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Current evidence and new challenges in periprosthetic hip and knee fractures

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Summary

Periprosthetic fractures (PPF) constitute an issue of increasing importance for orthopedic surgeons. With the continuous advancement of less invasive surgery techniques and the progressively ageing population, prosthetic replacement procedures have become routine. PPF are complex conditions that can compromise the outcome of surgery and the patient's quality of life. However, in some cases, revision surgery is required. In this article we will analyze the epidemiology, risk factors, different classifications, management, and evolution of treatment of hip and knee periprosthetic fractures.

Key word: hip, knee, femur, tibia, periprosthetic fracture

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Conflict of interest
The authors have no conflict of interest to declare.

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Introduction

The overall number of periprosthetic fractures (PPF) is rising, due to three main risk factors: the increasing number of total hip and knee replacements being performed in Western countries and the global median age combined with the prevalence of bone weakening pathologies in elderly patients [1].
Intraoperative periprosthetic fractures occur 14 times more frequently with un-cemented implants than with cemented ones, especially in patients over 65 years of age. Much more often, however, fractures occur in un-cemented prostheses because of low-energy trauma, regardless of gender [2]. The difficulty of treatment depends not only on fracture management, but above all on the stability of the prosthesis.
Furthermore, general and local factors can play an important role. General conditions, functional requests, patient compliance, and comorbidities are extremely important and must be taken into account. Local factors consist in the intraoperative stability of the implant, bone stock, and biology of the bone. In case of elderly patients with other pathologies, who poorly comply with their therapeutic and rehabilitative plan, choosing the least invasive type of procedure is preferred. Very often, however, in order to avoid complications due to extended bed rest and allow early load, prosthetic replacement is the surgical choice. For young patients, bone stock preservation is imperative, in consideration of their long-life expectancy and the high probability of a revision [3].

Epidemiology

In total hip arthroplasty (THA) the incidence of PPF varies from about 1 to 2.3% and is higher when using un-cemented prostheses instead of cemented ones (3 *vs* 0.2%); for women, compared to men, these percentages increase over the years. In THA revisions, the total incidence is even higher at 12.3% [2,4].

In total knee arthroplasty (TKA), the incidence of PPF varies between 0.3 and 2.5% for the first implants and increases up to 38% after revision, with an average of 25.5 months between the TKA and possible fracture [5,6].

The mortality rate following a femur PPF is significantly higher compared to a simple femur fracture. The increase in mortality affects both THA and TKA and is higher after surgery, reaching 8% in the first post-operative month and 27% after the first year. Survival decreases in older patients [2,7].

Risk factors

Numerous factors can predispose to PPF. Patient-associated factors include advanced age, female gender, neurological and walking disorders, and more generally all conditions causing a depletion of bone mass such as osteoporosis, osteomalacia, Paget's disease, and osteopenia due to corticosteroid therapy [1]. Prosthetic-related factors include local bone resorption and osteolysis phenomena, which can occur as a result of implant mobilization and bone defects [8].

Classification

PPF are generally categorized and classified based on the fracture site, but the classification can also take into account other criteria. For instance, how long after the prosthetic replacement surgery the fracture occurred and the stability of the implant [9].

The Vancouver classification for Periprosthetic Hip Fractures is the universal reference and is based on the fracture site and type, stability of the implant, quality of the periprosthetic bone stock (Tab. I) [10,11].

There are several classifications for periprosthetic knee fractures and the most widely used is Rorabeck and Taylor. It evaluates fractures of the femoral component and takes into account bone fragment displacement and stability of the prosthetic components, but does not evaluate bone stock quality (Tab. II) [12].

Felix's classification concerns PPF of the tibial component, although less frequent, and divides them into four categories (Tab. III).

Patella fractures are categorized following the Goldberg classification, which is based on the integrity of the extensor apparatus and stability of the patella surface [14].

Periprosthetic hip fracture

There are currently no defined guidelines for the treatment of hip PPF. The choice of treatment depends on the type of fracture according to the Vancouver classification [2].

In general, the loss of bone stock and the general conditions of the patient, often compromised, makes surgery more difficult. Revision surgery is basically inevitable in case of high comminution fracture or loosened prostheses [15,16].

The implant stability is evaluated both by CT scan and intraoperatively. The proposed treatments are, therefore, open reduction and internal fixation (ORIF) or revision [7].

Generally speaking, there is unanimity in defining internal fixation as the treatment of choice for B1 fractures and revision as the best treatment for B2, B3, and C fractures, whereas most AG-type fractures are avulsions of the greater trochanter which are treated conservatively [2,17,18].

Table I. Vancouver classification.

Classification		Fracture location	Treatment
A	AG	Greater trochanter fracture	Non-operative or ORIF
	AL	Lesser trochanter fracture	Non-operative or ORIF
B	B1	Fracture around the prosthesis, stem well fixed	ORIF
	B2	Fracture around the prosthesis, stem is loose	Revision arthroplasty
	B3	Fracture around the prosthesis, loose stem and poor proximal bone stock	Revision arthroplasty
C		Fracture distal to tip of stem	ORIF

Table II. Rorabeck and Taylor classification (from Rorabeck, Taylor, 1999, mod.) [5].

Type	Fracture		Treatment
I	Non-displaced fracture	Prosthesis is intact	Non-operative
II	Displaced fracture	Prosthesis is intact	Internal fixation
III	Non-displaced or displaced fracture	Prosthesis is loose or failing	Revision

Table III. Felix classification (from Benkovich et al., 2020, mod.) [13].

Type	Fracture
I	Fracture of tibial plateau
II	Fracture adjacent to tibial stem
III	Fracture of tibial shaft, distal to component
IV	Fracture of tibial tubercle

After the surgery, the aim is to reduce bed rest time in order to minimize complications, allowing fast functional recovery. The most frequent complications are: non-union, fracture recurrence, aseptic loosening, recurrent dislocations, local infections, post-surgical stiffness, and limping [2,17,19].

Periprosthetic knee fracture

As for fractures of the proximal femur, there are no precise indications regarding management of distal femur fractures in patients with TKA [6]. The conservative treatment of supracondylar fractures is based on skeletal traction and immobilization of the limb. Skeletal traction is hard to implement because it requires prolonged immobilization and can lead to local and systemic complications, such as pressure ulcers and thromboembolic events. For these reasons, it is no longer in use [20].

The most used surgical osteosynthesis techniques for supracondylar fractures are plate and screw synthesis and intramedullary nailing [6]. In this case, early patient mobilization is essential to minimize complications associated with internal fixation, among which non-union stands out [21,22].

In patients with low bone stock or significant bone loss, obtaining a stable fracture synthesis is not possible, and therefore the use of megaprostheses should be considered. The use of this technique allows the patient to gain early weight bearing, recovery of an acceptable range of motion, and a better long-term result, despite an increased rate of post-operative complications and mortality [23,24].

Tibial fractures are a minority of periprosthetic knee fractures with a prevalence of 0.07-0.1% [25]. Tibial plateau fractures generally cause loss of implant stability and are treated with revision arthroplasty, while fractures without mobilization can be treated with open reduction and internal fixation (ORIF) [26].

Methods

For the purpose of this study, we searched the PubMed and Cochrane databases with "periprosthetic fractures, femur, tibia, hip, knee, revision, megaprosthesis" as keywords. We crossed referenced the current insights on periprosthetic fracture treatment with our personal experience, to produce a review of the existing literature about treatment and management of PPF.

Results

By analysis of literature data about treatment of proximal femur PPF, the most common fracture is the Vancouver B1 type. The average age of patients according to Cox et al is 76.6 years; 1-2% of periprosthetic hip fractures were treated conservatively, 70% with ORIF and 27% with revision. Hospital mortality rate was 2.6% [4].

According to Abdel et al., the rate of PPF is much higher in cases treated with un-cemented implants than with cemented ones (7.7 *vs* 2.1%). 82% of AG-type fractures are avulsion fractures of the greater trochanter and 89.7% of these cases were treated conservatively. Among B1 fractures, 77% are treated with ORIF. Among fractures of types B2, B3, and C, 94.2% of cases were treated with THA revision [2,28]. In cases of type B2 and B3 fractures, the most recent studies show that ORIF and the prosthetic revision are comparable in terms of results [27]. It should be noted that a prosthetic replacement of the proximal femur, with massive bone loss, brings about an infection rate of around 2% and a percentage of instability close to 19% [29].

For periprosthetic knee fractures, the average age is 70-76 years. Rorabeck type II fracture is the most frequent, followed by Rorabeck III and I [30]. According to Herrera et al, angular-stable plates give better long-term results than traditional plates. The medullary nail provides better fracture reduction but, in long-term follow-up, has a higher rate of pseudo-arthrosis than plate fixation [31]. Several studies have observed that, the surgical treatment success rates of Rorabeck Type II fractures for patients treated with locking plate systems are similar to that of patients treated with intramedullary nail, respectively reaching 87 and 84% [32-34]. Other studies, however, have shown better results when using locking plate system [35]. Megaprostheses are a valid choice in distal femur PPF, especially if comminuted with bone stock loss; periprosthetic infections are the main complication [36].

Analyzing comminuted fractures of the distal femur, Darrit B. et al pointed out that there is no significant difference in terms of blood loss between ORIF and prosthetic replacement. Moreover, multivariate analyses showed that the mortality rate of the two groups appeared to be overlapping [37]. However, Saidi et al. concluded in their study that blood loss and recovery time are reduced when revision surgery was performed [38].

Discussion

Considering the increased incidence, long-term consequences, and increased mortality rate, hip and knee PPF constitute an issue of increasing importance for orthopedic surgeons. Currently used osteosynthesis systems represent an evolution in the treatment of this type of fracture. Locking plate systems preserve periosteal vascularization, allow minimally invasive techniques, and give better stability in poor bone stock compared to conventional plating systems. Low contact plates respect bone biology and minimize soft tissue damage. The load is distributed from the screw to the plate allowing for both compression and/or angular stability (depending on the surgeon's choice and the fracture type). However, callus formation is sometimes inconsistent and asymmetrical, so that their use can cause delayed union and pseudo-arthrosis. As stated by Bottlang et al., the high stiffness of the angularly stable plates reduces micro-movements around the fracture site, reducing callus formation [39].

Far cortical locking (FCL) screws can be seen as a new frontier in traumatology. Combined with locking plates, FCL screws show greater elasticity of the construct, promoting callus formation [40]. Moazen et al. demonstrated in 2016 that FCL screws guarantee and increase fracture site micro-movements, but also the stability of the PPF synthesis under axial and torsional loads. Therefore, their use is recommended in case of stable fractures (possibly with 1 mm gaps between each fracture fragment). However, other methods of synthesis such as long revision stems are advisable in case of PPF with unstable implant [41].

Prevention is a continuous process, starting from the first implant surgery, and then with post-operative radiographic checks to be repeated over the following months. When PPF occur, the primary objective of treatment must be functional rehabilitation for rapid recovery of the patient, in order to ensure implant stability and reduce mortality.

Although the literature does not present a precise and defined management algorithm for these cases, the use of classifications that take into account various aspects is crucial.

When choosing to proceed with ORIF, the principles that must be respected are stable fixation, preservation of soft tissues, and careful pre-operative planning (Fig. 1).

The use of resection prostheses or megaprostheses, in cases with large bone loss and highly comminuted fractures, is a pos-

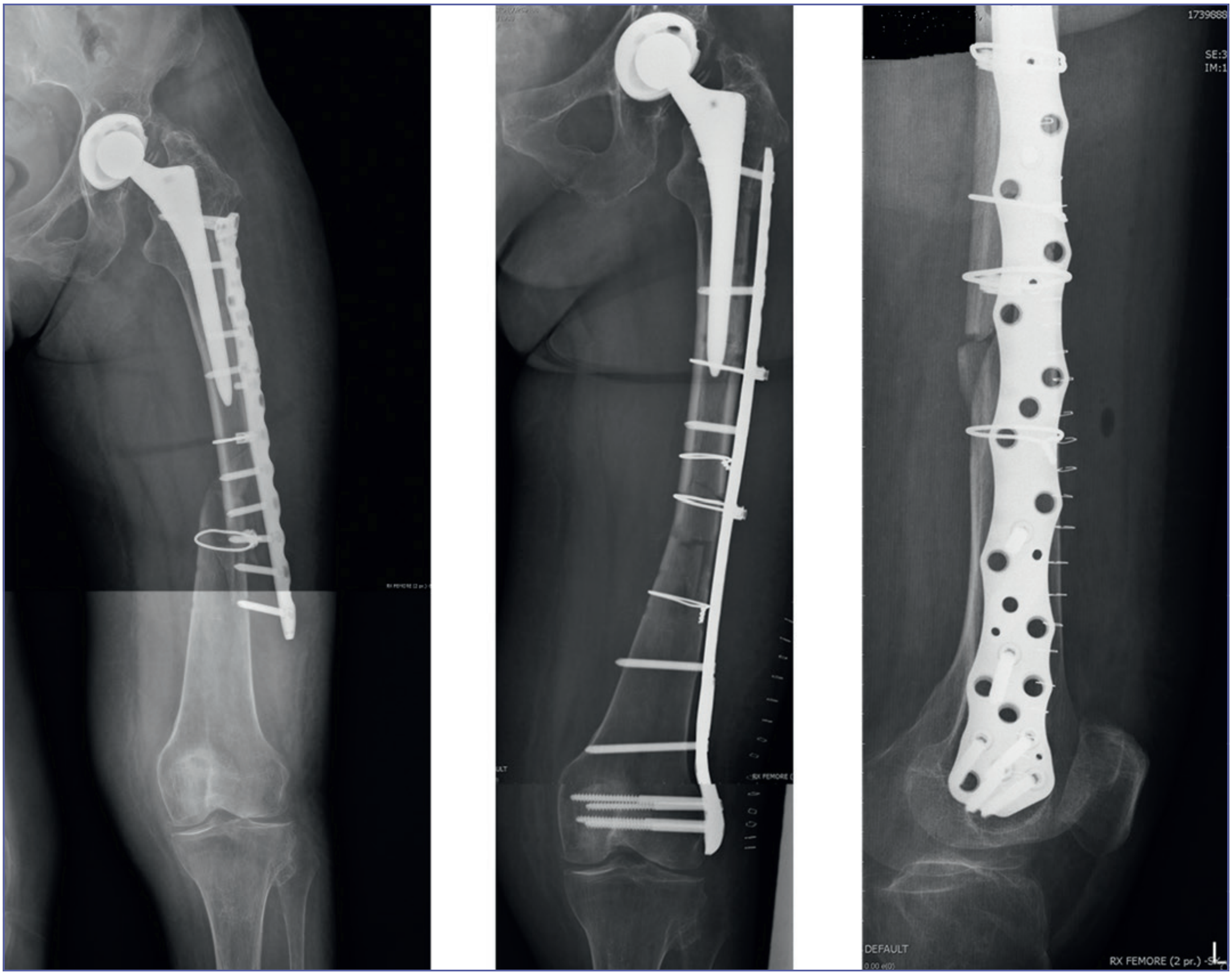

Figure 1. Revision surgery in a failed ostheosynthesis of a periprosthetic fracture.

sible choice. However, we would like to point out the importance of having a team of experienced surgeons, accustomed to using this type of implant and to filling large segmental defects (for example in oncological orthopedic surgery) (Fig. 2) [42].
For the distal femur, there is no significant difference in terms of function, considering the Knee Society Score [37], for fractures treated with prosthesis instead of ORIF. Very often, distal femur fractures, or in any case of fractures involving the joint component, even when treated with ORIF, the result is a severe osteoarthritis which in most cases subsequently requires a prosthetic implant.
The complexity of using resection prostheses or megaprosthesis is complex, and many cases of severe complications are described in the literature, which are often hard to manage. There is a high incidence of dislocations in proximal femur replacements. On the contrary, a high rate of infections is reported in distal femur replacements [36]. Choosing replacement surgery with this type of implant means having to deal with very severe complications to which traumatologists are often not accustomed.
Taking into account to all the above, choosing the right course of action among all the available surgical treatment options is a difficult task, since conservative treatment is not always to be preferred and, in selected cases, it would be appropriate to consider using megaprosthesis.
In addition to improving megaprosthetic skills, the current challenges involve treating fractures in patients who have already undergone treatment of a PPF using ORIF; for example, patients with THA and proximal plate and screws. Our experience has led us to treat cases such as the aforementioned through the use of classic plates modeled preoperatively on the anatomy of the bone segment to be synthesized (Fig. 3).
In other cases, when inter-prosthetic fracture occurs combined with the presence of an ipsilateral THA and TKA, Patel NK et al. suggest to proceed with a reconstruction technique, by using a custom-made megaprosthesis that allows direct attachment to the stem of the retained knee prosthesis [43].

Conclusions

The management of PPF represents a complex challenge. In fact, there is currently no clear boundary between synthesis and revision. The choice is influenced by several factors and the various classifications constitute a valid support, but are not completely sufficient to choose the most suitable surgical procedure. The use of megaprostheses in multi-fragmented and comminuted fractures with bone loss is a viable option, but surgeons must be familiar with surgical techniques and implants. Nowadays, the types of treatment for standard fractures have reached unambiguous indications, as opposed to PPF which require further advancement in terms of approach and treatment. In the most complex cases, such as fractures adjacent to prior PPF, the new perspective should include megaprostheses

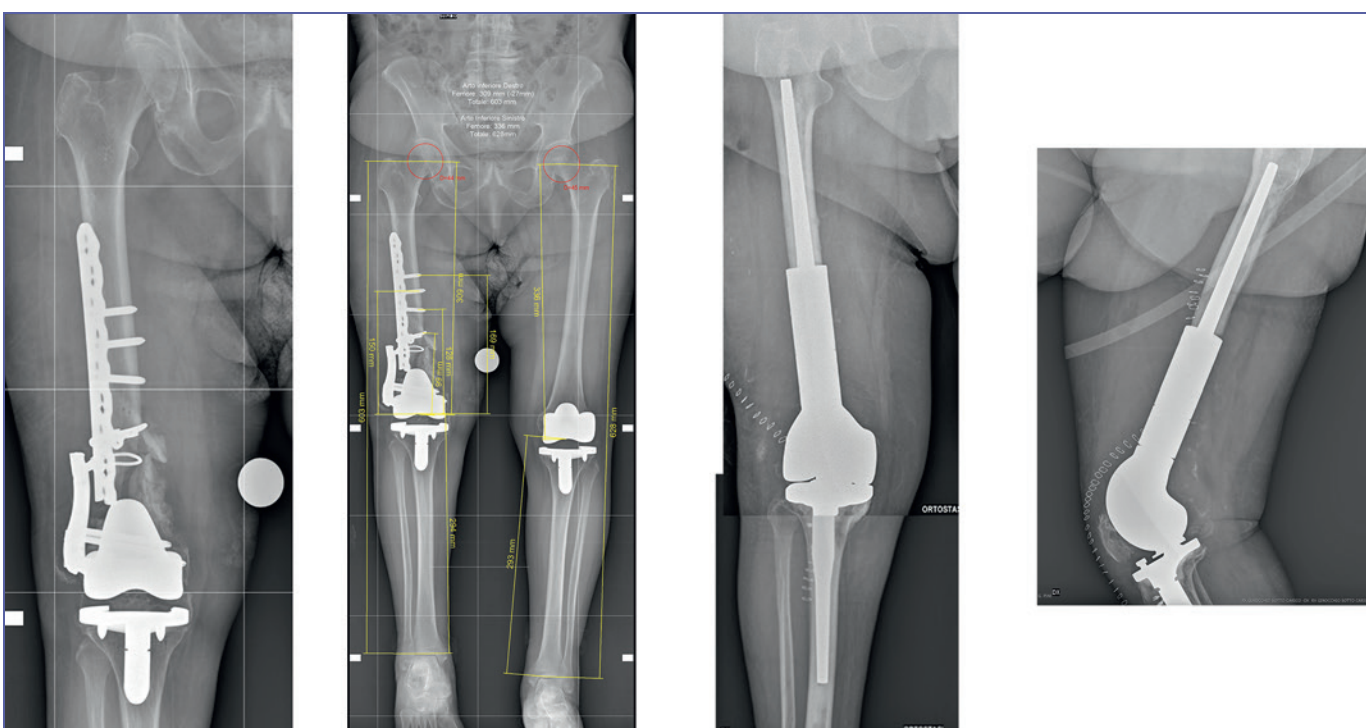

Figure 2. Distal femur replacement with a megaprosthesis in a failed osteosynthesis of periprosthetic fracture.

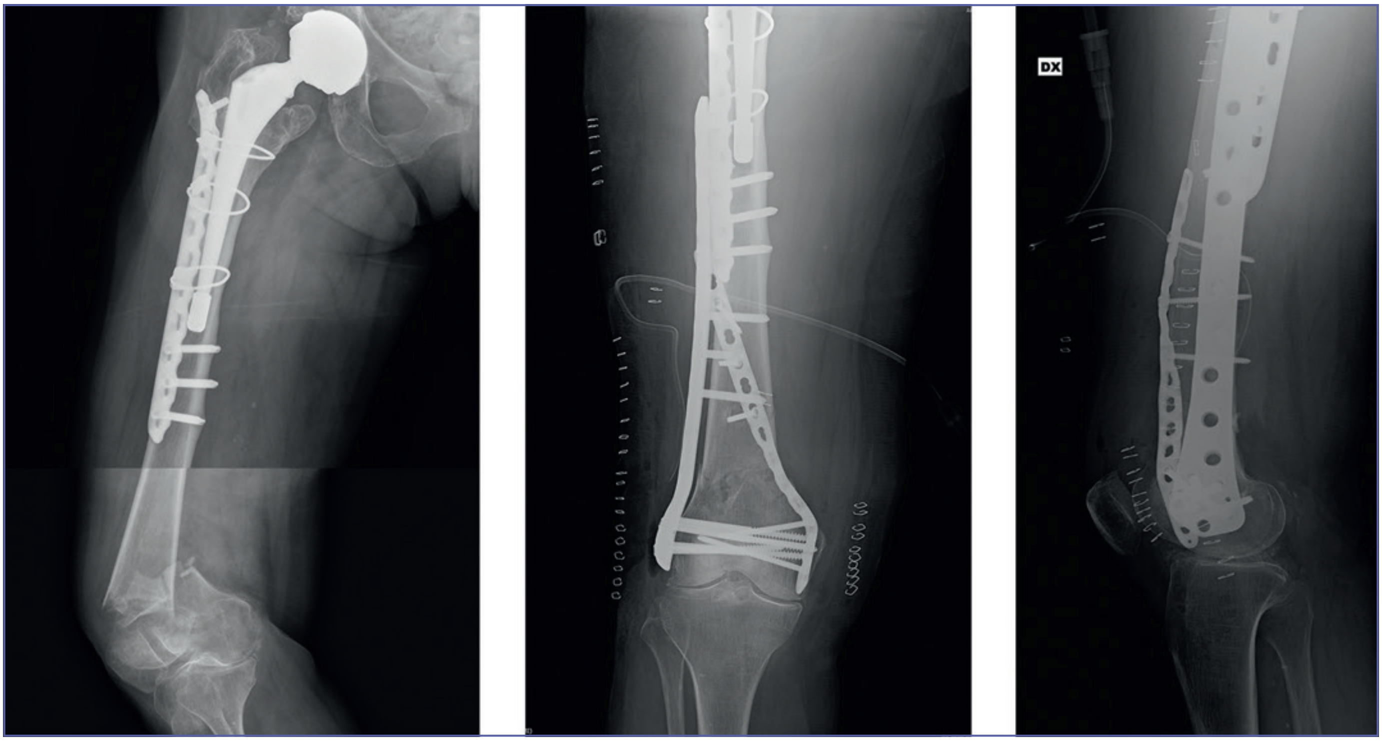

Figure 3. Classic plates modeled preoperatively on the anatomy of the bone segment to be synthesized.

or, alternatively, advanced and patient-specific techniques of synthesis.

References

1. Eschbach D, Buecking B, Kivioja H, et al. One year after proximal or distal periprosthetic fracture of the femur – two conditions with divergent outcomes? Injury 2018;49:1176-1182. https://doi.org/10.1016/j.injury.2018.04.025
2. Abdel MP, Watts CD, Houdek MT, et al. Epidemiology of periprosthetic fracture of the femur in 32 644 primary total hip arthroplasties: a 40-year experience. Bone Joint J 2016;98-B:461-467. https://doi.org/10.1302/0301-620X.98B4.37201. Erratum in: Bone Joint J 2020;102-B:1782
3. Solomon LB, Hussenbocus SM, Carbone TA, et al. Is internal fxation alone advantageous in selected B2 periprosthetic fractures? ANZ J Surg 2015;85:169-173. https://doi. org/10.1111/ans.12884
4. Cox JS, Kowalik TD, Gehling HA, et al. Frequency and treatment trends for periprosthetic fractures about total hip arthroplasty in the United States. J Arthroplasty 2016;31(9 Suppl):115-120. https://doi.org/0.1016/j.arth.2016.01.062
5. Rorabeck CH, Taylor JW, Periprosthetic fracture of the femur complicating total knee arthroplasty, Orthopedic Clinic 1999;30:265-277.
6. Ebraheim NA, Kelley LH, Liu X, et al. Periprosthetic distal femur fracture after total knee arthroplasty: a systematic review. Orthop Surg 2015;7:297-305. https://doi.org/10.1111/os.12199
7. Drew JM, Griffin WL, Odum SM, et al. Survivorship after periprosthetic femur fracture: factors affecting outcome. J Arthroplasty 2016;31:1283-1288. https://doi.org/10.1016/j.arth.2015.11.038
8. Giaretta S, Momoli A, Porcelli G, et al. Diagnosis and management of periprosthetic femoral fractures after hip arthroplasty. Injury 2019;50(Suppl 2):S29-S33. https://doi.org/10.1016/j.injury.2019.01.053
9. Legosz P, Platek AE, Rys-Czaporowska A, et al. Correlations between Vancouver type of periprosthetic femur fracture and treatment outcomes. J Orthop 2019;16:517-521. https://doi.org/10.1016/j.jor.2019.05.011
10. Masri BA, Meek RM, Duncan CP. Periprosthetic fractures evaluation and treatment. Clin Orthop Relat Res 2004;420:80-95.
11. Menken LG, Rodriguez JA, Femoral revision for periprosthetic fracture in total hip arthroplasty, J Clin Orthop Trauma 2019;11:16-21. https://doi.org/10.1016/j.jcot.2019.12.003
12. Konan S, Sandiford N, Unno F, et al. Periprosthetic fractures associated with total knee arthroplasty: an update. Bone Joint J 2016;98-B:1489-1496. https://doi.org/10.1302/0301-620X.98B11.BJJ-2016-0029.R1
13. Benkovich V, Klassov Y, Mazilis B, et al. Periprosthetic fractures of the knee: a comprehensive review. Eur J Orthop Surg Traumatol 2020;30:387-399. https://doi.org/10.1007/s00590-019-02582-5
14. Goldberg VM, Figgie HE 3rd, Inglis AE, et al. Patellar fracture type and prognosis in condylar total knee arthroplasty. Clin Orthop Relat Res 1988;:115-122
15. Sheth NP, Brown NM, Moric M, et al. Operative treatment of early peri-prosthetic femur fractures following primary total hip arthro-

plasty. J Arthroplasty 2013;28:286-291. https://doi.org/10.1016/j.arth.2012.06.003
16 Moore RE, Baldwin K, Austin MS, et al. A systematic review of open reduction and internal fixation of periprosthetic femur fractures with or without allograft strut, cerclage, and locked plates. J Arthroplasty 2014;29:872-876. https://doi.org/10.1016/j.arth.2012.12.010
17 Hoffmann MF, Lotzien S, Schildhauer TA. Outcome of periprosthetic femoral fractures following total hip replacement treated with polyaxial locking plate. Eur J Orthop Surg Traumatol 2017;27:107-112. https://doi.org/10.1007/s00590-016-1851-2
18 Pires RE, de Toledo Lourenço PR, Labronici PJ, et al. Interprosthetic femoral fractures: proposed new classification system and treatment algorithm. Injury 2014;45(Suppl 5):S2-6. https://doi.org/10.1016/S0020-1383(14)70012-9
19 Abdel MP, Cottino U, Mabry TM. Management of periprosthetic femoral fractures following total hip arthroplasty: a review. Int Orthop 2015;39:2005-2010. https://doi.org/10.1007/s00264-015-2979-0
20 Lombardo DJ, Siljander MP, Sobh A, et al. Periprosthetic fractures about total knee arthroplasty. Musculoskelet Surg 2020;104:135-143. https://doi.org/10.1007/s12306-019-00628-9
21 Streubel PN. Mortality after periprosthetic femur fractures. J Knee Surg 2013;26:27-30. https://doi.org/10.1055/s-0033-1333905
22 Campbell ST, Lim PK, Kantor AH, et al. Complication rates after lateral plate fixation of periprosthetic distal femur fractures: a multicenter study. Injury 2020;51:1858-1862. https://doi.org/10.1016/j.injury.2020.05.009
23 Saidi K, Ben-Lulu O, Tsuji M, et al. Supracondylar periprosthetic fractures of the knee in the elderly patients: a comparison of treatment using allograft-implant composites, standard revision components, distal femoral replacement prosthesis. J Arthroplasty 2014;29:110-114. https://doi.org/10.1016/j.arth.2013.04.012
24 Windhager R, Schreiner M, Staats K, et al. Megaprostheses in the treatment of periprosthetic fractures of the knee joint: indication, technique, results and review of literature. Int Orthop 2016;40:935-943. https://doi.org/10.1007/s00264-015-2991-4
25 Felix NA, Stuart MJ, Hanssen AD. Periprosthetic fractures of the tibia associated with total knee arthroplasty. Clin Orthop Relat Res 1997;345:113-124.
26 Kim H-J, Park K-C, Kim J-W et al. Successful outcome with minimally invasive plate osteosynthesis for periprosthetic tibial fracture after total knee arthroplasty. Orthop Traumatol Surg Res 2017;103:263-268. https://doi.org/10.1016/J.OTSR.2016.10.007
27 Stoffel K, Blauth M, Joeris A, et al. Fracture fixation versus revision arthroplasty in Vancouver type B2 and B3 periprosthetic femoral fractures: a systematic review. Arch Orthop Trauma Surg 2020;140:1381-1394. https://10.1007/s00402-020-03332-7
28 Franceschini M, Barbera L, Anticonome A, et al. Periprosthetic femoral fractures in sideways fall configuration: comparative numerical analysis of the influence of femoral stem design. Hip Int 2020;30(2 Suppl):86-93. https://doi.org/10.1177/1120700020971312
29 Parvizi J, Tarity TD, Slenker N, et al. Proximal femoral replacement in patients with non-neoplastic conditions. J Bone Joint Surg Am 2007;5:1036-1043.
30 Kamal A, Dong RJ, Shah R, et al. Management of periprosthetic fractures of knee arthroplasty with revision surgery. J Orthop 2020;22:118-123. https://doi.org/10.1016/j.jor.2020.03.061
31 Herrera DA, Kregor PJ, Cole PA, et al. Treatment of acute distal femur fractures above a total knee arthroplasty: systematic review of 415 cases (1981-2006). Acta Orthop 2008;79:22-27. https://doi.org/10.1080/17453670710014716
32 Gondalia V, Choi DH, Lee SC, et al. Periprosthetic supracondylar femoral fractures following total knee arthroplasty: clinical comparison and related complications of the femur plate system and retrograde-inserted supracondylar nail. J Orthop Traumatol 2014;15:201-207. https://doi.org/10.1007/s10195-014-0287-x
33 Kiluçoğlu OI, Akgül T, Sağlam Y, Yazicioğlu O. Comparison of locked plating and intramedullary nailing for periprosthetic supracondylar femur fractures after knee arthroplasty. Acta Orthop Belg 2013;79:417-421
34 Aldrian S, Schuster R, Haas N, et al. Fixation of supracondylar femoral fractures following total knee arthroplasty: is there any difference comparing angular stable plate fixation versus rigid interlocking nail fixation? Arch Orthop Trauma Surg 2013;133:921-927. https://doi.org/10.1007/s00402-013-1730-9
35 Horneff JG 3rd, Scolaro JA, Jafari SM, et al. Intramedullary nailing versus locked plate for treating supracondylar periprosthetic femur fractures. Orthopedics 2013;36:e561-566. https://doi.org/10.3928/01477447-20130426-16
36 Vaishya R, Thapa SS, Vaish A. Non-neoplastic indications and outcomes of the proximal and distal femur megaprosthesis: a critical review. Knee Surg Relat Res 2020;32:18. https://doi.org/10.1186/s43019-020-00034-7
37 Darrith B, Bohl DD, Karadsheh MS, et al. Periprosthetic fractures of the distal femur: is open reduction and internal fixation or distal femoral replacement superior? J Arthroplasty 2020;35:1402-1406. https://doi.org/10.1016/j.arth.2019.12.033
38 Cannon SR. The use of megaprosthesis in the treatment of periprosthetic knee fractures. Int Orthop 2015;39:1945-1950. https://doi.org/10.1007/s00264-015-2969-2
39 Bottlang M, Doornink J, Lujan TJ, et al. Effects of construct stiffness on healing of fractures stabilized with locking plates. J Bone Joint Surg Am 2010;92(Suppl 2):12-22.
40 Ries ZG, Marsh JL. Far cortical locking technology for fixation of periprosthetic distal femur fractures: a surgical technique. J Knee Surg 2013;26:15-8. https://doi.org/10.1055/s-0033-1333899
41 Moazen M, Leonidou A, Pagkalos J, et al. Application of far cortical locking technology in periprosthetic femoral fracture fixation: a biomechanical study. J Arthroplasty 2016;31:1849-1856. https://doi.org/10.1016/j.arth.2016.02.013
42 Evans S, Laugharne E, Kotecha A, et al. Megaprostheses in the management of trauma of the knee. J Orthop 2015;13:467-471. https://doi.org/10.1016/j.jor.2015.10.024
43 Patel NK, Whittingham-Jones P, Aston WJ, et al. Custom-made cement-linked mega prostheses: a salvage solution for complex periprosthetic femoral fractures. J Arthroplasty 2014;29:204-209. https://doi.org/10.1016/j.arth.2013.03.032