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Review article

Periprosthetic Fractures in the Knee Joint Area. A Literature Review

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Abstract

Periprosthetic fractures represent a multifactorial problem due to the diverse morphology of injuries, the wide range of implants used, and the high proportion of low-energy trauma – primarily falls – caused by patient comorbidities and osteoporosis. Given the limitations of existing classification systems, it becomes evident that an individualized approach is necessary for each type of fracture. With the continuous development and implementation of various osteosynthesis techniques, including minimally invasive technologies, advancements in metal fixators (including patient-specific designs), and the active use of bone graft substitutes, surgical approaches to treating the same type of periprosthetic fracture can vary significantly.
This review aims to present a literature review on the epidemiology, risk factors, and modern treatment approaches for periprosthetic fractures of the knee joint.
Based on an analysis of the literature, the article presents fixation methods that have demonstrated the best outcomes depending on the level and type of periprosthetic knee fracture. It should be noted that osteoporosis prevention, fall prevention, control of comorbid conditions in the preoperative period, early mobilization of the patient, and ensuring safe postoperative conditions are the most important measures for reducing the risk of periprosthetic fractures.
Knowledge in this area continues to evolve, with numerous risk factors identified related to the patient's condition, type of implant, and surgical technique. These findings help increase patient awareness and improve surgical team preparation, thereby reducing morbidity and improving treatment outcomes for these complex injuries.

Keywords: Periprosthetic knee fractures, Primary Total Knee Arthroplasty, Fracture after total knee arthroplasty.

1. Introduction

A periprosthetic fracture is defined as a fracture that occurs in close proximity to or around the components of a prosthesis, as well as within 15 cm of the joint line or 5 cm of the intramedullary stem of the implant [1]. Currently, due to the increasing average life expectancy, the number of primary total knee arthroplasty (TKA) procedures is also rising. According to international data, primary TKA accounts for approximately 2.5% to 7.4% of all periprosthetic fractures [2- 6].

Periprosthetic fractures are a multifactorial problem due to the varying fracture morphology, the wide range of implants used, and the high proportion of low-energy trauma—primarily falls—largely associated with patient comorbidities and osteoporosis [7]. From a practical standpoint, the complexity of this issue is driven by challenging clinical scenarios for several reasons: advanced age and comorbid conditions commonly seen in patients with periprosthetic knee fractures make surgical treatment particularly difficult, while implant-associated factors and poor bone quality may pose technical challenges during surgery.

As a result, patients with periprosthetic fractures require a specialized approach to treatment selection, taking into account their comorbid background, previously implanted prosthesis, and bone quality.

The primary goal of treatment for these patients is early functional recovery, minimizing the risk of hypostatic complications [8].

The purpose is to present a literature review on the current state of knowledge regarding the epidemiology, risk factors, and treatment approaches for periprosthetic knee fractures.

2. Methodology

A literature search was conducted for publications from 1988 to 2023. The search was performed using the PubMed/MedLine and Google Scholar databases. References for periprosthetic fracture classifications are based on original sources published between 1988 and 1999. References regarding treatment methods for periprosthetic fractures are, in several cases, based on primary sources from 2008 to 2023.

Studies focusing on surgical treatment of periprosthetic fractures involving component replacement, as well as fractures associated with periprosthetic infection, were excluded from this review.

3. Epidemiology and Etiology Incidence

Periprosthetic fractures of the femur occur in 0.3–2.5% of cases [1, 9]. The second most common site is the proximal tibia, with reported incidences ranging from 0.4% to 1.7% [1, 10]. Patellar fractures without surface resurfacing occur in about 0.05% of cases [1]. However, when patellar resurfacing is performed, the risk increases significantly, ranging from 0.5% to 21% [1].

The incidence of intraoperative periprosthetic fractures varies between 0.3% and 3.13% of all periprosthetic fractures [6]. Alden et al. analyzed 17,389 primary total knee arthroplasties (TKAs) performed between 1985 and 2005 and identified 67 cases of intraoperative periprosthetic fractures. Of these, 48 involved the femur and 19 involved the tibia [11].

The vast majority of periprosthetic fractures occur in the postoperative period and are associated with low-energy trauma, such as falls, particularly in elderly patients [12, 13]. According to a meta-analysis by Liu et al., 13.1% of patients experienced falls after TKA, with 1.0% of these falls occurring during hospitalization [14].

An important factor to consider is the time interval between total knee arthroplasty and the onset of a periprosthetic fracture. This interval is influenced by both patient-specific factors and implant-associated variables. According to Lizaur-Utrilla, the average time to fracture after primary TKA was 7.3 years (range: 2.7–15 years), while after revision TKA it was 2.8 years (range: 1.7–3.9 years). For fractures of the distal femur, the average time to fracture was approximately 25.5 months [1, 15]. Patellar periprosthetic fractures occurred postoperatively in 68% of cases within 2 years and in 82% within 3 years [16, 17].

Thus, both intraoperative and postoperative periprosthetic fractures following total knee arthroplasty represent a significant clinical issue that demands close attention. While it is nearly impossible to describe all the diverse causes and predisposing factors for periprosthetic fractures, identifying the main risk factors is the first step toward implementing preventive measures and, consequently, reducing the incidence of these complications.

4. Risk Factors

Several studies have reported that patients over the age of 65 are more susceptible to periprosthetic knee fractures, with a higher incidence observed among female patients [1, 6, 18, 19]. The most common underlying conditions that indirectly increase the risk of periprosthetic fractures include diseases that raise the likelihood of falls, such as epilepsy, Parkinson's disease, and, in some cases, anemia, chronic respiratory diseases, and cardiovascular conditions.

Another critical risk factor is osteoporosis of various origins. Diabetes mellitus is considered a secondary risk factor, primarily due to its effects on tissue trophism and the progression of diabetic polyneuropathy [20]. Most of these conditions act as indirect causes, increasing the likelihood of falls, which in turn raises the risk of periprosthetic fractures.

Intraoperative risk factors should also be highlighted separately, particularly in relation to fractures of the femur and patella. For instance, during femoral preparation, a "notching" depth greater than 3 mm significantly increases the risk of a periprosthetic femoral fracture [1, 6, 21]. Risk factors contributing to patellar fractures include patellar devascularization during surgical handling and a reduction in patellar thickness, especially after resurfacing. Additional causes of patellar fractures include improper positioning of prosthetic components and patellar maltracking [4].

5. Classifications

In this literature review, we have identified several of the most widely used classifications for periprosthetic fractures of the knee joint. Despite their variability, all of these classifications address key considerations necessary for determining the appropriate treatment approach: the stability of the knee joint prosthesis component and the location of the fracture line in relation to the prosthetic component.

One universal classification suitable for describing periprosthetic fractures across all segments is the UCS (Unified Classification System). Its main advantage lies in the ability to describe periprosthetic fractures of any location using standardized alphanumeric codes (Table 1). This classification serves as a universal communication tool when providing a general description of periprosthetic fractures [22].

However, despite its universality, the UCS classification is complex and offers a superficial descriptive character, which limits its utility as a comprehensive guide for treatment decision-making.

Table 1 – UCS Classification of periprosthetic fractures [22]

Type	Name	Comment
A	Apophysiolysis	Fractures of the proximal and distal poles of the patella, femoral epicondyle and tibial tuberosity. Treatment depends on the function of the knee joint
B1	Good bone, stable implant (fracture at implant level)	ORIF (open reduction and internal fixation)
B2	Good bone, unstable implant.	Revision endoprosthesis/+ ORIF
B3	Bad bone, unstable implant.	Revision endoprosthesis/reconstruction with bone grafting material
C	Fracture away from the component of the endoprosthesis	ORIF. Type C doesn't apply to the patella
D	Fracture between two different implants	Femur: between hip and knee endoprostheses. Tibia: between knee and ankle endoprostheses
E	Fracture of both bones holding a single endoprosthesis	Fractures of the femur and tibia, femur and patella, patella and tibia, patella and tibia, or, theoretically, all three bones.
F	Fracture articular surface	A fracture is not repaired or replaced bone, but is still considered periprosthetic because it faces the joint and articulates with it during endoprosthetics, such as a patella fracture.

There are also classifications that are more specifically focused on certain anatomical segments. For fractures of the femur, the most commonly used classifications are those by Rorabeck and Su [3, 23].

The Rorabeck classification emphasizes the presence of fragment displacement and the stability of the femoral prosthetic component:

Type I fracture: The femoral component is stable; the fracture is non-displaced.

Type II fracture: The femoral component is stable; the femoral fracture shows displacement of bone fragments.

Type III fracture: The femoral component is unstable; the femoral fracture is accompanied by displaced bone fragments (Figure 1) [3].

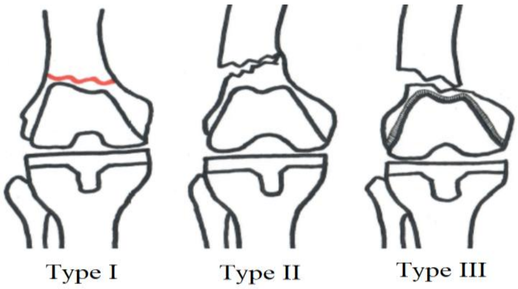


Figure 1 –Classification of periprosthetic femoral fractures according to Rorabeck et al. [3]

The Su classification focuses on the location of the fracture in relation to the femoral component of the prosthesis.

Type I: Fracture proximal to the femoral component.

Type II: Fracture originating at the tip of the femoral component and extending proximally.

Type III: Fracture where any part is distal to the anterior flange of the femoral component of the prosthesis (Figure 2) [23].

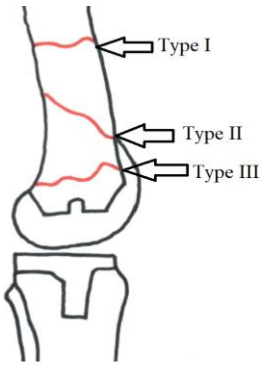


Figure 2 – Classification of periprosthetic femoral fractures according to Su et al. [23]

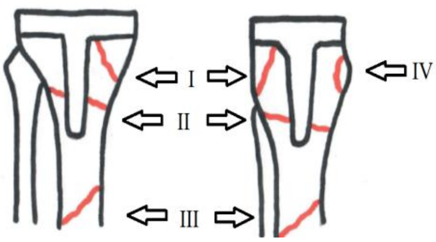


Figure 3 – Classification of periprosthetic femoral fractures according to Felix et al. [24]

One of the most commonly used classifications for fractures at the level of the tibia is the *Felix classification* (Figure 3) [24]. This classification is based on the location of the fracture in relation to the tibial component:

Type I: fracture at the level of the tibial component plateau, Type II: fracture at the level of the stem of the tibial component,

Type III: fracture distal to the stem of the tibial component,

Type IV: avulsion fracture of the tibial tuberosity.

The classification also includes modifiers such as the stability of the tibial component and whether the fracture occurred intraoperatively.

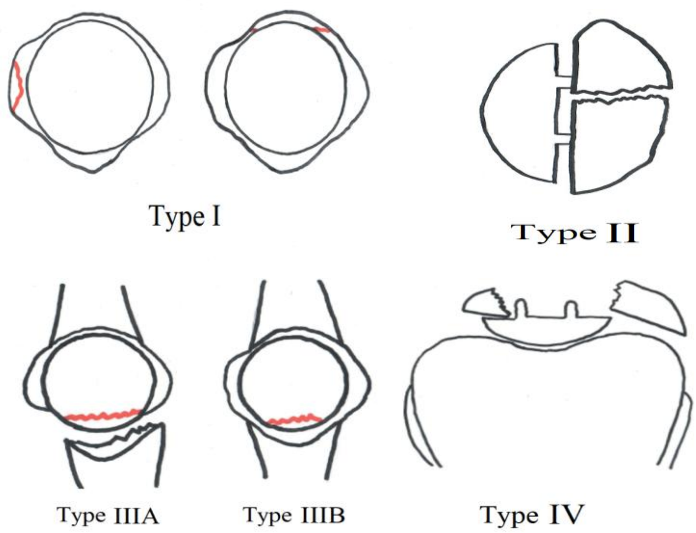


Figure 4 – Classification of periprosthetic patellar fractures according to Goldberg et al. [25]

The Goldberg classification [25] is most commonly used for assessing patellar fractures. This classification emphasizes the proximity of the fracture line to the patellar implant component, as well as involvement of the extensor mechanism:

Type I: patellar fracture without involvement of the implant, cement mantle, or extensor mechanism,

Type II: fracture line is in contact with the implant or cement mantle,

Type IIIA: fractures of the inferior pole of the patella with disruption of the patellar ligament,

Type IIIB: fractures of the inferior pole of the patella without disruption of the patellar ligament,

Type IV: patellar fracture-dislocation.

Ortiguera and Berry Classification [26]. The main criteria of this classification are the integrity of the extensor mechanism, the stability of the patellar component, and the quality of the remaining bone (Table 2).

Table 2 – Classification of periprosthetic patellar fractures according to Ortiguera and Berry

Type	Characteristic
I	Stable implant, extensor mechanism intact
II	Stable implant, extensor mechanism injured
III	Unstable implant
III A	Remaining bone within reasonable limits
III B	Loose bone*

*Note: *Residual patellar thickness less than 10 mm.*
Severe bone comminution making it unsuitable for component fixation

Given the narrow focus of the classifications, the need for an individualized approach to each type of fracture becomes evident. With the continuous development and implementation of various osteosynthesis techniques — including minimally invasive methods — the improvement of fixation devices, including custom implants, and the active integration of bone substitute materials into clinical practice, the surgical treatment methods for the same type of periprosthetic fracture may vary.

6. Surgical Methods for the Treatment of Periprosthetic Fractures

The principles of treating patients with periprosthetic fractures include restoring limb alignment and length, achieving stable fixation, preserving further knee joint function, and ensuring early patient mobilization. Adhering to these key elements of successful treatment can be challenging due to factors such as poor bone quality, the presence of other prosthetic implants in the same limb, the nature of the fracture, previous unsuccessful arthroplasty, and the specific design features of the prosthetic components [27].

Periprosthetic Femoral Fractures:

The most well-known and extensively discussed methods in modern literature for the surgical treatment of periprosthetic femoral fractures with a stable femoral component are the periosteal and intramedullary osteosynthesis techniques [12]. The most common and widely described method is periosteal osteosynthesis with plates. In this case, the minimally invasive periosteal osteosynthesis technique using plates and screws with angular stability helps create more favorable conditions for fracture consolidation and reduces the risk of infectious complications. The use of

When using intramedullary osteosynthesis, retrograde insertion of the intramedullary rod is preferred, as this method provides more stable fixation compared to antegrade nailing [32]. This method is recommended for periprosthetic femoral fractures of type Rorabeck II and Su I and II (Figures 1 and 2).

Several authors noted several advantages of intramedullary osteosynthesis compared to open reduction and periosteal osteosynthesis with plates: shorter operation time, relatively low intraoperative blood loss, and lower infection risk [20]. According to a meta-analysis by Magill et al., no significant differences were found in operation time, functional outcomes, consolidation times, nonunion rates, and revision rates when comparing different surgical methods [33]. Pellegrino et al. [20] also mentioned no differences in consolidation times for Rorabeck I, II fractures when using retrograde intramedullary osteosynthesis and periosteal osteosynthesis with plates. A series of studies [34-37], comparing ORIF with plates and DFR (distal femoral replacement) for periprosthetic femoral fractures, found that DFR is on par with ORIF with plates and can be the method of choice for fractures

this technique shows a higher percentage of consolidation compared to open reduction and osteosynthesis with plates and screws [20]. The improvement of surgical techniques and the appearance of low-profile plates with polyaxial screw insertion allows the plate to be fixed to areas with the greatest bone stock, while avoiding contact with the implant, making it possible to perform osteosynthesis in "distal" fractures [28]. For example, Hoffmann et al. in a study of 35 patients with periprosthetic femoral fractures reported lower nonunion rates with minimally invasive periosteal osteosynthesis compared to open reduction [29]. Althausen et al., in a literature review, demonstrated the clear advantages of minimally invasive periosteal osteosynthesis: less blood loss and shorter operation time compared to traditional periosteal osteosynthesis; however, minimally invasive periosteal osteosynthesis still has higher trauma compared to intramedullary osteosynthesis [30]. Large et al. reported better results in terms of reduction and restoration of the lower limb axis with periosteal osteosynthesis compared to other treatment methods [31].

located above the proximal part of the femoral component of the endoprosthesis. Lee et al. found no significant differences in outcomes between patients treated with periosteal and intramedullary osteosynthesis [38].

Contraindications for the use of intramedullary osteosynthesis in surgical treatment of periprosthetic fractures include: Patella Baja (low patella), ankylosis of the knee joint, femoral component intercondylar distance less than the thickness of the intramedullary rod, previous intramedullary rod in the femoral canal, unstable endoprosthesis, and structural features of the femoral component (closed femoral component design, PS type endoprosthesis, and endoprosthesis with a higher degree of component linkage, and femoral components with an intramedullary stem) [20, 33, 39]. Another limitation for intramedullary osteosynthesis is a fracture located distal to the anterior flange of the endoprosthesis component (Su type III), in which case periosteal osteosynthesis with plates and screws with angular stability is more appropriate.

Periprosthetic fractures combined with femoral component instability: Rorabeck and Su type III fractures may require revision endoprosthesis surgery using an implant with diaphyseal fixation. To create a stable construct, considering potential bone defects, bone replacement materials combined with internal fixation with angular stability plates may be useful [20]. The general recommendations for the choice of treatment for periprosthetic femoral fractures are presented in Table 3. The choice of treatment method should take into account the specific characteristics of the installed femoral component of the endoprosthesis. For example, for posterior-stabilized endoprostheses and those with a higher degree of component linkage, installation of an intramedullary rod may not be technically possible due to the "closed box" femoral component design.

Table 3 – Algorithm for the Treatment Strategy of Periprosthetic Femoral Fractures [7]

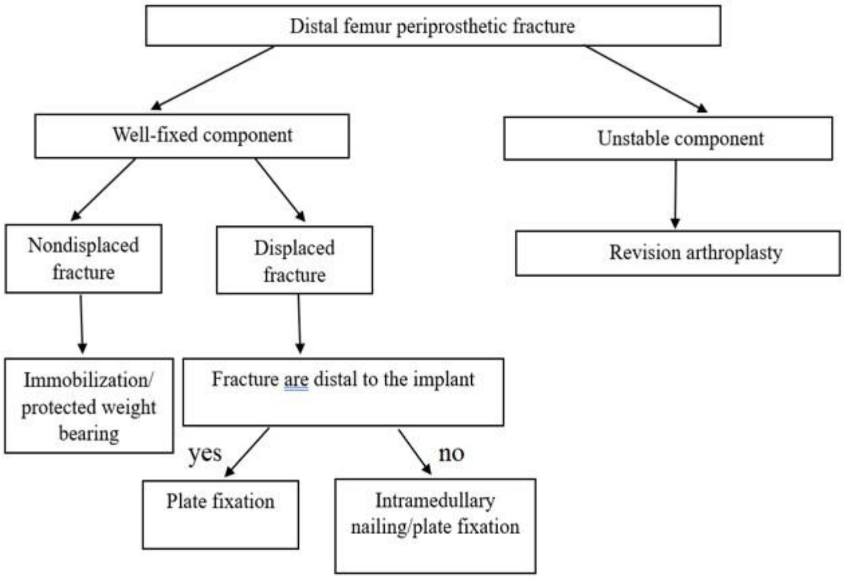
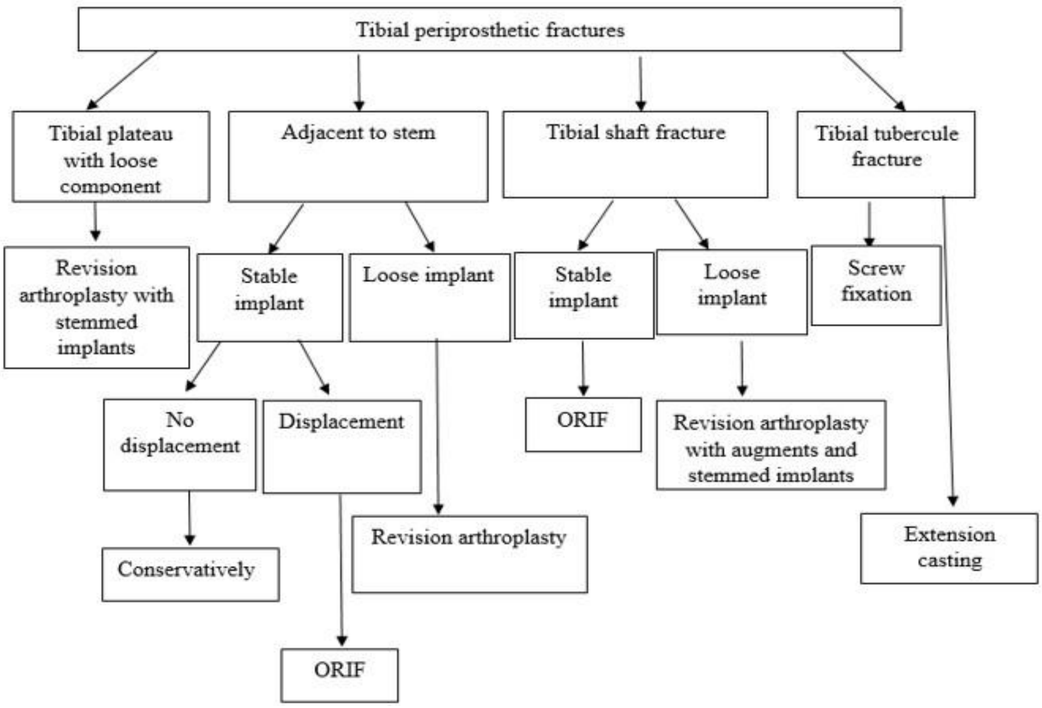


Table 4 – Algorithm for the Treatment Strategy of Periprosthetic Tibial Fractures [7]



Periprosthetic Tibial Fractures

To assess periprosthetic fractures at the level of the tibia, the Felix classification [40] is most commonly used (Figure 3). For stable fractures without displacement of bone fragments, types I and II, satisfactory results can be achieved using conservative treatment (immobilization) [20]. In the case of tibial component instability with fractures of type I and type II, it is recommended to use a tibial component with a long stem for better fixation in the canal, along with fragment fixation using screws. For fractures with displacement of bone fragments and a stable tibial component, ORIF (plate and screws) is the method of choice.

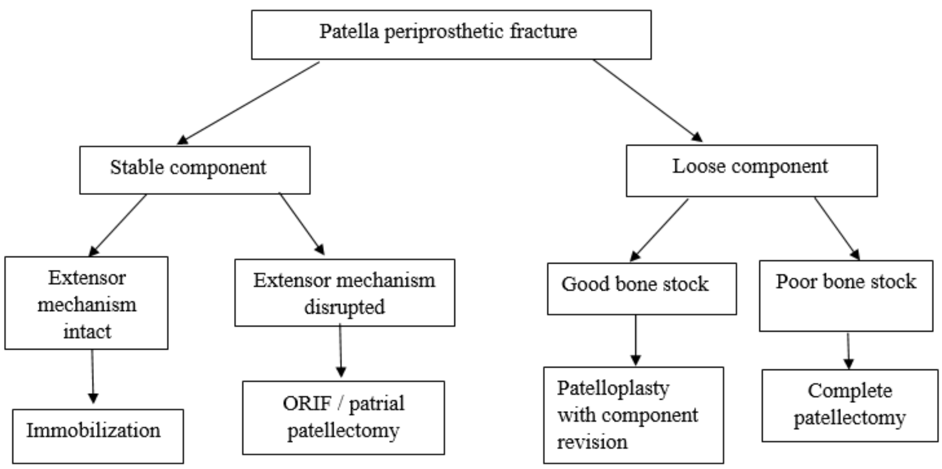
Patients with type III fractures can be treated either conservatively (6-week immobilization) or surgically using plate osteosynthesis, with the choice of method depending on the nature of the fracture and the degree of displacement [20].

In type IV fractures, osteosynthesis with screws is performed, with an effort to avoid damaging the ligamentous apparatus of the knee joint.

Regarding the installation of megaprostheses, foreign colleagues [10, 20] suggest using them only for comminuted fractures of Felix type I, in cases where reconstruction is not possible.

The summarized data on the choice of treatment strategy for periprosthetic fractures in the tibia are presented in Table 4.

Table 5 – Algorithm for the Treatment Strategy of Periprosthetic Patellar Fractures [7].



Patella

For patellar fractures of type Goldberg 1 and 3B, conservative management in a cast or brace is possible [20]. In a study, foreign colleagues note that patellar fractures without damage to the extensor mechanism can be treated conservatively [41]. If non-operative treatment is chosen, either a plaster cast on the lower leg with a good liner or a hinged patella brace should be used for 6-10 weeks. In other cases, to speed up activation and reduce the risk of knee joint contracture, patella reconstruction and restoration of the knee extensor mechanism function is recommended.

In the case of damage or instability of the patellar component of the endoprosthesis, surgical intervention is generally indicated: for a stable endoprosthesis component, patella osteosynthesis is performed; for an unstable component, the possibility of its replacement should be considered. If patella osteosynthesis is not possible, resection of the patella and plastic surgery of the knee extensor mechanism are appropriate. Total patellectomy should be considered as a last resort when other methods are ineffective or in cases of severely comminuted fractures. It is recommended to use a hinged knee brace with fixation for 6-10 weeks after open internal fixation before starting physiotherapy procedures to restore the range of motion [42].

Summarized data on the choice of treatment strategy for periprosthetic patellar fractures are presented in Table 5.

7. Conclusions

To date, periprosthetic fractures in the knee joint remain a significant problem due to the increased average life expectancy, the growing number of primary and revision joint replacement surgeries, as well as the variety of treatment strategies for fractures and the lack of a unified approach to the treatment of periprosthetic fractures of the bones forming the knee joint. Based on the analyzed data from the literature, the article presents various fixation methods that have been more reliably recommended depending on the level and type of periprosthetic knee fracture.

In conclusion, it should be noted that the prevention of osteoporosis, fall prevention, management of concomitant therapeutic conditions in the preoperative period, and early activation, along with the creation of safe conditions in the postoperative period, are measures that help reduce the risk of periprosthetic fractures. Knowledge about these fractures continues to evolve, and numerous risk factors related to the patient, implantation, and surgical technique have been identified. This knowledge allows us to educate our patients and surgical team to reduce morbidity and improve the treatment of these complex fractures.

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Тізе буынының перипротездік сынықтары: Әдеби шолу

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Түйіндеме

Перипротездік сынықтар әртүрлі зақымдану морфологиясына, қолданылатын импланттардың кең ауқымына және пациенттердің қатар жүретін аурулары мен остеопорозға байланысты төмен энергиялы жарақаттардың жоғары үлесіне-ең алдымен құлауға байланысты мультифакторлық проблема болып табылады. Қолданыстағы жіктеу жүйелерінің шектеулерін ескере отырып, сынудың әр түріне жеке көзқарастың қажеттілігі айқын болады. Остеосинтездің әртүрлі әдістерін, соның ішінде аз инвазивті технологияларды, жетілдірілген металл бекіткіштерді (соның ішінде жекелендірілген конструкцияларды) үздіксіз дамыту және енгізу және сүйек алмастырғыштарын белсенді пайдалану перипротездік сынықтың бір түрін емдеудің хирургиялық тәсілдерінде айтарлықтай айырмашылықтарға әкеледі.

Бұл шолудың мақсаты – эпидемиология, қауіп факторлары және тізе буынының перипротездік сынықтарын емдеудің заманауи тәсілдері туралы әдебиеттерге талдау жасау.

Әдебиет деректерін талдау негізінде мақалада тізе буынының перипротездік сыну деңгейі мен түріне байланысты ең жақсы нәтиже көрсеткен бекіту әдістері келтірілген. Остеопороздың алдын алу, құлаудың алдын алу, операция алдындағы кезеңде ілеспе патологияны бақылау, пациентті ерте мобильдеу және отадан кейінгі кезеңде қауіпсіз жағдайларды қамтамасыз ету перипротездік сыну қаупін азайтудың маңызды шаралары болып табылатынын атап өткен жөн. Осы саладағы білім дамуды жалғастыруда: науқастың жағдайына, имплантация түріне және операция техникасына байланысты көптеген қауіп-қатер факторлары анықталды. Аталмыш деректер пациенттердің хабардарлығын арттыруға және хирургиялық топтың дайындығын жақсартуға ықпал етеді. Ал бұл өз кезегінде ауырсынуды азайтады және осы күрделі зақымданулар үшін емдеу нәтижелерін жақсартады.

Түйін сөздер: тізе буынының перипротездік сынуы, тізе буынының бастапқы толық эндопротезі, тізе буынының толық эндопротезінен кейінгі сыну.

Перипротезные переломы коленного сустава: Обзор литературы

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Резюме

Перипротезные переломы представляют собой мультифакторную проблему из-за разнообразной морфологии повреждений, широкого спектра используемых имплантатов и высокой доли травм с низкой энергией – в первую очередь падений – обусловленных сопутствующими заболеваниями пациентов и остеопорозом. С учетом ограничений существующих классификационных систем становится очевидной необходимость индивидуального подхода к каждому типу перелома. Постоянное развитие и внедрение различных методов остеосинтеза, включая малоинвазивные технологии, усовершенствованные металлические фиксаторы (в том числе индивидуализированные конструкции), а также активное использование заменителей костной ткани приводят к значительным различиям в хирургических подходах к лечению одного и того же типа перипротезного перелома.

Цель данного обзора – представить анализ литературы по эпидемиологии, факторам риска и современным подходам к лечению перипротезных переломов коленного сустава.

На основе анализа данных литературы в статье представлены методы фиксации, показавшие наилучшие результаты в зависимости от уровня и типа перипротезного перелома коленного сустава. Следует отметить, что профилактика остеопороза, предотвращение падений, контроль сопутствующей патологии в предоперационный период, ранняя мобилизация пациента и обеспечение безопасных условий в послеоперационном периоде являются важнейшими мерами по снижению риска перипротезных переломов.

Знания в данной области продолжают развиваться: выявлено множество факторов риска, связанных с состоянием пациента, типом имплантата и техникой проведения операции. Эти данные способствуют повышению информированности пациентов и улучшению подготовки хирургической команды, что, в свою очередь, снижает заболеваемость и улучшает результаты лечения при этих сложных повреждениях.

Ключевые слова: перипротезные переломы коленного сустава, первичное тотальное эндопротезирование коленного сустава, перелом после тотального эндопротезирования колена.