Combined Surgical And Medical Treatment For Periprosthetic Femoral Fractures Over A Stable Stem (Vancouver Type B1 And C): A Proposal Of A Therapeutic Algorithm To Reduce The Risk Of Nonunion.

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Abstract

Background: There is lack of consensus regarding best operative fixation strategy for periprosthetic femoral fractures (PFFs) around a stable stem. Based on our experience in the treatment of nonunions after PFFs and other challenging cases and on Literature, we propose an algorithm that can guide in choosing the ideal surgical technique even for first-time PFFs with a stable stem.

Methods: We retrospectively reviewed data on patients who failed to heal after a surgically treated Vancouver type B1 or C PFF. All patients were treated with locking plate, double structural allograft and autologous bone marrow concentrate (BMC) over a platelet-rich plasma (PRP)-based membrane at fracture site. All patients were also pharmacologically treated with Teriparatide in the postoperative period. We studied patients with radiograms, histological evaluation of the nonunion area, and phosphocalcic metabolism. Patients were assessed subjectively, clinically and radiographically until healing and then annually.

Results: All nonunions healed over a six months period, and functional recovery appeared to be good. Retrospective evaluation of the proposed algorithm showed that none of the patients met biological or mechanical criteria such as to make valid the treatment with locking plate alone.

Conclusion: Mechanical factors are not the only issues that should be taken into account when choosing the surgical approach to PFFs over a stable stem. Systemic and local biological conditions are factors that should drive to a rigid fixation with absolute stability (using a plate and structural allograft) plus local biological support (structural allograft and autologous BMC in a PRP-based scaffold) and systemic anabolic treatment (Teriparatide) in the first instance. A therapeutic algorithm is proposed, given the prosthetic stem to be stable, taking into account mechanical and biological criteria.

Background

The incidence of periprosthetic femoral fractures (PFFs) is reported to be between 1% and 11% over a primary hip femoral stem and up to 18% over a revised hip femoral stem [1–5]. Their treatment is based on level of fracture, implant stability and quality of bone stock, and the comorbidity of the patient [2, 6–9]. The Vancouver classification developed by Duncan and Masri [10] is the most widely used for guiding the surgeon in pre-operative planning [7, 11–13], and it has been developed into the Unified Classification System for Periprosthetic Fractures [14, 15]. New patterns of fracture has also been described for PFF around a hip femoral stem, with different prevalence over uncemented or cemented stem and apparently over stem geometry [16–21]. Modified Vancouver classification and correspondent proposed treatment from Literature are shown in Tables 1 and 2, respectively. Anyway, there is no clear consensus on the optimal method of treatment for fractures around a stable femoral stem hip implant [22–24]. Type B1 fractures represent 30% and type C fractures represent 10% of all PFFs, and their treatment can be associated to a higher risk of complication than other PFFs types and high risk of failure due to nonunion with implant loosening and/or re-fracture [8, 25–31]. Clearly, this entails an important economic expense

[32–34] and a high rate of morbidity and disability for these patients; moreover, mortality after PFFs and their treatment varies with patient age and concomitant disease between 4.5% and 22% [29, 35–39].

To date, most of the studies have produced therapeutic algorithms that focus on implant stability, leaving the choice of treatment to the habit of the surgeon, not defining the best surgical strategy; both minimally invasive plate osteosynthesis (MIPO) obtaining an elastic fixation or open reduction and internal fixation (ORIF) with plate and cerclage with or without a structural allograft (or a second plate) have been advocated, based on mechanical issues [7, 25, 26, 28, 40–45]. Anyway, the biological aspect of the patient has been neglected, considering it as not fundamental for the type of PFF and the surgical approach. Instead, patients with prostheses can present biological systemic and local issues that commonly include multiple medical comorbidities and long lasting medical therapies, and difficulties with postoperative rehabilitation [46]. Also, the PFF can happen over a bone of very poor quality and/or present a pattern such that mechanical issues are not the only local factors to consider to be deficient.

Moreover, studies are present in the literature suggesting that Teriparatide can be usefull in fractures' and nonunions' management as well as for osteoporosis [47–52]. This drug works by stimulating osteoblasts and reducing osteoblast apoptosis, increasing callus formation, improving mechanical strength, and resulting in increased osteoblast life span. To date, Teriparatide is often prescribed to promote bone healing, especially in femoral shaft fractures occurred in patients treated with bisphosphonates (BPs) for a long period.

The aim of this paper is to propose an algorithm of treatment of PFFs over a stable stem (Vancouver B1 and C types), taking into account both mechanical and biological (local and systemic) criteria that can guide the surgeon in choosing the ideal approach, based on results in the Literature and starting from our own results in the treatment of re-fractures / nonunions on PFFs and other challenging cases as atypical femoral fractures (AFFs) over deformed bones or re-fractures over an implant.

Methods

We retrospectively reviewed data of patients who failed to heal after fixation for a PFF, classified as Vancouver type B1 or C, whose re-fractures / nonunions we successfully treated with a combined surgical and medical approach with femoral stem retention.

We surgically aimed to a rigid fixation (absolute stability) plus biological (osteoconductive, osteoinductive and osteogenic) support. All patients were treated using a low contact lateral plate with polyaxial angular stability screws and cerclages (NCB system, ZimmerBiomet, Warsaw, IN, USA) or a compression plate with screws and cerclages (Cable-Ready Extended GTR Plate, ZimmerBiomet, Warsaw, IN, USA), a double cortical structural fresh frozen allograft (medially and anteriorly placed, at 90° each other; mechanical and osteoconductive support) and local apposition of autologous bone marrow cells concentrate (BMC) embedded in an autologous platelet-rich plasma (PRP)-based membrane (Regenkit BMC and Regenkit Extracell Membrane glue, RegenLab, Le Mont-sur-Lousanne, CH) at fracture site (osteoinductive and osteogenic support). All patients were also pharmacologically treated with Teriparatide (Forsteo, Eli Lilly

and Company, Indianapolis, IN, USA) in the postoperative period for at least three months. Teriparatide was prescribed *off label* after adequate informed consent was acquired and under guidance of the Bone Metabolic Unit. Outpatient follow-up was performed at 1, 3, 6, 9 and 12 months after surgery and then annually, including subjective and clinical evaluation with Harris hip score (HHS) [53] and radiographical evaluation.

We studied all radiographs of the patients: pre-operative and post-operative radiographs relative to the first fixation surgery were analysed for potential bone defects, unadvised stem loosening and possible surgical technical errors, and actual radiographs after the re-fracture and in subsequent follow-up visits for fracture healing. All patients were studied for phosphocalcic metabolism before surgery (Table 3), and patient's history was analysed for biological impairment that could be initially unadvised. In some patients, also, a histological study of the nonunion area was performed. Based on these findings, we set up a list of biological local and systemic criteria to be taken into consideration as risk factors for nonunion together with mechanical criteria. All cases were reviewed and evaluated regarding these proposed criteria.

At our Institutions, no Institutional Review Board nor Ethical Committee Approval is necessary for retrospective studies, and patients gave their consent to data collection and anonymous use of them for scientific and teaching purposes.

Results

We present, as example, the cases of the three patients operated on of revision of osteosynthesis with retention of the stem for nonunion over a PFFs with a stable stem. We analysed the reason why, in our opinion, the PFF did not heal and looked for associated biological factors that could justify an increased risk.

In the first patient, a 80-years-old female, (Fig. 1) the PFF was at the tip of an uncemented tapered fluted long revision stem (Vancouver type B1) positioned five years before (second stem revision on a dysplastic hip); she had being on BPs for seven years. Breakage of the plate occurred at 15 months from first osteosynthesis, with revision surgery already scheduled for nonunion. She had no impairment of phosphocalcic metabolism, but it appeared evident that technical errors had been made, the medial cortex comminution not being addressed and, as for the fixation, only cables were used by necessity in the proximal fragment: the femur was very small and completely filled with the stem. Histology showed fibrocartilaginous tissue with some bony islands with osteoclasts and fibroblastic cells, with very rare osteoblasts. At re-fracture surgery, proximal fixation was still with only cables by necessity, but the whole femur was spanned, and rigid fixation was achieved with compression of the structural allograft to the host diaphysis. Bone healing was well evident at three months post-operatively, and it appeared complete at six months.

The second patient was a 77-years-old female (Fig. 2) who experienced a type C PFF over an uncemented double-wedge stem positioned 12 years before for a fragility fracture of the femoral neck; since then, she

had been on BPs therapy. She presented hypovitaminosis D, and at surgery histological findings of giant osteoblasts consistent with an AFF were found. No gross surgical errors were evident but the medially placed structural allograft fractured during fixation, so medial buttress was lost. Also, in the first post-operative period, patient did not assume the prescribed therapy with Teriparatide. At re-fracture surgery, three months after, a hooked plate with only proximal cerclages was used; again, absolute stability was guarantee by compression of the plate and the structural allograft to the host diaphysis. Radiographic bone healing occurred at six months post-operatively.

The third patient (Fig. 3) was a 76-years-old female on chronic corticosteroid (CCS) therapy for myasthenia gravis and presented hypoparathyroidism secondary to a thymoma; she experienced a PFF clear of an uncemented tapered rectangular stem positioned ten years before for hip osteoarthritis; ORIF with morselized bone graft impacted into the medullary canal was performed; fixation was adequate but possibly too much dissection was carried on to access the fracture, resulting in possibly excessive devascularization. Plate breakage occurred at four months from initial surgery; at re-fixation, histology showed nonunion with almost total absence of osteoblasts. A long plate was used, also to bridge the stem with a proximal cerclage to avoid a stress riser between the tip of the stem and a shorter osteosynthesis.

All patients underwent complete clinical and radiographic healing over a six months period, and functional recovery appears to be satisfactory with progressive increase in HHS records. All patients presented more mechanical and biological criteria as risk factors for nonunion, and based on the therapeutic algorithm, they should have been operated on for the first-time PFF with the multimodal combined surgical and medical approach we propose.

Discussion

The main limitations of this study are the small group of patients we analysed and the absence of a control group. Anyway, we focused on a particular group of patients presenting re-fracture / nonunion of a PFF that were treated with repeated osteosynthesis and stem retention: revision arthroplasty for failed osteosyntheses can guarantee good results [54, 55] and re-osteosynthesis can be applied to few cases, even if in continuous increase. Also, we based our proposal of a therapeutic algorithm to reduce failures in PFFs' treatment not only on the analyses of our series but also on the review of Literature [25, 28, 34, 42, 56]. Fractures with a stable stem (Vancouver B1 and C) are commonly treated by ORIF or by MIPO; ORIF can be enhanced with a structural allograft or with a second plate. The variety of methods and implants used, and their combinations implies that no "gold standard" exists. Elastic fixation (relative stability) with minimal soft-tissue damage seems to be preferred [24, 40, 57, 58], relying on biological potentiality of the fracture, while a rigid fixation (absolute stability) is advocate in some other cases [6, 41, 59]. Anyway, all Authors focused their attention over mechanical issues of the PFF [60, 61], without taking into account patient's biological criteria.

As for mechanical criteria, these are already well known. Characteristics of the fracture and type of hardware have been evaluated, with biomechanical studies [60, 62–69] confirming clinical remarks. The use of bicortical screws around the stem is preferable over cerclages alone or cerclages plus monocortical screws, even if a recent clinical study showed no differences in results when only proximal cables where used with a non-locking plate [70]. Also, it can be advisable to span the whole femur with the plate [71]. However, there are fracture's patterns, such as the comminution/resorption of the medial cortex, the presence of a transverse or short oblique fracture at the tip of the stem, the comminution or poorness of bone-stock at fracture site, in which an adequate torsional/sagittal and bending stiffness cannot be guarantee by a lateral plate alone. In these cases, a second mechanical support appears useful. A structural allograft is recommended medially while anteriorly both a structural allograft or a second plate can be used [28, 56, 72–74], sounding better a medial than an anterior reinforcement [64]. A structural allograft is in our opinion better than a second plate as it can bring osteoconductive support as well, especially if a pharmacological anabolic treatment is performed.

Anyway, mechanical elements are not the only factors that should indicate the use of a structural allograft, and biological issues has to be taken into account, as well. A PFF around or at the tip of a cemented stem [20, 75, 76] or over an osteoporotic bone are known to have higher complication rate than other cases [77]. Conditions such as osteoporosis and rheumatoid arthritis or other autoimmune or endocrinological diseases, long lasting CCSs or BPs assumption, AFFs or previous surgeries are indicators of a local and systemic biological impairment that suggest the use of structural allograft even if mechanically it would be unnecessary [6, 9, 31, 78]. Also, smoking is known to be a negative prognostic factor for bone healing, and it has been found in a systematic review as the only biological patient-depending risk factor for nonunion [79].

As for fracture's healing, it is well known that an adequate environment includes mechanical stability and biological osteoconductive, osteoinductive and osteogenic support [80–82]. Also, metabolic pharmacological therapy with Teriparatide showed promising results when mechanical issues are present [73].

Our initial experience on re-fractures [52, 83–85], the one with AFFs when intramedullary nailing is not possible (over a deformed bone or in "periprosthetic" AFFs) [51] and with proximal femur fractures in the elderly (in which we always do a metabolic study of the patient, and eventually proposed an antiosteoporotic pharmacological treatment together to the Bone metabolism Unit) and the review of Literature [47, 86–88], lead us to proposed a surgical aggressive and combined pharmacological treatment even to some first-time PFFs.

In such PFFs that may fail to heal because of mechanical or biological issues, we propose a combined mechanical-biological approach that consists in a rigid fixation (absolute stability) with a lateral plate and structural allograft (better if possible a double strut allograft, at 90° each other, medially and anteriorly) with apposition of autologous BMC & PRP at the fracture site plus medical therapy with

Teriparatide in the postoperative period. In our experience it appeared evident that patients who already failed in previous fixation are likely to achieve a complete healing without further complications.

We so developed a therapeutic algorithm, given the prosthetic stem to be stable (Vancouver type B1 and C) and willing to retain it, taking into account mechanical and biological criteria that could lead us to decide for such an aggressive approach even in first-time PFFs. Mechanical criteria can be major: 1) deficient medial cortex (resorption, wedge fracture or comminution), 2) inability to guarantee an adequate fixation around the stem with only the plate; or minor: 3) a transverse fracture at the tip of a stem, 4) fracture comminution, 5) poorness of bone-stock. Biological criteria can be local or systemic; local criteria are: 1) a fracture around a cemented stem, 2) estimated wide surgical dissection or a previous open access at the affected site, or 3) an atypical pattern of the fracture; systemic criteria are: 4) diseases affecting phosphocalcic metabolism (osteoporosis, rheumatic and/or autoimmune diseases, primary or secondary endocrinological diseases, osteomalacia, Paget's disease, ..), 5) long lasting pharmacological therapies with CCSs or BPs, 6) heavy smoking (≥ one pack/day).

Some of these biological criteria can link each other (for example: an atypical pattern of fracture seems more frequent in osteoporotic patients on long lasting BPs therapy) and can coexist. As for cemented stems, in our opinion it is more a biological issue than a mechanical one: an overlooked failure of the stem-cemented interface has been advocate as a mechanical cause of failure in PFFs around a cemented stem [29, 76] but a reduce capability of bone healing (less viable area, no endosteal callus formation) and an absent opportunity for re-osteointegration are biological issues that are undoubtedly present. Alike, a transverse fracture at the tip of the stem has always been considered a mechanical problem but it also implies biological issues (less surface for bone healing).

If no criterion or just one minor mechanical criterion is present, a MIPO or ORIF technique achieving relative or absolute stability without adding any biological support can be indicated. If one major mechanical or one biological criterion is present, we prefer to perform ORIF with the addition of a medial cortical structural allograft, achieving absolute stability of the construct with some osteoconductive support. If two or more criteria are present (no matter if mechanical ones are major or minor), we suggest ORIF with double structural allograft plus osteoinductive/osteogenic support with autologous BMC and PRP at the site of the fracture. Post-operative systemic anabolic pharmacological therapy with Teriparatide can be added in all cases but, being an *off label* application, we reserve it to patients with one biological criterion or with two or more criteria (or in cases of delayed union). All proposed criteria to be taken into account are recapped in Table 4, and the proposed therapeutic algorithm in Fig. 4.

Onlay cortical structural allograft is a known option for the treatment of PFFs around a stable femoral stem as adjunctive fixation when a plate is used [89]. A structural allograft has both mechanical and biological properties: it confers stability to fracture site, allows a longer working length of the screws if put medially, it has osteconductive properties and it can incorporate and ultimately increase the femoral bone stock [90]. On the other hand, extensive soft tissue dissection and longer operating time for allograft application result in decreased periosteal blood supply to the fracture site and this can be a reason for a

longer time-to-heal (even to nonunion) and a higher infection rate [41, 58, 91]. If we have only one structural allograft, we use to put it medially; anyway, it also depends on femoral bowing, level of fracture and length of the stem with revision stems more likely to need an anteriorly placed allograft as straight stem can head to the anterior cortex and stresses are to be counter on sagittal plane. Anyway, in our setting fresh frozen structural allograft are entire diaphyses and not emidiaphyseal, so we usually have the opportunity to use a double structural allograft.

To reduce such a risk of delayed union or non-union related to extensive dissection, we look for osteoinductive ed osteogenic properties as well [49, 80–82]. BMC is derived from autologous bone marrow, and it is composed of a variety of cells, including mesenchymal stem cells that can contribute to the regeneration of mesenchymal tissues, capable of self-renewal and differentiation into various cell types such as bone, muscle, tendon and ligament. These properties have a positive influence on bone formation, neoangiogenesis and fracture healing [51, 83]. Also, a PRP-based membrane as a scaffold for BMC has already shown enhanced osteogenic and angiogenic properties [92].

Lastly, systemic anabolic support can be of help especially in biologically impaired patients. Parathormone (PTH) is a single-chain 84-aminoacid secreted polypeptide that plays a critical role among the calcium regulating hormones. Although hyperparathyroidism is associated with bone loss, intermittent administration of PTH or its N-terminal 1–34 fragment (Teriparatide) is known to increase bone mass, as anabolic properties of PTH dominate over its catabolic effects. Also, PTH acts upregulating the marker genes associated with osteoblast differentiation. Physiological PTH actions include stimulation of osteogenesis by direct effects on cells responsible of bone formation (osteoblasts) and indirectly by increasing intestinal absorption of calcium and increasing the renal tubular reabsorption of calcium and elimination of phosphate. Evidence is present in the Literature that Teriparatide can be useful in the treatment of nonunions, delayed unions and AFFs [47–52]. Also, in an animal model a combined administration of subcutaneous Teriparatide and systemic human mesenchymal stem cells showed a synergic positive effect on bone healing [93].

We therefore are proposing such an anabolic medical treatment, together with the Bone Metabolic Unit, in foreseeable difficult cases or when surgical dissection is wide and devascularization is likely.

For those reasons, in our opinion, in selected cases it is worthwhile a more aggressive and multimodal approach to avoid re-fractures in PFFs. A more invasive surgery (rigid fixation and absolute stability of the fracture) with local biological support and systemic anabolic medical therapy are key to fracture healing. The intent of our study is to shift attention towards biological parameters to better frame the patient and avoid failures. More studies and even multicentric evaluation can be useful to validate or to reject this algorithm, and to evaluate eventual increase in other complications such as infections.

Conclusions

Nonunions, re-fractures and implant failures can happen after treatment of PFFs, the choice of a correct surgical strategy is essential to avoid new complications and ensure complete healing. In our experience,

MIPO techniques do not always meet biological or mechanical criteria such as to make treatment with locking plate alone sufficient. On the other hand, ORIF especially if associated to structural allograft can jeopardize local vascularization due to the extensive exposure needed. Our therapeutic algorithm is designed to have a more complete vision of the patient and give a more satisfactory surgical approach to these fractures. Our biological and mechanical approach has been proven successful in re-fractures over PFFs cases and other impaired cases (such as AFFs). In our opinion such an approach already at first-time PFF can increase healing rates.

Abbreviations

25(OH)D: cholecalciferol (vitamin D3)

AFFs: atypical femoral fractures

ALP: alkaline phosphatase

BMC: bone marrow concentrate

BPs: bisphosphonates

Ca: calcium

CCSs: corticosteroids

CTX: C-telopeptide of type I collagen

HHS: Harris hip score

MIPO: minimally invasive plate osteosynthesis

ORIF: open reduction and internal fixation

P: phosphorus

P1NP: aminoterminal pro-peptide of type I procollagen

PFF: periprosthetic femoral fractures

PRP: platelet-rich plasma

PTH: Parathormone

Declarations

Ethical approval: Not necessary at our Institution for such a work; the local Ethical Committee confirmed that no formal ethical approval was required.

Consent to participate and for publication: All patients gave their consent to data collection and anonymous use of them for scientific and teaching purposes.

Availability of data and material: raw data are available upon request to corresponding Author.

Conflicts of interest/Competing interests: None to disclosure.

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Authors' contributions: NM conceptualized the study, wrote and reviewed the paper, cured editing. GBC, FM and CC cured data acquisition, collection and analysis, and interpreted the data and drafted the work. VB and SG conceptualized the study, wrote and reviewed the paper. All Authors approved the submitted version and agree to be accountable for all aspects of the work.

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Tables

Table 1. Modified Vancouver classification of PFF.

Modified Vancouver classification of PFF					
A	Apophyseal	A_G	around the greater trochanter		
		A_L	around the lesser trochanter		
B	Bed of implant	B1	around the stem or just below it, stable stem		
		B2	around the stem or just below it, loose stem, good bone-stock	burst	comminution, more frequent in cemented stem
				clamshell	displaced fracture of medial cortex including residual neck, calcar and lesser trochanter, stem stable or loose, more frequent in uncemented stem
				reverse clamshell	displaced fracture of lateral cortex with a “reverse obliquity” pattern, stem loose
				spiral	more frequent in cemented stem
		B3	around the stem or just below it, loose stem, poor bone-stock		
C	Clear of the implant		well below the prosthesis		

Table 2. Proposed treatment for PFF according to modified Vancouver classification.

Treatment of PFFs according to Vancouver types & subtypes					
A	Apophyseal	A_G	A_{GU}	undisplaced	conservative
			A_{GD}	displaced ≥ 2 cm	osteosynthesis
		A_L			conservative
B	Bed of implant	B1	$B1_U$	undisplaced	conservative or osteosynthesis
		B1	$B1_D$	displaced	osteosynthesis
			$B1_C$	at the tip of a cemented stem	revision or osteosynthesis
		B2	$B2_B$	burst	revision
			$B2_{CS}$	clamshell, stable stem*	conservative or osteosynthesis
			$B2_{CL}$	clamshell, loose stem	revision
			$B2_{RS}$	reverse clamshell, stable stem*	conservative, osteosynthesis or revision
			$B2_{RL}$	reverse clamshell, loose stem	revision
			$B2_S$	spiral	revision
		B3			revision
C	Clear of the implant				osteosynthesis
* being the stem stable, they should not probably be considered as B2 PFFs and should be moved into B1 PFFs					

Table 3. Suggested "short" phosphocalcic metabolic panel, including only blood testing without any precise preparation nor a 24-hours urine collection. ALP: alkaline phosphatase, Ca: calcium, P: phosphorus, PTH: Parathormone, CTX: C-telopeptide of type I collagen, P1NP: aminoterminal pro-peptide of type I procollagen, 25(OH)D: cholecalciferol (vitamin D3).

Suggested “short” panel for phosphocalcic metabolism
ALP, U/L (range 55–142)
Ca, mg/dL (range 8.9–10.1)
P, mg/dL (range 2.5–4.5)
PTH, pg/mL (range 15–65)
CTX, ng/L (range 100–700 over 50 years)
P1NP, µg/L (range 15–75 over 50 years)
25(OH)D, ng/mL (range 30–100)
Creatinine, mg/dL (range 0.6–1.1)

Table 4. Criteria used in the proposed therapeutic algorithm. Mechanical criteria can be major or minor, biological criteria can be local or systemic.

Mechanical criteria		Biological criteria	
major	minor	local	systemic
deficient medial cortex[^]	transverse fracture at the tip of a stem	fracture around a cemented stem	diseases affecting phosphocalcic metabolism[§]
inability to guarantee an adequate fixation around the stem with only the plate	fracture comminution	estimated wide surgical dissection or a previous open access at the affected site	long lasting pharmacological therapies with CCSs or BPs
	poorness of bone-stock	atypical pattern of the fracture	heavy smoking
[^] resorption, wedge fracture or comminution			
[§] osteoporosis, rheumatic and/or autoimmune diseases, primary or secondary endocrinological diseases, osteomalacia, Paget’s disease, ..			

Figures

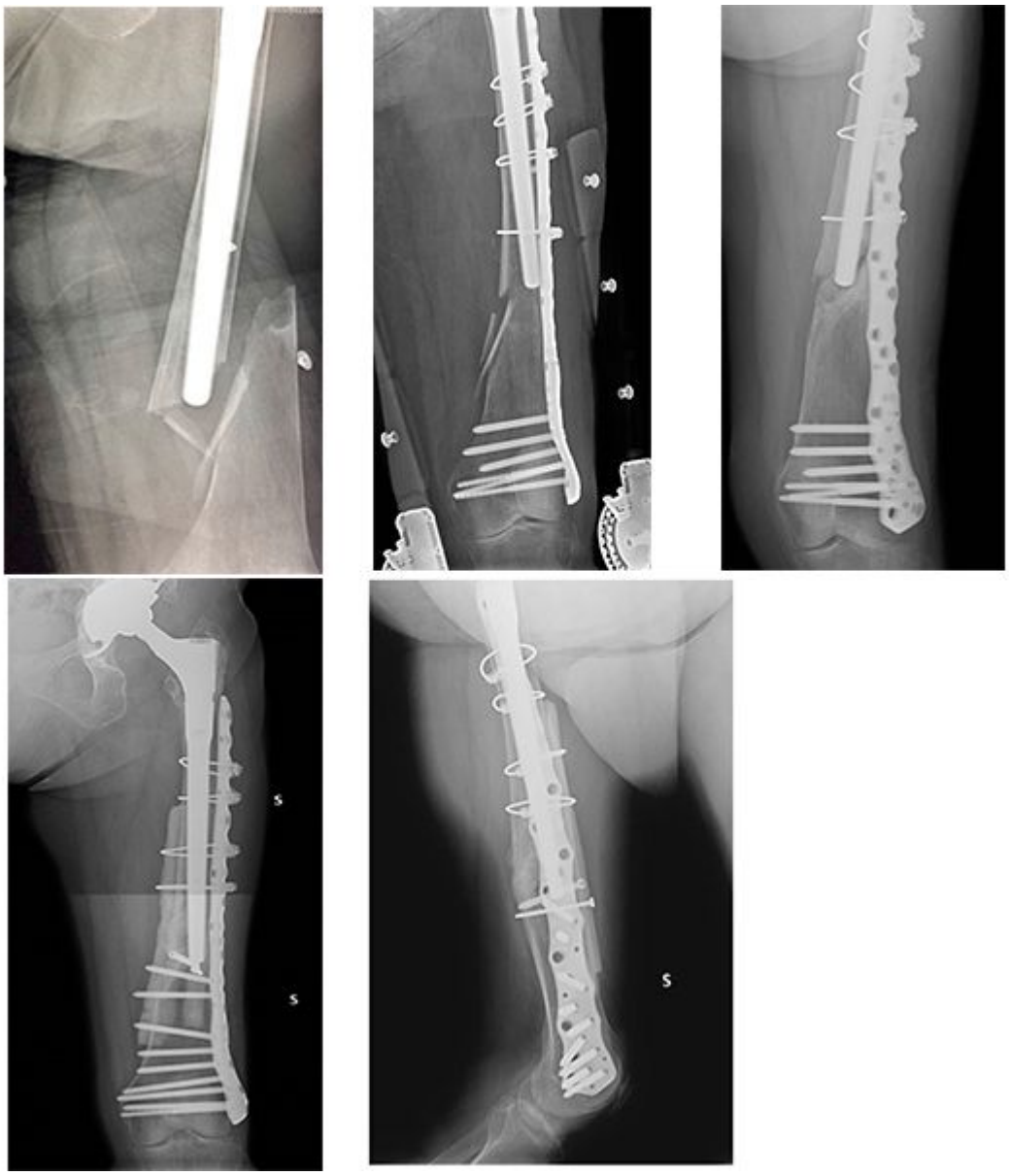

Figure 1

A Vancouver type B1 PFF. B, Elastic fixation with relative stability with MIPO; medial comminution not addressed, only cables by necessity in the proximal fragment. C, transverse nonunion (medial comminuted fragments united to distal major segment) at 14 months; plate breakage occurred a month later. D, E, healing occurred at six months after revision surgery.

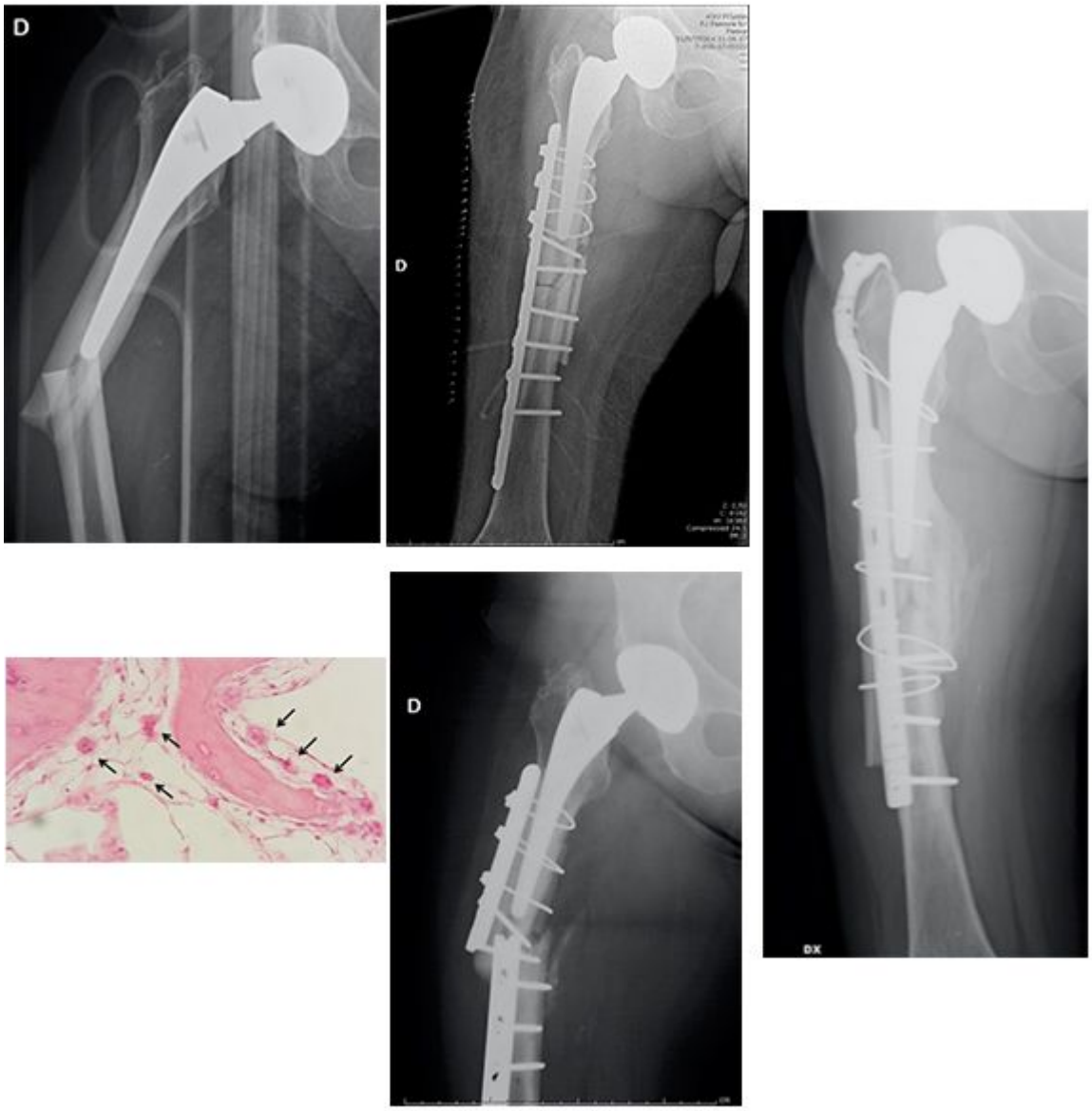

Figure 2

A, Vancouver type C PFF. B, initial treatment with ORIF (plate and screws and cerclages, and a cortical strut), allograft fractured during fixation and medial buttress was lost. C, histological finding of giant osteoblasts (arrows) consistent with an AFF. D, plate breakage at months. E, the fracture healed at six months.

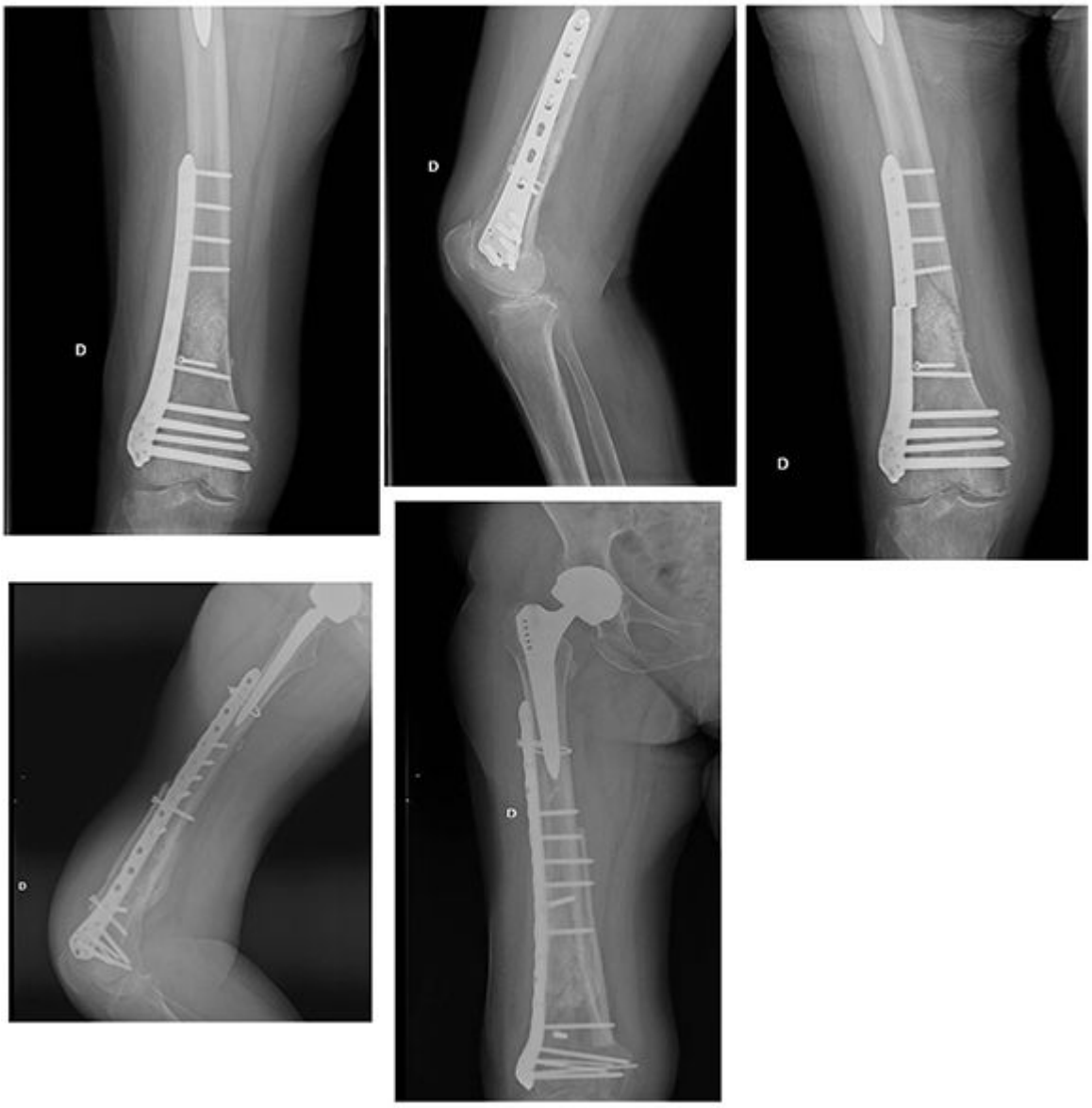

Figure 3

A, B, a Vancouver type C PFF treated with absolute stability (ORIF) and apposition of morcellized allograft. C, Plate breakage and re-fracture at four months. D, E, radiographs at six months showed complete healing, re-fixation was done with a long plate to bridge the stem.

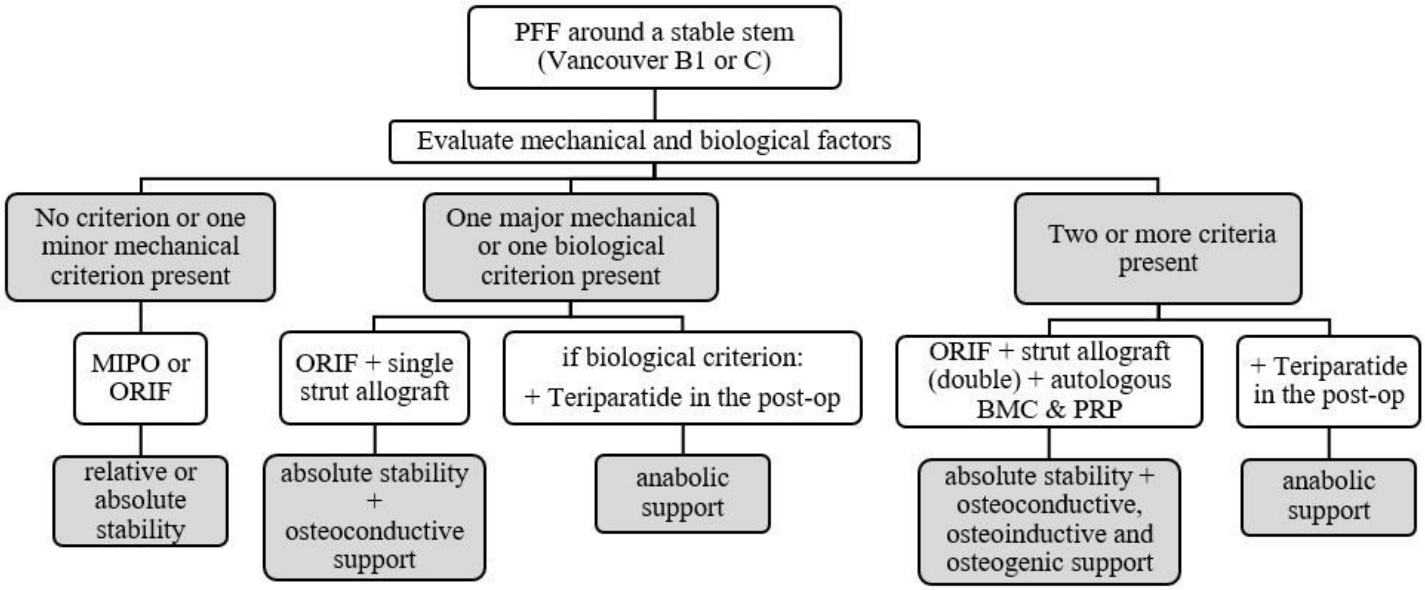

Figure 4

The proposed therapeutic algorithm for periprosthetic femoral fractures over a stable stem (Vancouver type B1 and C). In case of two or more criteria, no matter if mechanical ones are major or minor.