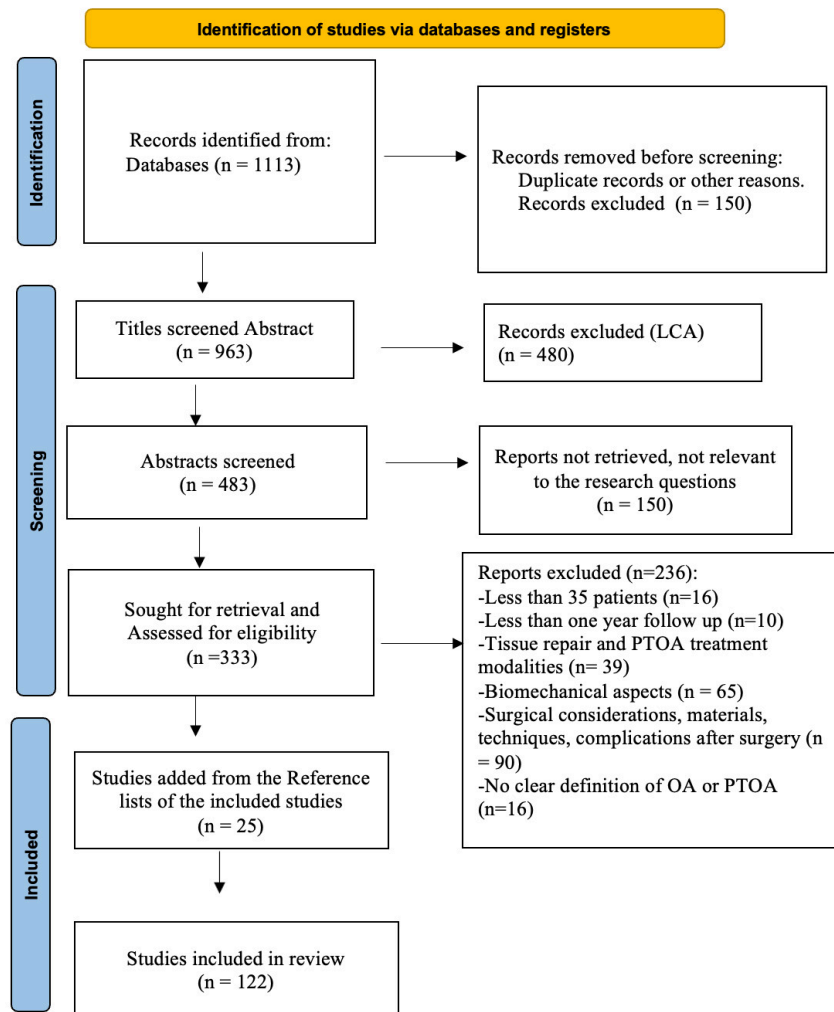


Figure 1. Prisma Flow diagram for the systematic review.

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ* 2021;372:n71. doi: 10.1136/bmj.n71

ORIF for tibial plateau fractures.⁴² A study with 7,701 patients with PTF determined the risk of TKR following proximal tibia fracture (PTF) over five years (SD±3) follow up.⁴³ TKR was performed in 340 (4.3%) patients with a prior PTF after a mean of 2.1 (SD 2.0) years post-fracture, 60% in the operatively treated group versus 40% in the nonoperatively treated group.⁴³ Similarly, in another study with 288 cases of TPF, 4.5% of patients underwent one of the reconstructive procedures for end-stage OA just after two years of the fracture.⁴⁴ The authors concluded that operative treatment, female sex, and high age were risk factors for TKR after PTF.⁴³ In an older study, female sex and obesity were risk factors for conversion to TKR.⁴⁵ PTOA is generally estimated to occur in approximately 23% to 36% of cases following intra-articular fracture (IAF).^{39,41,46–49} However, radiological signs of osteoarthritis have generally been reported in 10% to 83% of studied cases with tibial plateau fractures.^{37,39,49–52} In a prospective matched case-control study with 48,791 patients with knee fractures, patients with knee fractures had a 3.7 times greater risk of TKR in the first three years after knee fracture, and the risk

remained higher throughout their life when compared with the population in the controls group, without fractures.⁵³

In most of those studies, the incidence of OA is predicted by the severity of the lesion, usually determined by Schatzker's grading system classification for TPFs.^{47,54–56} It means that those patients with more severe fractures, comminuted fractures (Schatzker types V and VI) or complete articular fractures and fractures with articular depression > 2mm will have the worst prognosis regarding OA.^{51,54} The included studies showed that this type of trauma has a higher incidence in males and females older than 50.^{38,54,57–59} In addition, it seems that unicondylar fractures have better functional results after treatment than bicondylar fractures in younger patients.³⁹ Older age might have a worse functional outcome in treated fractures.^{60,61} The probability of early OA increases with older age at the time of injury, fracture comminution, and comorbidity.^{42,61,62} As for other knee injuries, a high BMI negatively affects functional outcomes and scores after surgical treatment of TPFs.^{54,63}

On top of the severity of the fracture, including concomitant fractures, knee malalignment, including a deviation of the mechanical axis in varus, step-off and meniscus lesion, might increase the risk of having osteoarthritis at follow up.^{39,54–56,59,64} Treatment options include open reduction and internal fixation with or without arthroscopy. Closed reduction with percutaneous fixation is considered if the meniscus is intact at arthroscopy.⁴⁷ Open anatomic reduction with internal fixation is the treatment of choice for articular fractures. However, non-operative management or primary arthroplasty are considered.^{41,64,65} Outcomes after internal fixation of intra-articular fractures of the distal femur are good, with a low rate of subsequent TKA.^{45,65–67} However, despite a good to excellent functional outcome in patients younger than forty years, it has been reported that between 23% to 50% of patients might present moderate to severe signs of OA after one year to 14 years of surgery.^{46,47,68}

Regarding surgery, preserving stability and alignment are very important for preventing PTOA of the knee.^{39,40,62} The association between joint stability and the development of PTOA has been well established.⁶⁹

Comparing the conversion rate to TKA between tibial plateau fractures and distal femur fractures, the conversion rate for tibial plateau fractures is higher at 4.5% compared to 2.3% for distal femur fractures.⁷⁰

PATELLAR DISLOCATION

Acute patellar dislocation represents 2% to 3% of knee lesions and is the second most common cause of traumatic hemarthrosis of the knee.⁷¹ In the long term, acute patellar dislocations can result in patellar instability with recurrence rates of 15% to 44% after non-operative treatment, pain, inability to return to sports as high as 55% of cases, and patellofemoral OA.⁷² Subjects with patellofemoral instability are more likely to be female, older, and genetically more prone to dislocation.⁷³ Patellar dislocation occurs more frequently in active young individuals practising sports, and females have a 33% higher risk of patellar instability and dislocation than males. Generally, rates for patellar dislocation are between 0.058 and 0.070 per 1000 person-years in the general population.⁷³ This rate has been higher in the aged 10–17 years: 0.29 per 1,000 patient-years, and military personnel: 0.69 per 1000 person-years than in the general population.^{74,75} Cartilage lesions are common after patellar dislocation and appear to increase with the frequency of dislocation.^{76,77} The risk of OA increases with the number of years after dislocation as well. Studies with only two or five years of follow up showed no significant increase in OA compared with patients with other patellofemoral problems.^{73,77} After thirteen years, OA risk is around 22%, and it achieves 50% after 25 years of follow up, depending on whether patients had a recurrent dislocation and the type of treatment received.⁷⁸ Chronic dislocation, osteochondral injury, trochlear dysplasia, female sex and older age are risk factors for PTOA in these patients.^{76,78,79}

Non-operative treatment is recommended for patients with traumatic, first-time patellar dislocation.^{71,80} How-

ever, in some cases, conservative treatment can lead to recurrent instability. No evidence exists that stabilising patellar surgery by different procedures would decrease the long-term risk of OA.^{79,81–83} On the contrary, some studies have also shown increased osteoarthritic changes following different operative interventions.^{81,84} Cartilage lesions were found on magnetic resonance (MR) images from 78% of patients who underwent patellofemoral stabilizing surgery after 12 years.⁸¹ In another study, 28% of patients presented full-thickness patellofemoral articular cartilage lesions after a median of seven years follow up. However, the lesions were considered unrelated to the treatment form. The patients were randomly allocated to be treated with initial surgical stabilization or managed with an orthosis without significant differences at the end of the follow up between these groups.⁸¹ Finally, it is essential to consider that no trials examined people with recurrent patellar dislocation comparing surgical and non-surgical interventions and long-term outcomes, including OA.⁸³

ACETABULAR FRACTURES

The incidence of acetabular fractures is relatively low but has increased in Europe in recent decades. Acetabular fracture represents between 2% to 8% of all fractures, and it has been estimated in around 3–4/100,000 persons/year in the UK and 8.1/100,000 persons/year in Europe.^{85,86} The most common mechanism for acetabular fractures is high energy trauma and accidents in the young population and low energy trauma such as falling in the elderly. This fracture occurs principally in males and subjects with osteoporosis.^{85,87,88} Open reduction and internal fixation are suitable for most patients with incongruity or instability of the hip; however, some fractures will require total hip replacement due to OA, principally when residual articular incongruity.^{89–92} Management of acetabular fractures is complex, especially when it is complicated by central hip dislocation.⁹³ Arthroplasty might be required in between 10% till 30% of cases if the reduction does not reach the required quality.^{88,89,92–96} Posttraumatic osteoarthritis might occur just six months after the fracture in subjects older than 60. Males are also more affected, as in other cases of PTOA. PTOA might occur after five years of follow up in between 13% to 57% of all cases, including subjects treated with open reduction and internal fixation, principally when the reduction is not satisfactory (>2mm).^{85,88,89,97–102} Open reduction and internal fixation of displaced acetabular fractures have successfully prevented the need for subsequent total hip arthroplasty (THA) within twenty years in approximately 79% of the patients.^{95,98,103–105} The quality of fracture reduction seems to be the most important factor that decreases the risk of hip-PTOA.^{89,99,106} Displacement greater than 2 mm increases the rate of PTOA development after this type of fracture.^{101,107} The type of fracture influences the quality of the reduction. Both column fractures and type A1 are more common in males, the most difficult, with more significant degenerative changes than other types.^{103,108}

Displacement, intraarticular fractures with fragments, type of fracture (comminuted posterior wall fracture the

worst case), and an associated injury (for example, sciatic nerve injury) are associated with a worse long-term functional outcome after acetabular fractures. Further, acetabular fractures with these characteristics present higher complication rates and conversion to late THA.^{90,93,99,109–111} In general, the management options include non-operative measures, open reduction and internal fixation (ORIF), THA, or ORIF with concomitant THA (ORIF-THA). ORIF is considered the standard care for young patients, less effective in older subjects with osteopenia or osteoporosis.¹¹² End-stage OA is the most common complication after ORIF, achieving 36% of the cases, with failure to maintain reduction as one of the contributing factors.¹¹³

Male sex, age older than 40 years, obesity, associated chondral or osseous lesions of the femoral head, involvement of the posterior wall and incongruence of the acetabular roof are risk factors for PTOA.^{89,96,104,105,114,115} Posterior wall fracture is more common than anterior, and patients with this type of fracture have shown higher rates of PTOA when compared with other types of fracture.^{99,116} In a study with patients older than 60 years, the rate of conversion to THA was 23.6% at 10.5-month postinjury.¹¹² A recent study found that the probability of THA after acetabular fracture increases by 6% per year. It is 21% higher for every mm more in subluxation and approximately 3.5 and 3.7 odds higher when there is the involvement of the posterior wall, contusion and impaction of the femoral head.⁹⁷ Finally, some authors found no difference in osteoarthritis rates between patients with and without dislocation associated with acetabular fractures.^{90,109,110,116}

FEMORAL FRACTURES

Femoral fractures characterized by femoral shaft malunion and malalignment might increase the risk of hip OA and, in less degree, knee OA. Only 8% and 5% of patients with femoral fractures, presented ipsilateral or contralateral radiographic evidence of knee OA after 22 years. However, there were clinical signs and symptoms of OA in 16 patients (26%) who exhibited mild pain or stiffness in the ipsilateral knee.¹¹⁷

Hip fractures are generally less associated with PTOA than acetabular fractures; however, they have a higher incidence. That is the case of the femoral neck and intertrochanteric fractures. Proximal femur fractures are prevalent in the elderly with high morbidity and mortality. They are treated with surgery, usually using intramedullary nails or an extramedullary sliding hip screw.¹¹⁸ Other cases are handled with hemiarthroplasty or total hip arthroplasty (THA), depending on the patient's condition and the decision of the surgeon.¹¹⁹ In young patients, a hemiarthroplasty is linked to high rates of acetabular erosion and the need for conversion to THA due to secondary osteoarthritis.¹¹⁹ The age-adjusted incidence of femoral neck fractures in the United States is 63.3 per 100,000 person-years for women and 27.7 cases per 100,000 person-years for men.¹²⁰ Besides, the incidence of trochanteric fractures is about 180–190/100,000 in men and 410–440/100,000 in women. A higher incidence of these fractures has been reported in the military, representing 3.5%–8% of stress fractures in

military recruits.¹²¹ THA is a treatment used not only for acute femoral neck fractures but also for failed osteosynthesis of femoral neck fractures. THA is recommended in the first intention when an acetabular fracture involves the femoral neck in elderly patients. Around 11% of all performed THA are sequelae or failed internal fixation after proximal femur fracture.^{122,123} Few studies compare the risk of OA after different types of proximal femur fracture, partly due to the high number of cases that undergo THA.

However, it seems there is a tendency for a higher incidence of OA in patients with trochanteric fractures than in patients with cervical fractures.¹²² A retrospective study followed 417 patients for around 3.4 years (68% women, median age: 78 years) with a minimally displaced femoral neck fracture treated with internal fixation, and found that 0.5% of cases developed PTOA. A study comparing 349 patients with proximal femoral fractures and 112 patients with hip contusion found that the rate of hip OA between patients with these types of fractures and hip contusion were similar, 16% and 18%, respectively.¹²² Femoral neck fractures are slightly more common than intertrochanteric fractures, and there is little evidence regarding which one has a higher risk of OA.^{122,124,125} In a study analysing 102 patients after a minimum 2-year follow up, failed internal fixation for hip fracture (38% intertrochanteric- and 72% femoral neck fractures), 32 cases had THA due to PTOA. 25% had a prior femoral neck fracture, and 20% had an intertrochanteric fracture.¹²⁴ There is no much literature regarding the risk of OA in patients after these fractures because most of them are treated with THA or by hemiarthroplasty.¹²⁶ In young and middle-aged patients, internal fixation is the preferred treatment option for both injuries to preserve the native hip joint.

HIP DISLOCATION

Traumatic hip dislocations might be divided into simple or complex when they present with associated fractures. Acetabular fractures are present in up to 70% of patients with traumatic hip dislocations, which might worsen the prognosis.^{116,127,128} It is essential to consider that posterior hip dislocations are nine times more common than anterior hip dislocations. In most patients, emergent closed or open reduction is initially performed for this type of trauma within 6 hours of dislocation. Hip dislocations are prevalent in younger males between 14 or 16 years to 40, happening in subjects till 72 years.^{116,129–131} PTOA is the most common long-term sequelae of a simple hip dislocation.^{116,127,132} Posttraumatic osteoarthritis might usually appear two years after the initial injury, being more common after ten years, where it might be present in up to 24% of cases.^{116,130,131,133} Some authors recommend a closed dislocation reduction in less than six hours of the injury, considering this a risk factor for bad outcomes, including OA.¹³¹ Others recommend arthroscopic repair or debridement of labral tears to reduce the risk of posttraumatic osteoarthritis; however, most authors agree that delayed reduction increases the risk of OA.^{116,131,134,135}

The principal factor associated with the incidence of PTOA in subjects with traumatic hip dislocation is the

severity of the injury. Severe injuries are associated with femoral or acetabular fractures and cartilage or osseous fragments, which may inhibit congruent reduction.^{116,123,136} In a study including 69 patients with “hip joint associated injuries”, assessed at a mean follow-up of 36.9 months after surgery, 12 patients (17%) developed OA, two of them before the first year after surgery. The principal factor common for these patients was dislocation, a high-energy trauma, principally among males with car and motorcycle accidents.¹³⁷

There are reports of PTOA after anterior dislocation. Rates from 0.12 for dislocation with or without minor fracture to 0.83 for those associated with a femoral head fracture.^{136,138} Femoral head fracture is associated mainly with posterior hip dislocation. This type of injury is far less common than isolated dislocations or dislocations combined with acetabular fractures representing only 6 to 15% of all types of dislocations however, they are relevant regarding PTOA.^{123,127,139} PTOA has been reported in between 16-30% of patients with posterior dislocation, rising to more than 50% when associated with femoral head fractures; although the association is rare, it is an incident of 4 to 17% of cases.^{116,139-142}

DETERMINING THE RISK OF PTOA

According to this review, the likelihood of having OA after injury will depend principally on the type and severity of the trauma, strongly influencing the disease risk estimates.^{5,7,47,50,51,136,138} Fractures are the most common traumatic mechanism related to PTOA, and this is a predominant injury in males, one of the reasons for having a higher number of males than females with PTOA.^{15,39,143} Among the studied injuries, meniscal tears have a higher incidence, principally in young population^{19,35}; They also might appear on routinely MRIs of elderly individuals as chronic degenerative injuries.^{15,26,35} However, in the long term, radiological signs of OA have been reported in up to 83% of cases after proximal tibial fractures and up to 71% of cases of meniscal damage. Patients with a more extensive or complicated fracture will have a worse prognosis, and the probability of developing OA increases with the patient's age at the time of the injury.^{4,51,87,107} Acute patellar dislocation is a the less common knee injury and principally occurs in females. The female population has a higher risk of instability and dislocation than men.⁷¹⁻⁷³ Chronicity, advanced age and heavyweight are the main risk factors for patients with patellar dislocation.^{75,77} Femoral fractures are the most common in the elderly; however, few studies compare the risk of OA after different types of proximal femur fracture because most of these fractures undergo surgical treatment. They are associated with OA to a lesser degree, principally in malunion or failed internal fixation cases. Hip fractures were the most common past injury reported from patients in studies involving PTOA of the hip, and acetabular fractures the most relevant regarding hip OA. Acetabular fractures have a low prevalence (1% of all fractures). However, posttraumatic osteoarthritis after these fractures occurs in between 40 to 50% of the cases, mostly in males.^{88,89,98} Hip dislocation is another trauma

highly associated with PTOA, reported in between 16-30% of cases being higher risk when associated with a femoral head or acetabular fracture.^{108,109,116,127,128}

For most traumatic injuries, operative treatment becomes a risk factor for future PTOA. Meniscectomy is a known factor in increasing the risk of OA, being more common in male patients than in women.^{5,23-26,28} Operative treatment of tibial plateau fractures is considered a risk factor for PTOA. Tibial plateau ORIF is associated with an approximately fivefold increased risk of TKR.⁴² In the case of first-time patellar dislocation, conservative treatment is indicated. No evidence that stabilising patellar surgery through different procedures would decrease the long-term risk of OA. In addition, in the case of hip dislocation, authors recommend early reduction, considering that the time between injury and surgery is an essential factor in OA's trauma recovery and development.^{89,116,134,135} Other risk factors concerning the operative treatment increase the risk of OA. The most mentioned are residual articular incongruity, instability, reduction quality and delayed treatment.

The time course in which clinically measurable PTOA develops is highly variable, ranging from as few as two years in articular fractures to decades for less severe joint injuries. The presence of additional patient risk factors, such as advanced age, obesity, joint malalignment or genetic risk factors, leads to a more severe outcome. In addition, it is essential to mention that some patients already had osteoarthritis at the moment of trauma, and the new injury can accelerate the progression of OA. [Table 1](#) summarises the principal findings regarding each type of injury.

AUTHORS' CONTRIBUTIONS

Conception and design: MCB. Identification, screening and inclusion of articles: MCB, CLM and CRM. drafting of the article: all authors, Critical revision of the article for important intellectual content: CRM and MCB), final approval of the article (all authors).Obtaining funding: MCB.

DISCLOSURES ABOUT POTENTIAL CONFLICT OF INTERESTS

The authors have no conflicts of interest to declare.

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Table 1. Traumatic injuries and post-traumatic (PTOA) hip and knee osteoarthritis risk factors.

Injury type	Incidence/Prevalence	Risk factors for this injury	Risk factors for OA	Risk of OA compared to uninjured subjects.
Meniscal injury	Incidence of 0.3-0.7/1000 inhabitants.	- Male gender - Sports	- Severity of the meniscal damage. - Meniscectomy - Female sex and age > 40 years - Obesity	- Increased risk from OR=3 mild to OR 7.9 (4.4-14) for severe meniscal damage. - After 19 years risk of OA increased by 11%, 24% after four years and 71% after 20 years.
Proximal Tibial Fractures (PTF)	Incidence of 0.1-0.13 per 1000 inhabitants	- Males younger than 50 years. - Accidents and high-energy traumas. - More severe fractures in patients older than 50 years.	- Operative treatment: - High age principally in treated fractures. - In younger patients: bicondylar fractures. - Osteoporosis and other comorbidities including a high BMI. - Malalignment of the knee, deviation of the mechanical axis in varus, articular step-off and meniscus lesion - The severity of the lesion: Fracture comminution and articular collapse. - Female sex. - It is higher during the first years than at long term.	- PTOA is generally estimated to occur in 23% to 36% of cases following an intra-articular fracture. - Between 21-75% of cases after operative treatment develop PTOA even when adequate reduction and stable fixation have been achieved. - Severe OA leading to TKR develops in 2.2-7.5% of operatively treated patients after 2 to 5 years post-trauma. Compared with all populations, these patients are at a 3.5 - to 5.3-fold higher risk of end-stage PTOA requiring TKR. - Radiological signs of OA were reported in 10% to 83% of studied cases.
Patellar dislocation	Between 0.058-0.070 per 1000 person-years.	- Active young individuals practicing sports. - Decreased depth, a flat or even convex trochlear surface. - Females have a 33% higher risk of patellar instability and dislocation than males. - Military personal.	- Patellofemoral instability due to recurrent dislocation. - Increases over time. - osteochondral injury and trochlear dysplasia. - Female sex and older age.	The risk of OA increases with the number of years after dislocation, from non-significant increase till 22% at t13 years, and it achieves 50% after 25 years of follow-up.
Acetabular fractures	Around 8.1/100,000 persons/year in Europe	High energy trauma and accidents in the young population and low energy trauma such as falling in the elderly.	- Residual articular incongruity, quality of fracture reduction. - Column fractures, posterior wall and type A1 fracture. - Male sex.	- OA appeared after five years of follow-up in between 13% to 57% of all cases. - OA was present in approximately 36% of cases after open reduction and internal fixation.

Injury type	Incidence/ Prevalence	Risk factors for this injury	Risk factors for OA	Risk of OA compared to uninjured subjects.
			- Age older than 40 years. - Obesity - Associated chondral or osseous lesions of the femoral head. - Involvement of the posterior wall and incongruence of the acetabular roof.	
Femoral Fractures	Femoral neck: 63.3 cases per 100,000 person-years for women and 27.7 cases per 100,000 person-years for men (90 percent of proximal femur fractures) Intertrochanteric: 34 men and 63 women/ 100,000 person years. They represents 38%-50% of all hip fractures, respectively.	- Patients with a higher falling risk. - Higher incidence of stress fractures in military. - Female sex - older age - osteopenia or osteoporosis.	- OA risk seems higher in trochanteric fractures than in patients with cervical fractures. - Femoral shaft malunions increase the risk of OA symptoms, pain and stiffness after long-term follow up (>20years). - In young patients, use of a hemiarthroplasty after femoral fractures has been linked to OA at follow up.	- PTOA in 0.5% of cases with minimally displaced femoral neck fracture treated with internal fixation. - After femoral shaft fractures and malunion, 8% of cases had radiographic evidence of OA. - PTOA in 31% of cases after a failed internal fixation for hip fracture with a minimum 2-year follow-up. - Around 11% of all performed THA are sequelae or failed internal fixation after proximal femur fracture.
Hip dislocations	- Most are posterior dislocations (90%). - Classified as simple or complex (when associated with fractures). - Acetabular fracture is present in up to 70% of patients with traumatic hip dislocations.	More prevalent in males between 14 or 16 years to 40.	- Delayed closed dislocation reduction (>six hours of the injury). - The severity of the injury correlates with an increase in the development of PTOA. - Associated with femoral head fracture increase the risk of OA.	- PTOA is the most common sequelae. - Might appear just two years after the initial injury, being more common after ten years. - It might be present in up to 24% of cases. - PTOA in between 16-30% of patients with posterior dislocation and 50% when associated with femoral head fracture.

REFERENCES

1. Kloppenburg M, Berenbaum F. Osteoarthritis year in review 2019: epidemiology and therapy. *Osteoarthritis Cartilage*. 2020;28(3):242-248. doi:10.1016/j.joca.2020.01.002
2. IHME) IFHMAE. Global, regional, and national incidence, prevalence, and years lived with disability for 354 diseases and injuries for 195 countries and territories, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet*. 2018;392(10159):1789-1858. doi:10.1016/s0140-6736(18)32279-7
3. Brown TD, Johnston RC, Saltzman CL, Marsh JL, Buckwalter JA. Posttraumatic osteoarthritis: a first estimate of incidence, prevalence, and burden of disease. *J Orthop Trauma*. 2006;20(10):739-744. doi:10.1097/01.bot.0000246468.80635.ef
4. Gelber AC, Hochberg MC, Mead LA, Wang NY, Wigley FM, Klag MJ. Joint injury in young adults and risk for subsequent knee and hip osteoarthritis. *Ann Intern Med*. 2000;133(5):321-328. doi:10.7326/0003-4819-133-5-200009050-00007
5. Muthuri SG, McWilliams DF, Doherty M, Zhang W. History of knee injuries and knee osteoarthritis: a meta-analysis of observational studies. *Osteoarthritis Cartilage*. 2011;19(11):1286-1293. doi:10.1016/j.joca.2011.07.015
6. Kramer WC, Hendricks KJ, Wang J. Pathogenetic mechanisms of posttraumatic osteoarthritis: opportunities for early intervention. *Int J Clin Exp Med*. 2011;4(4):285-298.
7. Showery JE, Kusnezov NA, Dunn JC, Bader JO, Belmont PJ Jr, Waterman BR. The Rising Incidence of Degenerative and Posttraumatic Osteoarthritis of the Knee in the United States Military. *J Arthroplasty*. 2016;31(10):2108-2114. doi:10.1016/j.arth.2016.03.026
8. Rivera JC, Wenke JC, Buckwalter JA, Ficke JR, Johnson AE. Posttraumatic osteoarthritis caused by battlefield injuries: the primary source of disability in warriors. *J Am Acad Orthop Surg*. 2012;20(Suppl 1):S64-S69. doi:10.5435/jaaos-20-08-s64
9. Buckwalter JA, Brown TD. Joint injury, repair, and remodeling: roles in post-traumatic osteoarthritis. *Clin Orthop Relat Res*. 2004;(423):7-16.
10. WHO. Waist circumference and waist-hip ratio: Report of a WHO expert consultation. Published 2011. <https://www.who.int/publications/i/item/9789241501491>
11. Snoeker B, Turkiewicz A, Magnusson K, et al. Risk of knee osteoarthritis after different types of knee injuries in young adults: a population-based cohort study. *Br J Sports Med*. 2020;54(12):725-730. doi:10.1136/bjsports-2019-100959
12. Øiestad BE, Holm I, Aune AK, et al. Knee function and prevalence of knee osteoarthritis after anterior cruciate ligament reconstruction: a prospective study with 10 to 15 years of follow-up. *Am J Sports Med*. 2010;38(11):2201-2210. doi:10.1177/0363546510373876
13. Madaleno FO, Santos BA, Araújo VL, Oliveira VC, Resende RA. Prevalence of knee osteoarthritis in former athletes: a systematic review with meta-analysis. *Braz J Phys Ther*. 2018;22(6):437-451. doi:10.1016/j.bjpt.2018.03.012
14. Hart L. Prevalence of osteoarthritis and arthroplasty in the hip and knee of former elite athletes. *Clin J Sport Med*. 2012;22(6):524-526. doi:10.1097/jsm.0b013e318275d58c
15. Øiestad BE, Engebretsen L, Storheim K, Risberg MA. Knee osteoarthritis after anterior cruciate ligament injury: a systematic review. *Am J Sports Med*. 2009;37(7):1434-1443.
16. Lawrence RC, Felson DT, Helmick CG, et al. Estimates of the prevalence of arthritis and other rheumatic conditions in the United States: Part II. *Arthritis Rheum*. 2008;58(1):26-35. doi:10.1002/art.23176
17. Nakata K, Shino K, Horibe S, et al. Arthroscopic anterior cruciate ligament reconstruction using fresh-frozen bone plug-free allogeneic tendons: 10-year follow-up. *Arthroscopy*. 2008;24(3):285-291. doi:10.1016/j.arthro.2007.09.007
18. Juhakoski R, Heliovaara M, Impivaara O, et al. Risk factors for the development of hip osteoarthritis: a population-based prospective study. *Rheumatology*. 2009;48(1):83-87. doi:10.1093/rheumatology/ken427
19. Johnson VL, Roe JP, Salmon LJ, Pinczewski LA, Hunter DJ. Does Age Influence the Risk of Incident Knee Osteoarthritis After a Traumatic Anterior Cruciate Ligament Injury? *Am J Sports Med*. 2016;44(9):2399-2405. doi:10.1177/0363546516648318
20. Hagino T, Ochiai S, Senga S, et al. Meniscal tears associated with anterior cruciate ligament injury. *Arch Orthop Trauma Surg*. 2015;135(12):1701-1706. doi:10.1007/s00402-015-2309-4

21. Englund M, Guermazi A, Gale D, et al. Incidental meniscal findings on knee MRI in middle-aged and elderly persons. *N Engl J Med*. 2008;359(11):1108-1115. doi:10.1056/nejmoa0800777
22. Özdemir M, Kavak R. Meniscal Lesions in Geriatric Population: Prevalence and Association with Knee Osteoarthritis. *Curr Aging Sci*. 2019;12(1):67-73. doi:10.2174/1874609812666190628112103
23. O'Connor DP, Laughlin MS, Woods GW. Factors related to additional knee injuries after anterior cruciate ligament injury. *Arthroscopy*. 2005;21(4):431-438. doi:10.1016/j.arthro.2004.12.004
24. Slauterbeck JR, Kousa P, Clifton BC, et al. Geographic mapping of meniscus and cartilage lesions associated with anterior cruciate ligament injuries. *J Bone Joint Surg Am*. 2009;91(9):2094-2103. doi:10.2106/jbjs.h.00888
25. Sri-Ram K, Salmon LJ, Pinczewski LA, Roe JP. The incidence of secondary pathology after anterior cruciate ligament rupture in 5086 patients requiring ligament reconstruction. *Bone Joint J*. 2013;95-B(1):59-64. doi:10.1302/0301-620x.95b1.29636
26. Claes S, Hermie L, Verdonk R, Bellemans J, Verdonk P. Is osteoarthritis an inevitable consequence of anterior cruciate ligament reconstruction? A meta-analysis. *Knee Surg Sports Traumatol Arthrosc*. 2013;21(9):1967-1976. doi:10.1007/s00167-012-2251-8
27. Bhattacharyya T, Gale D, Dewire P, et al. The clinical importance of meniscal tears demonstrated by magnetic resonance imaging in osteoarthritis of the knee. *J Bone Joint Surg Am*. 2003;85(1):4-9. doi:10.2106/00004623-200301000-00002
28. von Porat A, Roos EM, Roos H. High prevalence of osteoarthritis 14 years after an anterior cruciate ligament tear in male soccer players: a study of radiographic and patient relevant outcomes. *Ann Rheum Dis*. 2004;63(3):269-273. doi:10.1136/ard.2003.008136
29. Englund M, Roos EM, Lohmander LS. Impact of type of meniscal tear on radiographic and symptomatic knee osteoarthritis: a sixteen-year followup of meniscectomy with matched controls. *Arthritis Rheum*. 2003;48(8):2178-2187. doi:10.1002/art.11088
30. Moseley JB, O'Malley K, Petersen NJ, et al. A controlled trial of arthroscopic surgery for osteoarthritis of the knee. *N Engl J Med*. 2002;347(2):81-88. doi:10.1056/nejmoa013259
31. Englund M, Lohmander LS. Risk factors for symptomatic knee osteoarthritis fifteen to twenty-two years after meniscectomy. *Arthritis Rheum*. 2004;50(9):2811-2819. doi:10.1002/art.20489
32. Kirkley A, Birmingham TB, Litchfield RB, et al. A randomized trial of arthroscopic surgery for osteoarthritis of the knee. *N Engl J Med*. 2008;359(11):1097-1107. doi:10.1056/nejmoa0708333
33. Katz JN, Shrestha S, Losina E, et al. Five-Year Outcome of Operative and Nonoperative Management of Meniscal Tear in Persons Older Than Forty-Five Years. *Arthritis Rheumatol*. 2020;72(2):273-281. doi:10.1002/art.41082
34. Persson F, Turkiewicz A, Bergkvist D, Neuman P, Englund M. The risk of symptomatic knee osteoarthritis after arthroscopic meniscus repair vs partial meniscectomy vs the general population. *Osteoarthritis Cartilage*. 2018;26(2):195-201. doi:10.1016/j.joca.2017.08.020
35. Bodkin SG, Werner BC, Slater LV, Hart JM. Post-traumatic osteoarthritis diagnosed within 5 years following ACL reconstruction. *Knee Surg Sports Traumatol Arthrosc*. 2020;28(3):790-796. doi:10.1007/s00167-019-05461-y
36. Stein T, Mehling AP, Welsch F, von Eisenhart-Rothe R, Jäger A. Long-term outcome after arthroscopic meniscal repair versus arthroscopic partial meniscectomy for traumatic meniscal tears. *Am J Sports Med*. 2010;38(8):1542-1548. doi:10.1177/0363546510364052
37. Frattini M, Vaienti E, Soncini G, Pogliacomi F. Tibial plateau fractures in elderly patients. *Chir Organi Mov*. 2009;93(3):109-114. doi:10.1007/s12306-009-0038-y
38. Elsoe R, Larsen P, Nielsen NPH, Swenne J, Rasmussen S, Ostgaard SE. Population-Based Epidemiology of Tibial Plateau Fractures. *Orthopedics*. 2015;38(9):e780-786. doi:10.3928/01477447-20150902-55
39. Rademakers MV, Kerkhoffs GMMJ, Siersevelt IN, Raaymakers ELFB, Marti RK. Operative treatment of 109 tibial plateau fractures: five- to 27-year follow-up results. *J Orthop Trauma*. 2007;21(1):5-10. doi:10.1097/bot.0b013e31802c5b51
40. Giannoudis PV, Tzioupis C, Papathanassopoulos A, Obakponovwe O, Roberts C. Articular step-off and risk of post-traumatic osteoarthritis. Evidence today. *Injury*. 2010;41(10):986-995. doi:10.1016/j.injury.2010.08.003

41. Weigel DP, Marsh JL. High-energy fractures of the tibial plateau. Knee function after longer follow-up. *J Bone Joint Surg Am.* 2002;84(9):1541-1551. doi:10.2106/00004623-200209000-00006
42. Wasserstein D, Henry P, Paterson JM, Kreder HJ, Jenkinson R. Risk of total knee arthroplasty after operatively treated tibial plateau fracture: a matched-population-based cohort study. *J Bone Joint Surg Am.* 2014;96(2):144-150. doi:10.2106/jbjs.l.01691
43. Tapper VS, Pamilo KJ, Haapakoski JJ, Toom A, Paloneva J. Risk of total knee replacement after proximal tibia fracture: a register-based study of 7,841 patients. *Acta Orthop.* 2022;93:179-184. doi:10.2340/17453674.2021.1006
44. Mehin R, O'Brien P, Broekhuysen H, Blachut P, Guy P. Endstage arthritis following tibial plateau fractures: average 10-year follow-up. *Can J Surg.* 2012;55(2):87-94. doi:10.1503/cjs.003111
45. Stevens DG, Beharry R, McKee MD, Waddell JP, Schemitsch EH. The long-term functional outcome of operatively treated tibial plateau fractures. *J Orthop Trauma.* 2001;15(5):312-320. doi:10.1097/00005131-200106000-00002
46. Rademakers MV, Kerkhoffs GMMJ, Sierevelt IN, Raaymakers ELFB, Marti RK. Intra-articular fractures of the distal femur: a long-term follow-up study of surgically treated patients. *J Orthop Trauma.* 2004;18(4):213-219. doi:10.1097/00005131-200404000-00004
47. Markhardt BK, Gross JM, Monu J. Schatzker classification of tibial plateau fractures: use of CT and MR imaging improves assessment. *Radiographics.* 2009;29(2):585-597. doi:10.1148/rg.292085078
48. Jansen H, Frey SP, Doht S, Fehske K, Meffert RH. Medium-term results after complex intra-articular fractures of the tibial plateau. *J Orthop Sci.* 2013;18(4):569-577. doi:10.1007/s00776-013-0404-3
49. Elsoe R, Larsen P, Shekhrayka N, Ferreira L, Ostgaard SE, Rasmussen S. The outcome after lateral tibial plateau fracture treated with percutaneous screw fixation show a tendency towards worse functional outcome compared with a reference population. *Eur J Trauma Emerg Surg.* 2016;42(2):177-184. doi:10.1007/s00068-015-0497-9
50. Jagdev SS, Pathak S, Kanani H, Salunke A. Functional Outcome and Incidence of Osteoarthritis in Operated Tibial Plateau Fractures. *Arch Bone Jt Surg.* 2018;6(6):508-516.
51. Manidakis N, Dosani A, Dimitriou R, Stengel D, Matthews S, Giannoudis P. Tibial plateau fractures: functional outcome and incidence of osteoarthritis in 125 cases. *Int Orthop.* 2010;34(4):565-570. doi:10.1007/s00264-009-0790-5
52. Chan YS, Chiu CH, Lo YP, et al. Arthroscopy-assisted surgery for tibial plateau fractures: 2- to 10-year follow-up results. *Arthroscopy.* 2008;24(7):760-768.e2. doi:10.1016/j.arthro.2008.02.017
53. Vestergaard V, Becic Pedersen A, Borbjerg Hare K, Morville Schrøder H, Troelsen A. Knee Fracture Increases TKA Risk After Initial Fracture Treatment and Throughout Life. *Clin Orthop Relat Res.* 2020;478(9):2036-2044. doi:10.1097/corr.0000000000001099
54. Biz C, Maso G, Gambato M, et al. Challenging Surgical Treatment of Displaced Articular Tibial Plateau Fractures: Do Early Knee Radiographic Features Have a Predictive Value of the Mid-Term Clinical Functional Outcomes? *Orthop Surg.* 2019;11(6):1149-1162. doi:10.1111/os.12577
55. Parkkinen M, Lindahl J, Mäkinen TJ, Koskinen SK, Mustonen A, Madanat R. Predictors of osteoarthritis following operative treatment of medial tibial plateau fractures. *Injury.* 2018;49(2):370-375. doi:10.1016/j.injury.2017.11.014
56. Parkkinen M, Madanat R, Mustonen A, Koskinen SK, Paavola M, Lindahl J. Factors predicting the development of early osteoarthritis following lateral tibial plateau fractures: mid-term clinical and radiographic outcomes of 73 operatively treated patients. *Scand J Surg.* 2014;103(4):256-262. doi:10.1177/1457496914520854
57. Li RT, Lorenz S, Xu Y, Harner CD, Fu FH, Irrgang JJ. Predictors of radiographic knee osteoarthritis after anterior cruciate ligament reconstruction. *Am J Sports Med.* 2011;39(12):2595-2603. doi:10.1177/0363546511424720
58. He QF, Sun H, Shu LY, et al. Tibial plateau fractures in elderly people: an institutional retrospective study. *J Orthop Surg Res.* 2018;13(1):276. doi:10.1186/s13018-018-0986-8
59. Vestergaard V, Pedersen AB, Tengberg PT, Troelsen A, Schrøder HM. 20-year trends of distal femoral, patellar, and proximal tibial fractures: a Danish nationwide cohort study of 60,823 patients. *Acta Orthop.* 2020;91(1):109-114. doi:10.1080/17453674.2019.1698148
60. Su EP, Westrich GH, Rana AJ, Kapoor K, Helfet DL. Operative treatment of tibial plateau fractures in patients older than 55 years. *Clin Orthop Relat Res.* 2004;(421):240-248.

61. Barei DP, Nork SE, Mills WJ, Coles CP, Henley MB, Benirschke SK. Functional outcomes of severe bicondylar tibial plateau fractures treated with dual incisions and medial and lateral plates. *J Bone Joint Surg Am.* 2006;88(8):1713-1721. [doi:10.2106/00004623-200608000-00004](https://doi.org/10.2106/00004623-200608000-00004)
62. Davis JT, Rudloff MI. Posttraumatic Arthritis After Intra-Articular Distal Femur and Proximal Tibia Fractures. *Orthop Clin North Am.* 2019;50(4):445-459. [doi:10.1016/j.ocln.2019.06.002](https://doi.org/10.1016/j.ocln.2019.06.002)
63. Dinçel YM, Öner A, Arıkan Y, Çağlar S, Özcafer R, Güleç MA. Effect of BMI on outcomes of surgical treatment for tibial plateau fractures: A comparative retrospective case series study. *Chin J Traumatol.* 2018;21(2):104-108. [doi:10.1016/j.cjtee.2017.10.005](https://doi.org/10.1016/j.cjtee.2017.10.005)
64. Hung SS, Chao EK, Chan YS, et al. Arthroscopically assisted osteosynthesis for tibial plateau fractures. *J Trauma.* 2003;54(2):356-363. [doi:10.1097/01.ta.0000020397.74034.65](https://doi.org/10.1097/01.ta.0000020397.74034.65)
65. Conserva V, Vicenti G, Allegretti G, et al. Retrospective review of tibial plateau fractures treated by two methods without staging. *Injury.* 2015;46(10):1951-1956. [doi:10.1016/j.injury.2015.07.018](https://doi.org/10.1016/j.injury.2015.07.018)
66. Thomson AB, Driver R, Kregor PJ, Obremskey WT. Long-term functional outcomes after intra-articular distal femur fractures: ORIF versus retrograde intramedullary nailing. *Orthopedics.* 2008;31(8):748-750.
67. van den Berg J, Reul M, Nunes Cardozo M, et al. Functional outcome of intra-articular tibial plateau fractures: the impact of posterior column fractures. *Int Orthop.* 2017;41(9):1865-1873. [doi:10.1007/s00264-017-3566-3](https://doi.org/10.1007/s00264-017-3566-3)
68. Mattiassich G, Foltin E, Scheurecker G, Schneiderbauer A, Kröpfl A, Fischmeister M. Radiographic and clinical results after surgically treated tibial plateau fractures at three and twenty two years postsurgery. *Int Orthop.* 2014;38(3):587-594. [doi:10.1007/s00264-013-2174-0](https://doi.org/10.1007/s00264-013-2174-0)
69. Schenker ML, Mauck RL, Ahn J, Mehta S. Pathogenesis and prevention of posttraumatic osteoarthritis after intra-articular fracture. *J Am Acad Orthop Surg.* 2014;22(1):20-28. [doi:10.5435/jaaos-22-01-20](https://doi.org/10.5435/jaaos-22-01-20)
70. Scott BL, Lee CS, Strelzow JA. Five-Year Risk of Conversion to Total Knee Arthroplasty After Operatively Treated Periarticular Knee Fractures in Patients Over 40 Years of Age. *J Arthroplasty.* 2020;35(8):2084-2089 e2081. [doi:10.1016/j.arth.2020.03.041](https://doi.org/10.1016/j.arth.2020.03.041)
71. Stefancin JJ, Parker RD. First-time traumatic patellar dislocation: a systematic review. *Clin Orthop Relat Res.* 2007;455:93-101. [doi:10.1097/blo.0b013e31802eb40a](https://doi.org/10.1097/blo.0b013e31802eb40a)
72. Mehta VM, Inoue M, Nomura E, Fithian DC. An algorithm guiding the evaluation and treatment of acute primary patellar dislocations. *Sports Med Arthrosc Rev.* 2007;15(2):78-81. [doi:10.1097/jsa.0b013e318042b695](https://doi.org/10.1097/jsa.0b013e318042b695)
73. Fithian DC, Paxton EW, Stone ML, et al. Epidemiology and natural history of acute patellar dislocation. *Am J Sports Med.* 2004;32(5):1114-1121. [doi:10.1177/0363546503260788](https://doi.org/10.1177/0363546503260788)
74. Grewal B, Elliott D, Daniele L, Reidy J. Irreducible Lateral Patellar Dislocation: A Case Report and Literature Review. *Ochsner J.* 2016;16(2):180-184.
75. Hsiao M, Owens BD, Burks R, Sturdivant RX, Cameron KL. Incidence of acute traumatic patellar dislocation among active-duty United States military service members. *Am J Sports Med.* 2010;38(10):1997-2004. [doi:10.1177/0363546510371423](https://doi.org/10.1177/0363546510371423)
76. Vollnberg B, Koehlietz T, Jung T, et al. Prevalence of cartilage lesions and early osteoarthritis in patients with patellar dislocation. *Eur Radiol.* 2012;22(11):2347-2356. [doi:10.1007/s00330-012-2493-3](https://doi.org/10.1007/s00330-012-2493-3)
77. Nomura E, Inoue M. Second-look arthroscopy of cartilage changes of the patellofemoral joint, especially the patella, following acute and recurrent patellar dislocation. *Osteoarthritis Cartilage.* 2005;13(11):1029-1036. [doi:10.1016/j.joca.2005.07.004](https://doi.org/10.1016/j.joca.2005.07.004)
78. Sanders TL, Pareek A, Johnson NR, Stuart MJ, Dahm DL, Krych AJ. Patellofemoral Arthritis After Lateral Patellar Dislocation: A Matched Population-Based Analysis. *Am J Sports Med.* 2017;45(5):1012-1017. [doi:10.1177/0363546516680604](https://doi.org/10.1177/0363546516680604)
79. Schüttler KF, Struwer J, Roessler PP, et al. Patellofemoral osteoarthritis after Insall's proximal realignment for recurrent patellar dislocation. *Knee Surg Sports Traumatol Arthrosc.* 2014;22(11):2623-2628. [doi:10.1007/s00167-013-2485-0](https://doi.org/10.1007/s00167-013-2485-0)
80. Nikku R, Nietosvaara Y, Aalto K, Kallio PE. Operative treatment of primary patellar dislocation does not improve medium-term outcome: A 7-year follow-up report and risk analysis of 127 randomized patients. *Acta Orthop.* 2005;76(5):699-704. [doi:10.1080/017453670510041790](https://doi.org/10.1080/017453670510041790)

81. Sillanpää PJ, Mattila VM, Visuri T, Mäenpää H, Pihlajamäki H. Patellofemoral osteoarthritis in patients with operative treatment for patellar dislocation: a magnetic resonance-based analysis. *Knee Surg Sports Traumatol Arthrosc.* 2011;19(2):230-235. doi:10.1007/s00167-010-1285-z
82. Berruto M, Ubaldi F, Ferrua P, Vergottini G, Manunta A. Surgical Treatment of Objective Patellar Instability: Long-Term Results. *Joints.* 2018;6(1):33-36. doi:10.1055/s-0038-1636949
83. Smith TO, Donell S, Song F, Hing CB. Surgical versus non-surgical interventions for treating patellar dislocation. *Cochrane Database Syst Rev.* 2015(2):CD008106.
84. Stanton I, White LM, Satchithananda K, Compson J, Elias DA. The postoperative patellofemoral joint: expected radiological appearances and complications. *Curr Probl Diagn Radiol.* 2006;35(2):55-64. doi:10.1067/j.cpradiol.2005.12.001
85. Laird A, Keating JF. Acetabular fractures: a 16-year prospective epidemiological study. *J Bone Joint Surg Br.* 2005;87-B(7):969-973. doi:10.1302/0301-620x.87b7.16017
86. Rinne PP, Laitinen MK, Huttunen T, Kannus P, Mattila VM. The incidence and trauma mechanisms of acetabular fractures: A nationwide study in Finland between 1997 and 2014. *Injury.* 2017;48(10):2157-2161. doi:10.1016/j.injury.2017.08.003
87. Ferguson TA, Patel R, Bhandari M, Matta JM. Fractures of the acetabulum in patients aged 60 years and older: an epidemiological and radiological study. *J Bone Joint Surg Br.* 2010;92-B(2):250-257. doi:10.1302/0301-620x.92b2.22488
88. Chung TC, Chen TS, Hsu YC, Kao FC, Tu YK, Liu PH. Long-term total hip arthroplasty rates in patients with acetabular and pelvic fractures after surgery: A population-based cohort study. *PLoS ONE.* 2020;15(4):e0231092. doi:10.1371/journal.pone.0231092
89. Giannoudis PV, Grotz MRW, Papakostidis C, Dinopoulos H. Operative treatment of displaced fractures of the acetabulum. A meta-analysis. *J Bone Joint Surg Br.* 2005;87-B(1):2-9. doi:10.1302/0301-620x.87b1.15605
90. Nicholson JA, Scott CEH, Annan J, Ahmed I, Keating JF. Native hip dislocation at acetabular fracture predicts poor long-term outcome. *Injury.* 2018;49(10):1841-1847. doi:10.1016/j.injury.2018.07.032
91. O'Toole RV, Hui E, Chandra A, Nascone JW. How often does open reduction and internal fixation of geriatric acetabular fractures lead to hip arthroplasty? *J Orthop Trauma.* 2014;28(3):148-153. doi:10.1097/bot.0b013e31829c739a
92. Dunet B, Tournier C, Billaud A, Lavoinne N, Fabre T, Durandeau A. Acetabular fracture: long-term follow-up and factors associated with secondary implantation of total hip arthroplasty. *Orthop Traumatol Surg Res.* 2013;99(3):281-290. doi:10.1016/j.otsr.2012.12.018
93. Chen CY, Hsu CJ, Lin TL, Chen HT, Tsai CH. Acetabular Fractures with Central Hip Dislocation: A Retrospective Consecutive 50 Case Series Study Based on AO/OTA 2018 Classification in Midterm Follow-Up. *Biomed Res Int.* 2021;2021:6659640. doi:10.1155/2021/6659640
94. Matta JM. Fractures of the acetabulum: accuracy of reduction and clinical results in patients managed operatively within three weeks after the injury. *J Bone Joint Surg Am.* 1996;78(11):1632-1645. doi:10.2106/0004623-199611000-00002
95. Mears DC, Velyvis JH, Chang CP. Displaced acetabular fractures managed operatively: indicators of outcome. *Clin Orthop Relat Res.* 2003;(407):173-186.
96. Haefeli PC, Marecek GS, Keel MJ, Siebenrock KA, Tannast M. Patients undergoing surgical hip dislocation for the treatment of acetabular fractures show favourable long-term outcome. *Bone Joint J.* 2017;99-B(4):508-515.
97. Rollmann MF, Holstein JH, Pohlemann T, et al. Predictors for secondary hip osteoarthritis after acetabular fractures—a pelvic registry study. *Int Orthop.* 2019;43(9):2167-2173. doi:10.1007/s00264-018-4169-3
98. Boudissa M, Francony F, Kerschbaumer G, et al. Epidemiology and treatment of acetabular fractures in a level-1 trauma centre: Retrospective study of 414 patients over 10 years. *Orthop Traumatol Surg Res.* 2017;103(3):335-339. doi:10.1016/j.otsr.2017.01.004
99. Cahueque M, Martínez M, Cobar A, Bregni M. Early reduction of acetabular fractures decreases the risk of post-traumatic hip osteoarthritis? *J Clin Orthop Trauma.* 2017;8(4):320-326. doi:10.1016/j.jcot.2017.01.001
100. Makridis KG, Obakponovwe O, Bobak P, Giannoudis PV. Total hip arthroplasty after acetabular fracture: incidence of complications, reoperation rates and functional outcomes: evidence today. *J Arthroplasty.* 2014;29(10):1983-1990. doi:10.1016/j.arth.2014.06.001

101. Sen RK, Veerappa LA. Long-term outcome of conservatively managed displaced acetabular fractures. *J Trauma*. 2009;67(1):155-159.
102. Petsatodis G, Antonarakos P, Chalidis B, Papadopoulos P, Christoforidis J, Pournaras J. Surgically treated acetabular fractures via a single posterior approach with a follow-up of 2–10 years. *Injury*. 2007;38(3):334-343. doi:10.1016/j.injury.2006.09.017
103. Negrin LL, Seligson D. Results of 167 consecutive cases of acetabular fractures using the Kocher-Langenbeck approach: a case series. *J Orthop Surg Res*. 2017;12(1). doi:10.1186/s13018-017-0563-6
104. Zha GC, Sun JY, Dong SJ. Predictors of clinical outcomes after surgical treatment of displaced acetabular fractures in the elderly. *J Orthop Res*. 2013;31(4):588-595. doi:10.1002/jor.22279
105. Tannast M, Najibi S, Matta JM. Two to twenty-year survivorship of the hip in 810 patients with operatively treated acetabular fractures. *J Bone Joint Surg Am*. 2012;94(17):1559-1567. doi:10.2106/jbjs.k.00444
106. Bhandari M, Matta J, Ferguson T, Matthys G. Predictors of clinical and radiological outcome in patients with fractures of the acetabulum and concomitant posterior dislocation of the hip. *J Bone Joint Surg Br*. 2006;88-B(12):1618-1624. doi:10.1302/0301-620x.88b12.17309
107. Kreder HJ, Rozen N, Borkhoff CM, et al. Determinants of functional outcome after simple and complex acetabular fractures involving the posterior wall. *J Bone Joint Surg Br*. 2006;88-B(6):776-782. doi:10.1302/0301-620x.88b6.17342
108. Gänsslen A, Frink M, Hildebrand F, Krettek C. Both column fractures of the acetabulum: epidemiology, operative management and long-term results. *Acta Chir Orthop Traumatol Cech*. 2012;79(2):107-113.
109. Lichte P, Sellei RM, Kobbe P, Dombroski DG, Gänsslen A, Pape HC. Predictors of poor outcome after both column acetabular fractures: a 30-year retrospective cohort study. *Patient Saf Surg*. 2013;7(1):9. doi:10.1186/1754-9493-7-9
110. Moreta J, Foruria X, Sanchez A, Aguirre U. Prognostic factors after a traumatic hip dislocation. A long-term retrospective study. *Rev Esp Cir Ortop Traumatol*. 2017;61(6):367-374.
111. Meena UK, Tripathy SK, Sen RK, Aggarwal S, Behera P. Predictors of postoperative outcome for acetabular fractures. *Orthop Traumatol Surg Res*. 2013;99(8):929-935. doi:10.1016/j.otsr.2013.09.004
112. Navarre P, Gabbe BJ, Griffin XL, et al. Outcomes following operatively managed acetabular fractures in patients aged 60 years and older. *Bone Joint J*. 2020;102-B(12):1735-1742.
113. Sanders E, Finless A, Adamczyk A, et al. Outcome After Open Reduction Internal Fixation of Acetabular Fractures in the Elderly. *J Orthop Trauma*. 2022;36(3):130-136. doi:10.1097/bot.0000000000000224
114. Rommens PM, Ingelfinger P, Nowak TE, Kuhn S, Hessmann MH. Traumatic damage to the cartilage influences outcome of anatomically reduced acetabular fractures: a medium-term retrospective analysis. *Injury*. 2011;42(10):1043-1048. doi:10.1016/j.injury.2011.03.058
115. Lawyer TJ, Jankowski J, Russell GV, Stronach BM. Prevalence of post-traumatic osteoarthritis in morbidly obese patients after acetabular fracture fixation. *J Long Term Eff Med Implants*. 2014;24(2-3):225-231. doi:10.1615/jlongtermeffmedimplants.2014010505
116. Sahin V, Karakas ES, Aksu S, Atlihan D, Turk CY, Halici M. Traumatic dislocation and fracture-dislocation of the hip: a long-term follow-up study. *J Trauma*. 2003;54(3):520-529. doi:10.1097/01.ta.0000020394.32496.52
117. Phillips JRA, Trezies AJH, Davis TRC. Long-term follow-up of femoral shaft fracture: Relevance of malunion and malalignment for the development of knee arthritis. *Injury*. 2011;42(2):156-161. doi:10.1016/j.injury.2010.06.024
118. Brauer CA, Coca-Perraillon M, Cutler DM, Rosen AB. Incidence and mortality of hip fractures in the United States. *JAMA*. 2009;302(14):1573-1579. doi:10.1001/jama.2009.1462
119. Fischer H, Maleitzke T, Eder C, Ahmad S, Stöckle U, Braun KF. Management of proximal femur fractures in the elderly: current concepts and treatment options. *Eur J Med Res*. 2021;26(1). doi:10.1186/s40001-021-00556-0
120. Koval KJ, Zuckerman JD. Hip Fractures: I. Overview and Evaluation and Treatment of Femoral-Neck Fractures. *J Am Acad Orthop Surg*. 1994;2(3):141-149. doi:10.5435/00124635-199405000-00002
121. Evans JT, Guyver PM, Kassam AM, Hubble MJ. Displaced femoral neck stress fractures in Royal Marine recruits--management and results of operative treatment. *J R Nav Med Serv*. 2012;98(2):3-5.

122. Robstad B, Frihagen F, Nordsletten L. The rate of hip osteoarthritis in patients with proximal femoral fractures versus hip contusion. *Osteoporos Int*. 2012;23(3):901-905. doi:10.1007/s00198-011-1628-8
123. Tonetti J, Ruatti S, Lafontan V, et al. Is femoral head fracture-dislocation management improvable: A retrospective study in 110 cases. *Orthop Traumatol Surg Res*. 2010;96(6):623-631. doi:10.1016/j.otsr.2010.03.020
124. Archibeck MJ, Carothers JT, Tripuraneni KR, White RE Jr. Total hip arthroplasty after failed internal fixation of proximal femoral fractures. *J Arthroplasty*. 2013;28(1):168-171. doi:10.1016/j.arth.2012.04.003
125. Maluta T, Toso G, Negri S, Samaila EM, Magnan B. Correlation between hip osteoarthritis and proximal femoral fracture site: could it be protective for intracapsular neck fractures? A retrospective study on 320 cases. *Osteoporos Int*. 2019;30(8):1591-1596. doi:10.1007/s00198-019-05015-5
126. Zi-Sheng A, You-Shui G, Zhi-Zhen J, Ting Y, Chang-Qing Z. Hemiarthroplasty vs primary total hip arthroplasty for displaced fractures of the femoral neck in the elderly: a meta-analysis. *J Arthroplasty*. 2012;27(4):583-590. doi:10.1016/j.arth.2011.07.009
127. Clegg TE, Roberts CS, Greene JW, Prather BA. Hip dislocations—epidemiology, treatment, and outcomes. *Injury*. 2010;41(4):329-334. doi:10.1016/j.injury.2009.08.007
128. Beebe MJ, Bauer JM, Mir HR. Treatment of Hip Dislocations and Associated Injuries: Current State of Care. *Orthop Clin North Am*. 2016;47(3):527-549. doi:10.1016/j.ocl.2016.02.002
129. Dawson-Amoah K, Raszewski J, Duplantier N, Waddell BS. Dislocation of the Hip: A Review of Types, Causes, and Treatment. *Ochsner J*. 2018;18(3):242-252. doi:10.31486/toj.17.0079
130. Chigblo P, Tidjani IF, Lawson E, Hans-Moevi A. Traumatic hip dislocation in Cotonou. *J Orthop*. 2016;13(4):268-271. doi:10.1016/j.jor.2016.06.006
131. Ma HH, Huang CC, Pai FY, Chang MC, Chen WM, Huang TF. Long-term results in the patients with traumatic hip fracture-dislocation: Important prognostic factors. *J Chin Med Assoc*. 2020;83(7):686-689. doi:10.1097/jcma.0000000000000366
132. Sarwark JF. *Essentials of Musculoskeletal Care*.; 2010.
133. Tornetta P III, Mostafavi HR. Hip Dislocation: Current Treatment Regimens. *J Am Acad Orthop Surg*. 1997;5(1):27-36. doi:10.5435/00124635-199701000-00004
134. Kelly BT, Weiland DE, Schenker ML, Philippon MJ. Arthroscopic labral repair in the hip: surgical technique and review of the literature. *Arthroscopy*. 2005;21(12):1496-1504. doi:10.1016/j.arthro.2005.08.013
135. Obakponovwe O, Morell D, Ahmad M, Nunn T, Giannoudis PV. Traumatic hip dislocation. *Orthopaedics and Trauma*. 2011;25(3):214-222. doi:10.1016/j.mporth.2011.04.006
136. Kellam P, Ostrum RF. Systematic Review and Meta-Analysis of Avascular Necrosis and Posttraumatic Arthritis After Traumatic Hip Dislocation. *J Orthop Trauma*. 2016;30(1):10-16. doi:10.1097/bot.0000000000000419
137. Pascarella R, Fantasia R, Sangiovanni P, et al. Traumatic hip fracture-dislocation: A middle-term follow up study and a proposal of new classification system of hip joint associated injury. *Injury*. 2019;50:S11-S20. doi:10.1016/j.injury.2019.01.011
138. Bastian JD, Turina M, Siebenrock KA, Keel MJB. Long-term outcome after traumatic anterior dislocation of the hip. *Arch Orthop Trauma Surg*. 2011;131(9):1273-1278. doi:10.1007/s00402-011-1299-0
139. Scolaro JA, Marecek G, Firoozabadi R, Krieg JC, Routt MLC. Management and radiographic outcomes of femoral head fractures. *J Orthop Traumatol*. 2017;18(3):235-241. doi:10.1007/s10195-017-0445-z
140. Sanders S, Tejjwani N, Egol KA. Traumatic hip dislocation--a review. *Bull NYU Hosp Jt Dis*. 2010;68(2):91-96.
141. Giannoudis PV, Kontakis G, Christoforakis Z, Akula M, Tosounidis T, Koutras C. Management, complications and clinical results of femoral head fractures. *Injury*. 2009;40(12):1245-1251. doi:10.1016/j.injury.2009.10.024
142. Chiron P, Lafontan V, Reina N. Fracture-dislocations of the femoral head. *Orthop Traumatol Surg Res*. 2013;99(1 Suppl):S53-66.
143. Thomas AC, Hubbard-Turner T, Wikstrom EA, Palmieri-Smith RM. Epidemiology of Posttraumatic Osteoarthritis. *J Athl Train*. 2017;52(6):491-496. doi:10.4085/1062-6050-51.5.08