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REVIEW

Periprosthetic fractures after total knee arthroplasty: review

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Abstract
This review of literature classifies and describes the most common periprosthetic fractures after total knee arthroplasty. Classification systems are usually considered useful when they describe the condition and offer guidelines for the management of a certain condition and are specific and comprehensive. The Lewis and Rorabeck classification can be used to describe these fractures.
The review not only provides the results of the classic techniques, but also new and combined techniques tried by some of the authors. For this review, only original studies, published between 2013 and 2019, were selected. The articles included in the database were selected from PubMed, ScienceDirect and SpringerLink. The searched keywords used to identify the articles were TKA, periprosthetic fractures and total knee arthroplasty.
The aim of this paper was to review the clinical studies related to periprosthetic fractures after total knee arthroplasty from the last six years, in order to understand current perspectives, epidemiology, treatment, and management.
In conclusion, periprosthetic fractures after total knee arthroplasty represent an important problem in medicine, but due to the low number of cases. Despite the increase in incidence, guidelines are mostly based on retrospective studies, personal observations, and expert opinion. The consensus is that treatment should be assigned depending on the patient's profile and the fracture's characteristics. Further studies should be performed in order to guide future practitioners in the treatment of periprosthetic fractures.
Keywords: periprosthetic fractures, TKA, locking plates, intramedullary nailing, single plating, double plating

Introduction

The number of periprosthetic fractures after total knee arthroplasty (TKA) is currently increasing as the number of joint replacements is continuously growing, therefore treatment is becoming more necessary [1, 2]. Furthermore, due to better hospital care and higher life expectancy, the number of total knee arthroplasty has increased dramatically, and some authors consider it as one of the most common reconstructive procedures in well-developed countries such as the USA [3]. Usually, periprosthetic fractures after TKA fractures are classified by their location and prosthesis integrity, with the most common location involving the supracondylar region [4]. Rorabeck reported an incidence of supracondylar femur fractures after TKA ranging between 0.3-2.5% [4]. Many classifications are used to localize the periprosthetic fractures after TKA. Classification systems are usually considered useful when they describe the condition and offer guidelines for the management of a certain condition and are specific and comprehensive.

The most commonly used in the articles we reviewed were Lewis & Rorabeck et al. and Felix et al.

The most common fractures after TKA are supracondylar fractures, the reported incidence being between 0.3 to 2.5% [4]. In literature, many factors that could lead to these fractures are cited, including osteoporosis, rheumatoid arthritis, corticosteroid use, female gender, and certain neurological disorders, these factors being pointed out in most of the cases [5]. Lewis and Rorabeck classification can be used to describe these fractures (Fig. 1). The authors of this classification recommend treating type I fracture non-surgically and type II fractures in a surgical manner, by closed reduction and fixation with an intramedullary nail or open reduction and internal fixation with a plate. Also, for type III fractures, the authors suggest that fractures should undergo revision of the prosthesis using long-stemmed revision prosthesis or structural allograft depending on the bone stock available [4].

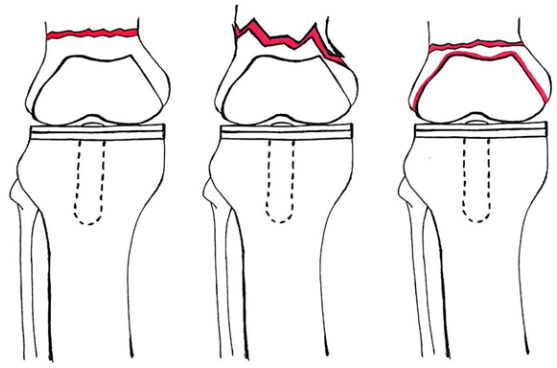

Fig. 1. Lewis & Rorabeck et al. classification of the femur associated with TKA
Type I: Nondisplaced; component intact
Type II: Displaced: component intact
Type III: Displaced; component loose or failing

Periprosthetic fractures of the tibia are less frequent and are often described using the classification proposed by Felx and Associates (Fig. 2). They can occur intraoperatively as a result of the impaction of a prosthesis with a stem that impinges on the cortex. They can also be caused by inadequate preparation of seating holes for pegs or fin [6, 7].

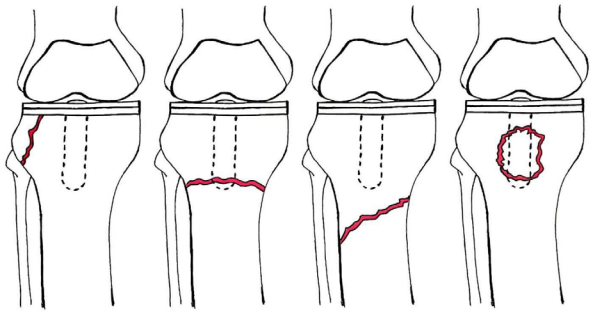

Fig. 2. Felix and Associates' Classification of Periprosthetic Fractures of the Tibia associated with TKA
Type I: Fracture of the tibial plateau
Type II: Fracture adjacent to the component
Type III: Fracture of the tibial shaft, distal to component
Type IV: Fracture of the tibial tubercle

Until present, multiple surgical and nonsurgical strategies have been described to manage periprosthetic fractures around the knee, all with the aim of achieving a functional, well-aligned, and stable knee. The mainstay of treatment has been osteosynthesis with either retrograde intramedullary nailing or fixed-angle plate fixation. Even though well-known classifications used nowadays have strong indications for using one of these techniques, none of them is perfect and they present some disadvantages. This review not only provides the results of the classic techniques, but also new and combined techniques tried by some of the authors.

Materials and methods

For this review, only original studies, published between 2013 and 2019, were selected. The articles included in the database were selected from PubMed, ScienceDirect and SpringerLink. The searched keywords used to identify the articles were TKA, periprosthetic fractures and total knee arthroplasty.

The research resulted in a database consisting of 32 articles. Seven articles were excluded because they were reviews, they included a low number of patients, or they strictly covered medical equipment.

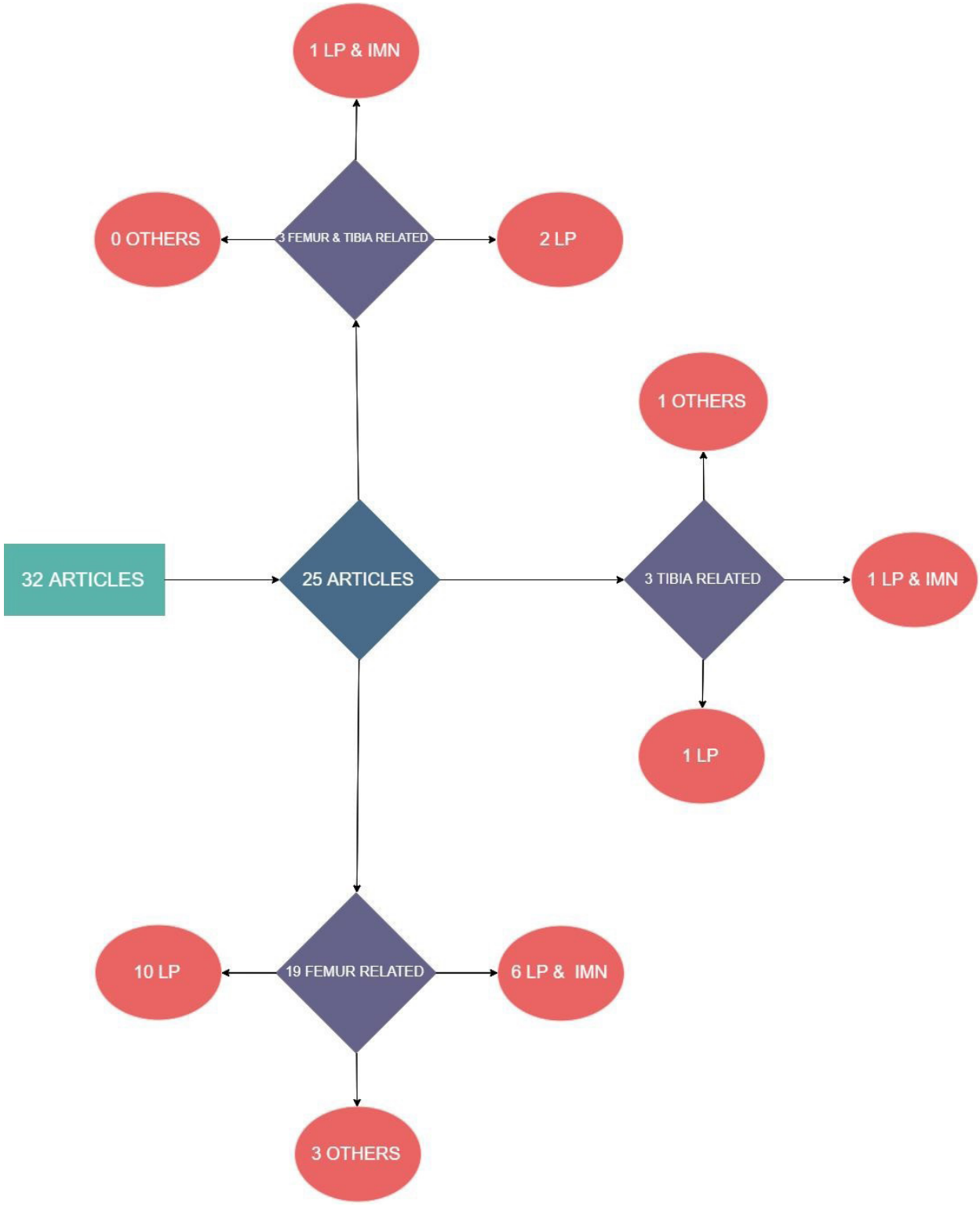

Fig. 3 Database. LP - locking plates | IMN - Intramedullary Nailing

Results

The final database consisted of 25 articles related to periprosthetic fractures after TKA. 19 articles covered fractures of the femur, 3 articles included the description of tibial fractures and 3 articles included femoral and tibial fractures as well (Fig. 3).

For femoral fractures, the following were used: locking plates (10 articles), intramedullary nails or locking plates (6 articles) or other methods (3 articles), including external fixation, prosthesis revision, and arthrodesis.

The approach to tibial fractures was similar in the 3 articles related to fractures of the shin bone, 1 article covered the treatment by using the locking plates system, 1 article included the use of locking plates and intramedullary nails as well and 1 article considered the use of arthrodesis, amputation and prosthesis revision along with locking plates.

Our database included 3 articles that comprised tibial fractures and femoral fractures as well and their treatment consisted of locking plates system (2 articles) and locking plates and intramedullary nails (1 article).

Ritter et al. [8] suggested that flexible intramedullary devices are the election treatment for periprosthetic fracture of the distal femur because they can be inserted by using a minimally invasive technique with a low rate of morbidity. There are two types of rods: flexible intramedullary rods and rigid intramedullary rods. The second ones require locking screw and they represent a good alternative for type I and II periprosthetic fractures of the distal femur in which the femoral implant is well attached to the bone. Intramedullary devices are also used in trauma surgery [9] and can be used in the fractures that are not deviated, if the consolidation has been achieved. The disadvantages of this technique are:

1. In fractures that follow a distal line, the limitation is greater compared to plates because of the positions of the holes for the distal crew.

2. Intramedullary nailing devices cannot be used in cases in which the femoral prosthesis presents a posterior stabilizer.

In order to increase local stability for the patients with advanced osteoporosis or with comminuted fractures, surgeons use homologous bone grafts [10] or acrylic cement alongside a nail or a plate [11].

Plate fixation

Another option for internal fixation is represented by open reduction with plates, 21 articles from our database covering this type of osteosynthesis. There are two possible methods of using plate fixation: the conventional plate, which is in contact with the underlying bone, requiring exact adaptation to the bony segment, otherwise resulting in non-union at the fracture site and, the second method, which is represented by the locking plate system that can be placed without intimate contact to the bone, as the screws will lock the plate, leading to less injury to the vascular structures.

Most of the authors have included in their studies locking plates, considering that conventional plating has been abandoned in the last years, due to a higher complication rate [12]. In a study conducted by Farouk et al. in 1999, the risk of damaging the vascular system when using the conventional plating system was 65% compared to no risk at all for the locking plates system [13].

Biswas SP et al. suggested that the external fixation could be another successful treatment for periprosthetic distal femur fractures [14]. This technique is not frequently used due to the requirement of placing the pins intra-articularly, which increases the risk of infection. Even more, pin placement in the quadriceps muscle can reduce the motion of the knee.

Articles covering femoral fractures after TKA

Plating as preferred method

Bae et al. [15] published in 2013 the first article related to femoral fractures from our database, in which they analyzed results and complications of periprosthetic supracondylar femoral fracture treatment using locking or non-locking plates. Out of the 33 patients, a

locking compression plate was used in 14 and a non-locking condylar buttress plate in 19 patients. The study showed no difference in the average time to bone union, KSS (Knee Society Score), or range of motion between the two groups. However, considering the alignment and the position of the implants, the study revealed that they were better without a loss in the reduction angle of >3° for the locking plate group. Moreover, the study showed that the locking plate fixation reduced the incidence of complications such as non-unions, malunions, and loss of reduction compared with non-locking plate fixation.

In 2014, Müller et al. [16] performed a study in order to examine the effectiveness of surgically treated periprosthetic femoral fractures with an orthogonal double plate system. Their study included 10 patients with a mean age of 79,5. The authors mentioned that the surgical indications for this procedure were heterogeneous. The patients presented periprosthetic fractures around total knee arthroplasty and total hip arthroplasty. The patients with TKA had a mean follow up of 22.6 months. Due to the small number of patients, the authors could not state that the orthogonal double plating could be used successfully as a salvage procedure and they recommended investigating in further studies on larger samples of patients. However, orthogonal double plating is not associated with a higher rate of complications in patients with periprosthetic femoral fractures and stable components.

The study conducted by Kim et al. [17], published in 2015, aimed to compare the results between single plating, double plating and the minimally invasive plate osteosynthesis technique for patients with periprosthetic fracture of the distal femur. The 32 patients included in the study were followed up for 25 months. All Su type I and II fractures were treated with single plating technique and Su type III fractures were treated using double plating and the minimally invasive plate osteosynthesis. Double plating technique consisted of two separate incisions and it was used for patients with extremely limited bone stock, such as type III fractures, medial comminution or large segmental butterfly fragments. The union rate was 93.8%, only two patients showed non-union and just one presented delayed union. Based on this statistically insignificant difference, the authors concluded that distal femur fractures can be successfully healed using any of these techniques, even for very distally extended fractures.

A retrospective study conducted by Boesmueller et al. in Wien [18], in 2015, covered 80 patients treated with locking plates system for the femoral fracture after TKA, emphasizing 7 plate failure cases. The purpose of the study was to evaluate the evolution of patients who developed this major complication. All the patients in the study underwent open reduction internal fixation and revision with long-stem prosthesis or bone grafts were used when comminution was present or the quality of the bone was poor. The authors suggested that plate failure is one of the most important complications when using the locking plate system and it should be treated according to the quality of the bone, describing bone grafts, bone cement, tumor prosthesis, or revision with long-stem prosthesis as possible options.

In 2018, Lotzien et al. [19] have published a retrospective study regarding periprosthetic femoral fractures after TKA, which included 45 patients. Interestingly, the aim of the study was to assess the quality of life and functional status by using 3 parameters: the SMFA-D score, mortality rate and union rate. SMFA-D (German short musculoskeletal function assessment questionnaire) is an instrument designed for the evaluation of patients with a wide range of musculoskeletal afflictions and it comprises 46 items divided into 2 sections: the dysfunction section and the bother section [20]. Furthermore, before surgery, patients were evaluated in terms of comorbidities by using The Charlson Comorbidity Index (CCI). CCI is based on the standardization of 19 comorbidities, each one assigned with a certain score depending on its prognosis and mortality risk [21]. The treatment for these patients consisted in locking the plates system and the results of the study showed that the functional

status will be limited and the quality of life will be affected after surgery. Moreover, due to the fact that there was a statistically significant association between the CCI and the SMFA-D score (p=0.045), the authors suggested that CCI could be an important instrument to be used as a predictive factor for postoperative outcome.

Plating vs. intramedullary nailing

In 2014, Gondalia et al. [22] published an article, which consisted of the clinical comparison and the related complications between a plate system and a retrograde-inserted supracondylar nail as treatments for periprosthetic femoral fractures after TKA. 42 patients with periprosthetic supracondylar femoral fractures were included in their database. 24 cases were treated with plating system and 18 cases were assigned to the retrograde-inserted supracondylar nail. Comparing the two groups based on clinical results, no significant differences were found. 7 out of 42 patients underwent revision surgery at a mean interval of 46.4 weeks without any significant difference between the two groups. As a conclusion, the authors stated that the complication rate did not depend on the type of internal fixation as the differences between the 2 groups were not statistically significant, but there was a trend toward higher non-union rates with the plating system method and higher re-fracture rate with the nailing method.

Another retrospective study designed to compare the outcomes of modern intramedullary nails with a locked distal screw versus locking plates for periprosthetic supracondylar femur fractures in TKA was published in the same year by Meneghini et al. [23]. The study described 91 fractures and all of them were displaced fractures with a stable prosthesis, also known as Rorabeck type II fractures. 29 patients underwent internal fixation by retrograde intramedullary nail and 66 patients received locking plates. During the study, six patients died and four were lost to follow-up. The authors reported 2 non-unions in the intramedullary nail group and 12 non-unions in the locked plate group. They also reported that the failure rate of locked plates was twice that of intramedullary fixation, despite a greater quantity of screws used in the distal fragment. Additionally, the authors stated that their study revealed that modern retrograde intramedullary fixation represents a viable technique for treating periprosthetic femur fractures, at least as good as the locking plates technique, even though the second one is more popular.

The comparison between the types of internal fixation went on. Two groups divided by the treatment used for the periprosthetic femoral fracture (intramedullary nailing - 20 patients and minimally invasive plating - 21 patients) were analyzed in a retrospective study in 2015, by Park et al. [24]. There was no statistical difference between the groups, neither preoperative nor postoperative and the evaluation was based on the arc range of motion, the WOMAC score, union and malunion and the fracture state. The WOMAC score (Western Ontario and McMaster Universities Osteoarthritis Index) is a self-administered questionnaire that should assess pain, stiffness and functional status of the knee. The WOMAC score was evaluated before surgery and one year after surgery for both groups. Despite a higher rate of malunion for patients treated by intramedullary nailing, there was no statistically significant difference between the two groups.

In the next year, a new study brought attention to another comparison. In 2016, Matlovich et al. [25] conducted a retrospective study about periprosthetic fractures of the femur, treated with locking plates or intramedullary nails, comparing the outcome based on the fracture site - above or at/below the total knee arthroplasty. Patients were assessed considering the functional status of the knee, time to union, additional requirements, such as blood transfusion or reoperation and postoperative complications. The study showed no statistical difference based on the fracture site, or on the type of internal fixation used for treatment.

In 2019, Kyriakidis et al. [26] aimed to compare not only the locking plates to intramedullary nails, but also cemented and uncemented nails in the treatment of

periprosthetic fractures regarding fracture healing, complications and functional results due to the conflicting results from previous studies, between the clinical outcome after retrograde supracondylar intramedullary nails against locking plates for the treatment of periprosthetic supracondylar femoral fractures. Their retrospective study included 60 patients with Rorarabeck type I or II fractures and 29 cases were treated with intramedullary nails. The authors observed that the locking plates group was significantly younger than the intramedullary group. In order to compare the two groups, they used the ASA score (American Society of Anaesthesiologists) that focuses on the health status of the patient before surgery [27], follow-up time, fracture type and mechanism of the injury and concluded that both methods are equally good if the bone stock of the patient is good. However, the authors mentioned that cemented nails might increase stability and healing capacity in elderly osteoporotic patients.

Other surgical treatments

A retrospective study conducted by Hoellwarth et al. [28] in 2017 focused on the comparison between locking plates for 87 patients and distal femoral arthroplasty for 53 patients, considering mortality, the motion of the knee and the need for further surgery. Their study suggested that there are no statistical differences between these two methods, but treatment should always be adequate for the patient's bone quality, quality of life before treatment, comorbidities and fracture location as well.

Allografts have also been considered in the treatment of periprosthetic fractures after TKA. A study of 68 patients performed in 2014 by Leino et al. [29] evaluated the outcome of the surgical treatment for periprosthetic supracondylar fractures. Internal fixation was used for patients with enough bone stock and patients with a loose prosthesis component underwent revision. The plating system was used with or without strut grafts with the purpose of evaluating the role of allografts in the healing of the fractures. The results showed there was no statistically significant difference between the internal fixation group or the revision group and the survival rate at 3 years was the same for both techniques, the survival rate of fractures that benefited from strut grafts was 80% compared to that of 51% observed in the group treated with internal fixation without strut grafts.

In 2014, Saidi et al. [30] proposed another comparison between three types of treatment methods for comminuted distal periprosthetic fractures of the femur. Their study included 23 patients with a mean age of 80. Their techniques included allograft prosthesis composite, revision system, and distal endoprosthesis. Their study showed that the operative time and the blood loss are significantly higher in patients with allograft prosthesis composite compared to the other techniques. However, there was no significant difference between the 6-week or the 6-month Knee Society Score. The authors also suggested that distal femur endoprosthesis should be used in elderly patients with poor bone quality.

In 2018, a retrospective study from Turkey, conducted by Çiçek et al. [31] included 22 geriatric patients with femoral fractures after TKA. The preferred method for treatment was the double locking plates system along with prosthesis revision when the union was not achieved or bone enhancing means for osseous defects or comminution. Their study resulted in early mobilization, but no other conclusion was drawn due to the lack of a control group.

Total knee arthroplasty associated with total hip arthroplasty

Another retrospective study covering the periprosthetic femoral fracture was published in 2016 by J. Zwingmann et al. [32], including 47 patients with fractures of the femur, after hip or hip and knee arthroplasty. The aim of the study was to compare the outcome of open reduction internal fixation to revision arthroplasty for periprosthetic femoral fractures after total hip arthroplasty, but 8 patients were also diagnosed with femoral fracture after TKA. All 8 patients underwent open reduction internal fixation with locking plates and, when necessary,

additional surgical treatment was used such as bone grafts or additional wires. Considering the Oxford Knee Score and the Knee Society Score, all patients achieved good or excellent results.

Total knee arthroplasty associated with total hip arthroplasty brought attention to another type of fractures - interprosthetic fractures. In 2019, Bonnevialle et al. [33] published a retrospective study related to 51 patients with fractures of the femur after total knee and total hip arthroplasty. Their study included both periprosthetic (21 fractures - 12 around the total hip arthroplasty and 9 around the total knee arthroplasty) and interprosthetic fractures (30 fractures involving the diaphysis segment with no implant). The study aimed to identify the mortality and morbidity, evaluate the clinical and radiological outcome and to create a certain guideline for the treatment of interprosthetic fractures. They recommended the use of a locking plate system over conventional plating for periprosthetic fractures, taking into consideration a lower risk of damaging the osseous tissue.

A previous article about interprosthetic fractures was published in 2015 by Hoffmann et al. [34], when 143 patients who presented periprosthetic fractures of the femur were screened for interprosthetic fractures as well. 32 out of 143 patients were diagnosed with an interprosthetic fracture and the purpose of the study was to evaluate the treatment, in terms of surgical procedure, clinical and radiological evolution, and complications. The study suggested that these fractures should be treated taking into consideration the patient and also the quality of the bone, along with the anatomy of the fracture site.

New perspectives on periprosthetic femoral fractures

Vestermark et al. [35] brought a new perspective to medical literature in 2018, with a retrospective article regarding 7 patients with femoral condyle insufficiency fracture after TKA. Interestingly, preoperatively, 5 patients had valgus alignment and they suffered a fracture of the medial condyle after TKA, whereas the other 2 patients had varus alignment and their fracture after TKA was situated at the lateral condyle. Surgery for this fracture involved femoral component revision and stemmed implants. Despite the low number of cases and the lack of a control group, these results suggested that patients with an abnormal alignment could suffer from a fracture of the unloaded preoperative femoral condyle after TKA and raised new concerns regarding the way TKA should be performed for these patients, especially for women with poor bone stock.

One of the most recent studies in our database was published in 2019, by Karam et al. [36]. The authors focused on an uncovered topic in previous articles: the comparison between prosthetic and non-prosthetic femoral fractures, treated with locking plates, based on risk factors and postoperative outcome. The retrospective study included 68 patients with periprosthetic fractures and 57 patients with non-periprosthetic fractures. The results showed that there are no statistically significant differences between these 2 types of fractures in terms of risk factors or outcome. The authors suggested that these results should lead to a future common approach to both femoral fractures.

Articles covering tibial fractures after TKA

In 2017, Kim et al. [37] aimed to evaluate the effectiveness of the minimally invasive plate osteosynthesis (MIPO) technique with locking plates for periprosthetic tibial fractures after TKA. Their study covered 16 patients. In four cases, they performed MIPO using locking plates on the medial side, in two cases, on the lateral side and in 10 cases, they used locking plates on both sides. Clinical and radiographic results confirmed their hypothesis. The authors noticed that a single locking plate usually provided good results in diaphyseal fracture and double plates were extremely efficient in metaphyseal fractures due to the lack of bone stock. They also suggested that minimally invasive approach could improve the union rate and lower the infection rate and should be further investigated.

In 2018, Schreiner et al. [38] conducted another study focusing on tibial fractures and it included 9 patients with periprosthetic fractures of the tibia. The surgeons performed 6 minimally invasive plate osteosynthesis, one revision arthroplasty, one arthrodesis, and one amputation. The postoperative complications included impaired wound healing, infection and re-fracture or peri-implant fractures. Radiological analyses showed 4 cases of abnormal alignment after reduction and plate fixation. The authors stated that the periprosthetic tibial fractures are not as common as periprosthetic femoral fractures, leading to no statistically significant results in literature. Their research on medical literature revealed that these fractures affect elderly patients with reduced bone quality and reveal a high complication rate and they suggested that individual planning and treatment should be done considering the patient's condition and reaching for a better recovery.

In 2019, Michael P. Morwood et al. [39] published a retrospective study involving 38 patients. There were two types of fractures based on the cause of the fracture: 21 patients sustained high-energy injuries and 17 sustained low energy injuries. All patients were treated with open reduction internal fixation (ORIF). The main purpose of the study was to investigate if there were any differences between dual and single plating. The authors concluded that there were no statistically significant differences regarding the bone healing at the fracture site or postoperative complications.

Articles covering femoral and tibial fractures after TKA

In 2015, a team in Berlin (Mardian et al. [40]) conducted a study aimed to analyze both the functional outcome and the quality of life after surgical treatment of periprosthetic fractures following TKA. Their study included 25 patients and the methods used for treatment were open reduction internal fixation by plates with addition revision when necessary. After a mean follow-up of 34 months, the Knee Society Score and Range of Motion were measured and their analysis showed that there was no impact on the outcome based on fracture type or treatment method. However, a significant correlation was revealed by the study, between the functional outcome (measured by the Knee Society Score) and the quality of life (evaluated with Short Form Health Survey [36], a self-administered questionnaire).

In their study from 2018, Nagwadia et al. [41] studied osteosynthesis for periprosthetic fractures with stable implants in 43 patients having 45 fractures operated between 2010 and 2015. The physicians used different implants according to the type of the fracture - locked compression plates, dynamic compression plates, and dynamic compression screws. Furthermore, patella fractures were treated by tension band wiring. They suggested that adequate treatment should always be assigned taking into consideration the anatomy of the fracture and the bone stock. Moreover, based on their sample, they mentioned that femoral fractures are more frequent than tibial or patellar fractures and they affect women more often.

A study published in 2018 emphasized that periprosthetic fractures are severe injuries and are associated with a high rate of adverse events after the surgical treatment. It was conducted by Schreiner et al. [42] and designed as a retrospective study that investigated 50 patients treated for periprosthetic fractures of the femur, tibia, or patella after TKA, between 2011 and 2015. After considering their data and analyzing their results, the authors concluded that these fractures especially affect patients with a complex background of comorbidities and a history of conditions related to the affected joint, such as joint infection. Due to these findings, they suggested that all periprosthetic fractures should be treated in specialized centers on traumatology and arthroplasty.

Discussions

The aim of this paper was to review the clinical studies related to periprosthetic fractures after total knee arthroplasty from the last six years, in order to understand current

perspectives, epidemiology, treatment, and management.

Our review summarized the data from 25 retrospective studies published between 2013 and 2019. Due to the heterogeneity of the articles, we considered that articles should be grouped depending on the type of fracture as the first criterion, secondly, on the preferred method of treatment and finally, depending on the year of the publication.

Femoral fractures are more frequent than fractures of the tibia [43-45]. Most of the articles covered the treatment of periprosthetic femoral fractures by using locking plates systems or by using both plates and intramedullary nails, in the attempt to guide future practitioners. Most of the articles concluded that there are no significant differences between these two methods. Non-locking plates have been used only in the study conducted by Bae et al. and the significant results showed that locking plates lead to a better outcome. Other studies included allografts and revision of the prosthesis as treatment, leading to similar results when compared to internal fixation. External fixation has been used in only one study, for only one patient.

Other aspects revealed by studies from our database were the association between The Charlson Comorbidity Index and SMFA-D, the importance of varus/ valgus alignment before total knee arthroplasty as a potential risk factor for periprosthetic fractures and the lack of significant differences when comparing the risk factors and the outcome of periprosthetic femoral fractures to those of the non-periprosthetic femoral fractures.

The articles discussing the tibial fracture after total knee arthroplasty had no statistical significant results to guide future practice, but authors suggested adapting the treatment to the characteristics of the fracture and the patient. A similar conclusion can be drawn considering the articles that include both femoral and tibial fractures.

Taking into consideration these findings, we can assert that further studies should be performed on larger samples of patients in order to achieve significant results.

In 2017, Canton et al. published their review, which included a larger database (52 studies) than ours, but the results were similar, concluding that arthroplasty, intramedullary nailing and locking plates are all appropriate methods of treatment that should be chosen depending on the patient and the fracture type [46]. The same conclusion was revealed by other reviewers before [47, 48], and some authors have tried to guide physicians on how to choose between these methods, based on some criteria that can be found in the articles from our database as well. Kuzyk et al. recommend choosing a fixation method, such as plates or nails, whenever the fracture occurs near a stable prosthesis, with enough bone quantity and quality to sustain fixation and competent collateral knee ligaments [49], otherwise revision should be considered. However, physicians should keep in mind that these recommendations are not based on studies with level 1 or 2 of evidence.

There was a wide range of comorbidities and risk factors described in our database; increased age, female gender, osteoporosis, obesity, diabetes and rheumatic afflictions were more frequent, which is similar to non-prosthetic fractures [50-52].

Despite the heterogeneity of our database, all articles imply that periprosthetic fractures are becoming more and more frequent, due to the increase in total arthroplasty and also to a better healthcare system, that allows a higher life expectancy.

The limitations of our study were related to sampling (a small sample size and a heterogeneous sample).

Conclusions

Periprosthetic fractures after total knee arthroplasty represent an important problem in medicine, but due to the low number of cases. Despite the increase in incidence, guidelines are mostly based on retrospective studies, personal observations, and expert opinion. The consensus is that treatment should be assigned depending on the patient's profile and the fracture's characteristics. Further studies

should be performed in order to guide future practitioners in the treatment of periprosthetic fractures.

Conflict of Interest statements

Authors state no conflict of interest.

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