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Current methods and treatment options for interprosthetic femur fracture: an overview

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Summary

As life expectation is prolonged and the elderly population increases, we are witnessing a growth in the number of prosthesis implanted; therefore, an increase in interprosthetic femoral fractures can be expected in the next future. For this reason, a proper and specific classification system needs to be.
Nowadays, depending on the localization of the fracture, Vancouver or Rorabeck classifications are used, and some attempts have been made to create a new one or adjust and adapt the previously mentioned systems. However, there is no unique classification system that is accepted worldwide.
The goal would be a classification that permits identifying the correct surgical treatment based on the type of interprosthetic femoral fracture. A pragmatic grading scale to provide a standardised approach, so that the best possible outcomes could be achieved. Despite minimal diffusion, in our opinion the Pires classification system should be universally accepted and used.

Key words: interprosthetic fracture, Vancouver classification, Rorabeck classification, SoFCOT classification

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Interprosthetic femoral fractures (IFF) are fractures occurring between two prosthetic components implanted in the same femur. They are considered as a developing issue over the last few years in the trauma field, due to the increase in the aging population and, as a consequence, the increase in joint prostheses implanted. Although the actual incidence remains unknown, Valle Cruz et al. reported an incidence of 8.8% [1,2].
IFFs represent a genuine challenge for orthopedic surgeons and are associated with high rates of mortality and revision surgery [3].
The first reported case in the literature about surgical treatment of this kind of fracture dates to 1995, when Dave et al. treated an interprosthetic fracture using a Mennen's plate [4].
Subsequent works focused on the investigation of IFF risk factors, epidemiology, classifications, biomechanics, surgical approaches and techniques, results and outcomes.
However, data in literature do not currently provide an official classification or a gold standard treatment. Moreover, studies are limited by cohort size, standardization and

level of evidence; the creation of a systematic approach appears challenging.

Given the current trend of the aging population, the number of implanted prostheses is increasing, and thus the number of patients at risk of interprosthetic femoral fractures; surgical treatment of such fractures is unavoidably destined to become a routine procedure.

In order to obtain appropriate standardization of classification systems, guidelines, indications, approaches and rehabilitation steps, a deeper insight on all aspects related to interprosthetic femoral fractures is needed. This is of great importance for several reasons: the severity of the injury and its substantial impact on patient morbidity and mortality; potential negative outcomes; level of surgical skills and knowledge needed to appropriately provide satisfactory treatments.

The aim of the present study is to carry out a narrative literature review on interprosthetic femoral fractures, including all relevant aspects and focusing primarily on classification, biomechanics and surgical indications; to sum up current knowledge about this type of fracture to highlight the most up to date evidence presented in literature and reporting our experience and considerations.

An electronic search was performed throughout the Pubmed, Embase and Cochrane databases. Studies were analyzed without concern for the time of publication.

Classification systems for IFF

While classification systems for hip and knee periprosthetic fractures have been widely studied and validated, a definitive classification system of IFF has not been validated yet. The Vancouver classification system has been internationally accepted as the most utilized and validated classification for hip periprosthetic fractures, while Su, Rorabeck or SoFCOT are well accepted for knee periprosthetic fractures [5-7].

In current clinical practice, the above-mentioned classification systems are routinely used to classify IFF and the choice among them is based on fracture proximity to the knee or hip implant.

In our review, we found 6 papers on the classification system (Fig. 1). The majority of these focused on the site of the fracture and stability of the implant.

The first attempt to classify IFFs dates to 2005 with the work of Fink et al. This classification system considers the presence of both stemmed or unstemmed prostheses and the stability of the prostheses [8-10].

Platzer et al. proposed a modified Vancouver classification system for IFFs established during the treatment of 23 patients treated between 1992 and 2008 after sustaining an IFF. Three subtypes based on the site of fracture and vicinity to the prosthesis were added to the Vancouver classification for IFFs [11].

Other authors added a subgroup D to Vancouver classification system: the authors highlighted the difficulty and the high failure rate to treat this pattern of fracture, while the importance to create this group is to provide a useful reminder for surgeons to place particular attention when choosing the surgical approach and technique due to the increased rate of failure [12-15]. Baba added the importance of such fracture in cemented or non-cemented stems to previous classification systems [16].

A dedicated classification system for IFFs was proposed by Pires et al. in 2014 [13]. These authors combined the introduction of a newly studied classification system to an algorithm of treatment for such fractures. Types of fracture were classified on the basis of the site of fracture (at the level of the hip, knee or femoral diaphysis), prosthesis stability, interprosthetic fracture fragment viability (if fragments are present at the level of the diaphysis) and bone stock. This system was considered to be appropriately accurate and well-structured with the very interesting possibility to provide an association between the type of fracture and treatment option. The types were: type I if around a total hip replacement (THR), type II if around a total knee replacement (TKR), type III if IFF with femoral extension stem. This classification system correctly emphasized the particular difficulties in treating fractures around a revised TKR [13]. In a following study, the system showed a good interobserver agreement and an appropriate structure, but lacked statistical significance [14].

Biomechanical aspects

The complexity of this type of fracture has led several authors to examine the most relevant biomechanical aspects as they were thought to be important in order to recognize and diagnose interprosthetic fractures, especially with regards to the most appropriate surgical treatment. We found 10 studies about biomechanical factors that can influence the risk of fracture and its treatment. The major limitation of these studies is the lack of reproducibility in real-life stresses and forces of daily life situations because of obvious ethical issues. Therefore, they mostly rely on cadaver bones or sawbone models.

Beals et al. highlighted the currently well accepted aspect that interprosthetic fractures involve the tip of the stem in 92% of cases [17,18].

The presence of an endomedullary component in the proximal area of the femur increase the risk of a fracture of 20% [19,20].

The same authors examined 30 cadavers and showed that significantly higher fracture force was required to cause a IFF to femurs with a resurface TKR and THR in comparison with a hip prosthesis and a distal retrograde nail [21].

Evaluating 48 cadaveric femurs Rupprecht et al. [22,23] showed that the higher resistance to fracture was exhibited by patients with both cemented prosthesis (THR and TKR). The lesser resistance was exhibited by the combination of THR and retrograde femoral nail. Intramedullary nails were noted to be the most unstable group due to the presence of a "locus minoris resistentiae" at the level of the screw point insertion [21,23].

Many authors focused on the interprosthetic gap, showing in

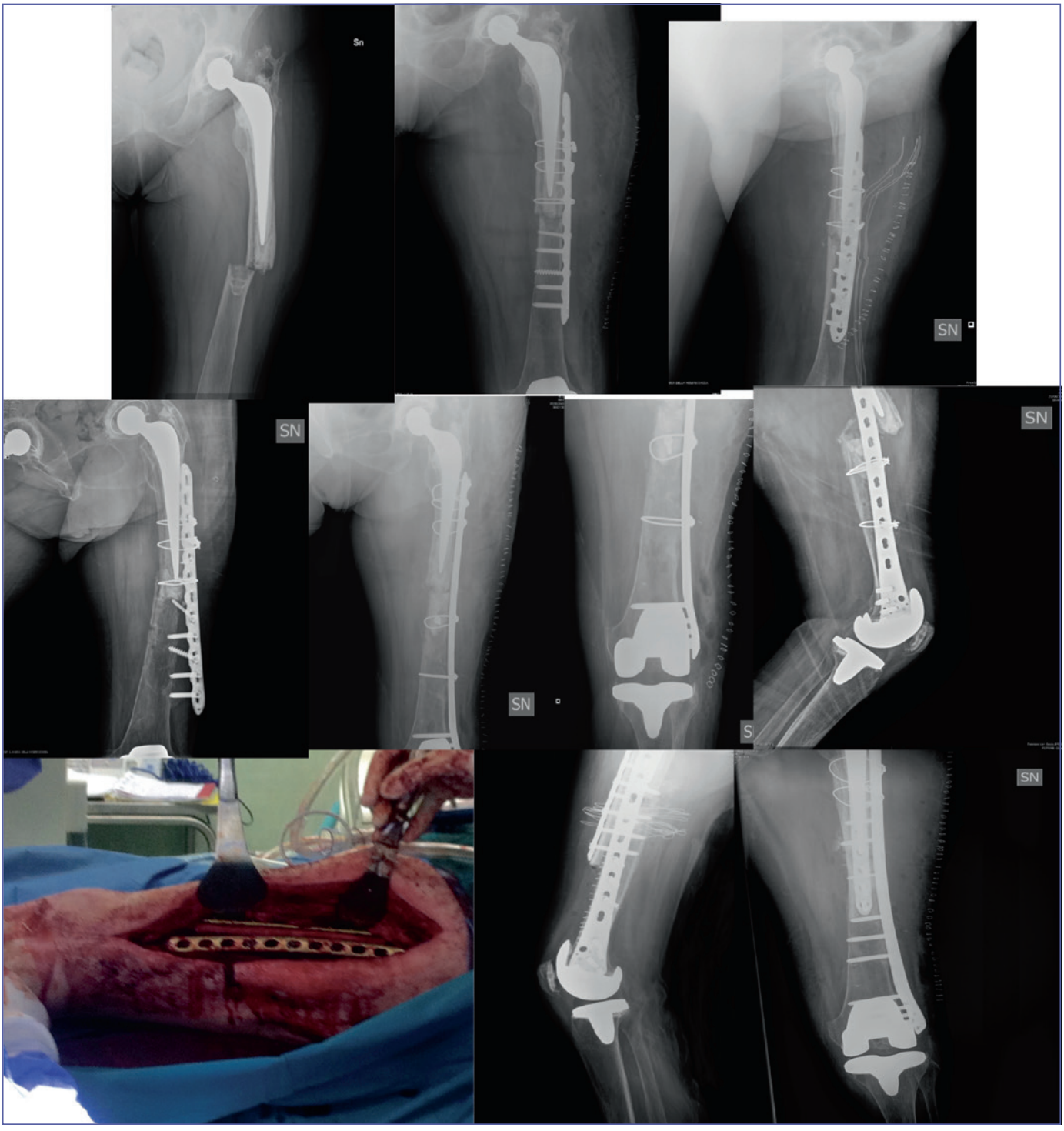

Figure 1. Surgical steps of case report.

cadaveric studies that this gap can influence the risk of IFF; however, the conclusions are conflicting.

Soenen et al. quantified 110 mm as the key measurement that influences stress risers. With any value smaller than this, the risk of fracture rapidly increased, particularly in osteoporotic bones [22]. A reduction of the interprosthetic space from 10 mm down to 1 mm was found to be able to provide better stability and a significant decrease of stress risers. This study suggests

that the optimal configuration when plating an interprosthetic femoral fracture between a TKA and a proximal femoral plate construct is to minimize the lateral interprosthetic distance, and to protect this gap with an anterior small fragment plate [24]. Other authors suggested that the risk of IFF is not correlated with the interprosthetic distance. Indeed, Iesaka et al. [19] studied the relationship between interprosthetic fractures and the distance between implants. They concluded that differences in the size of the gap between implants did not influence the stress risers in case of stable prosthesis components. Differently, stress risers are increased in case of prosthesis loosening. The highest values of stress and its peak were found to have an indirect relationship with the width of the related cortical bone. A decrease of 2 mm of cortical bone width was associated with doubling of the stress applied on the stems. Clinically, in order to minimize the risk of periprosthetic fracture, it appears to be more important to reconstruct and/or maintain cortical support and stabilize the stem fixation [19,25].

The same concept was postulated in other studies [26,27] testing 7 IFF with different gaps and several types of stemmed TKR, with the conclusion that small gaps do not act as stress risers [26,27]. In case of severe osteoporosis, a minimal gap of 6 cm is warranted, or an overlapping of at least 2 cortical width with the use of a plate to reduce the stress between forces and metalwork [27]. Whenever osteosynthesis is impossible or insecure because of poor bone stock, sleeve prosthesis has biomechanical properties for stability and early postoperative mobilization [25].

Considerations for surgical technique

The improvement of hardware technology and better knowledge of biomechanical backgrounds led to the creation of different approaches and techniques.

The first description of an IFF surgical fixation was that by Dave et al. in 1995 [4]; these authors described a single case of IFF treated with Mennen's Plate, three interfragmentary screws and bone graft with the final achievement of satisfactory clinical results and bone healing at 6 months post-operation.

Conversely, Kenny et al. reported discouraging results in a case series of 4 patients, reporting a 100% revision rate. The authors attributed these poor results to the presence of stemmed TKRs, which were thought to increase stress risers and hence the risk of failure [28].

The first percutaneous surgical technique was described by Della Valle et al., who treated a case of comminuted fracture between TKR and stable uncemented THR in a 66-year-old woman with rheumatoid arthritis using Dynamic Condilar Screw (12 holes, 95°). This technique was thought to have promising results as it allowed preservation of surrounding soft tissues and vascularization. An interesting suggestion from the authors was the use of a long plate so that two bicortical screws could be placed proximally to the femoral stem in order to avoid significant stress risers, with screws passing either behind or in front of the stem of the femoral component [29]. Better overall results were later obtained with the widespread use of locking plates [30]. This good success rate was presented by Sah et al. [31] who treated the IFF with minimally invasive procedures using single locking plates and locking screws. The key points to be taken into account for the achievement of these good results are: good surgical technique, experience of the surgeons, length of plates (allowing appropriate locking both proximally and distally), avoidance of excessive stripping at the site of fracture, and minimal use of cerclage wiring to preserve bone stock and his quality [31-34]. In 20 cases treated by Mamczak et al. [9], complications were limited to patients with a supracondylar fracture pattern. The authors concluded that good results in treating IFFs can be achieved if the same principles applicable when treating periprosthetic fractures are used. In fact, locking compression plates provide good results and low invasiveness; bypassing the hip stem with two femoral diameters is a key point to reduce stress risers [8,35-37]. Albareda et al. showed good results in 7 patients treated with an angular stability plate. No revision surgery was required [38]. LCP were used by Baba et al. for the treatment of a diaphyseal fracture, while a higher fracture location required revision with internal fixation with cables or plating [16].

A mini-invasive technique with an NCB plate allowed for the insertion of screws around the prosthesis stem and preservation of surrounding soft tissues [33,37,39].

The stability of the prothesis is essential for the success of surgery [40,41]. Fulkerson et al. [30] reported failure of surgery in patients with evidence of instability of knee prosthesis.

Good results without relevant complications were reported in a case series presented by Michla et al., who treated 9 patients with IFF between the age of 53 and 92. Patients underwent a different type of surgery depending on the pattern of the fracture: HIP Revision, Dall Miles cables, LISS, retrograde femoral nailing, DCS. Radiological bone healing was seen at 6 months from surgery [32].

A significant complication rate was reported by Platzer et al. (10 of 23 patients). 19 of 23 had stable prosthesis implants following fracture; these were treated with angular stable plates Among complications, in 2 cases an intra-operative mistake was noted and appropriate fracture reduction was not achieved; in one case, the authors found a notable secondary loss of reduction after operative stabilization (failure of device); in the last case, malpositioning of the plate in the supracondylar area was considered the reason for delay in bone consolidation [11].

A high rate of post-operative complications was recorded by Soenen et al. (52%) who presented a case series of 14 patients. Complications included: non-consolidation, early osteosynthesis material disassembly, non-union, superficial and deep infection, and any other event requiring revision surgery; 50% of cases did not need revision surgery [12].

More promising results were presented by Hou et al. in their case series of 13 patients. Adopting different types of fixation,

the authors concluded that good results in treating IFFs can be achieved if the same principles applicable when treating periprosthetic fractures are used. In fact, locking compression plates provide good results and low invasiveness; bypassing the hip stem by two femoral diameters is a key point to reduce stress risers [8].

In cases where the quality of bone does not allow internal fixation procedures, the use of interprosthetic sleeves was proposed by Citak et al. The procedure with sleeves was considered by the authors a suitable option in the presence of a stemmed prosthesis and low chances of favorable osteosynthesis due to poor bone quality [34]. In a more recent study, 26 patients achieved good results, but with a high rate of complications [42]. Bone stock should be analyzed since it is essential for treatment success when using a bone graft [36].

Pires et al. [13], in accordance with his classification system, used several surgical techniques and metalwork (LiSS plate, retrograde nail, Ilzarov, LiSS Plate and acetabular component revision, LCP and 95° Blade plate) on the basis of the fracture pattern and surgeon's preference. Only one relevant complication was recorded (infection of Ilzarov pins). Jennison et al. [44] documented good results in 19 of 23 patients in terms of bone healing, with a mortality rate of 20.8% at 2 year-follow-up.

Worldwide there is an increase in the rate of IFF. Beyond the difficulties in treating such complex patients (usually elderly cohorts with multiple comorbidities), the real challenge is good preoperative planning and a technically well performed surgery. The patient's expectations should also be taken into account. Difficulties are mainly related to previous implanted prostheses, pattern of fracture and patient's bone stock. Furthermore, the latter is not always predictable in the preoperative setting.

In our department, we routinely utilize the classification system according to Vancouver for THA, or Rorabeck for TKA, because of easier feasibility [5-7]. However, we recognize that Pires classification system can be a valuable and reproducible model to classify and treat this type of injury [13]. Compared to the other systems, Pires classification provides a well-structured and understandable algorithm for surgeons, with high interobserver reproducibility [14].

Concerning biomechanical aspects, close attention must be paid to avoid stress risers. The goal is to span the stemmed component for at least 2 times the cortical diameters, achieving good fixation both proximally and distally. This is also confirmed by laboratory studies [18,21-23], although some aspects are still controversial and debated [19,25-27]. However, such good fixation is not always possible because of the short bone viability and complexity of the fracture. Although in most cases the correct osteosynthesis length to avoid stress risers has been achieved, unfortunately plate length and stresses are not the only concerns when facing these fractures. This is a very important point; poor bone stock, related to age and multiple surgeries, is considered to be a major factor responsible for fixation failure [25-27]. From our experience, we learned that prompt use of bone graft from the first re-intervention should be encouraged. Therefore, a preoperative study should include a CT scan to look for bone loss and minimize the risk of failure.

A long experience in the trauma field and orthopedic replacement surgery is a prerequisite for this kind of surgery. Although this type of injury can be caused by low energy trauma, the pattern of these fractures can be insidious. The combined procedure of revision and osteosynthesis is not rare. The newest osteosynthesis technique and materials provide good reliability and safety in treatment. The studies we analyzed reported a variable rate of success, complications, and time to consolidation. Indeed, the complication rate ranges from 0% to 100% [4,11,12,28-39,41-44]. Modern plates, mini-invasive techniques and soft tissue sparing techniques guarantee fewer complications [33,35,36] compared to more rigid fixation systems [28]. Depending on the fracture pattern, we advocate the need for less invasive systems. LCP plate or LISS are routinely implanted in our institution. In the literature different systems are described: plate, nail, revision TKA and THA revision, and sleeve Prosthesis. There is a lack of standardization in treatment. Therefore, we cannot conclude which is the optimal choice. Moreover, no studies have described the use of other implants such as megaprostheses. In fact, they may be a treatment option in cases where bone stock and the patient's status are poor. The use of intramedullary nails should be discouraged even in the presence of a CR TKA, although consistent data are not reported in the papers reviewed. The presence of two stemmed implants should be considered a major risk of refracture. The first goal is to achieve length and rotation, but it is relatively rare to obtain with mini-invasive approaches. The fracture pattern, presence of other implants and viability do not always allow a mini-approach. Moreover, the need for early complete weight bearing in such patients causes the need for more aggressive approaches. The complications of prolonged immobilization are well known and described. Early weight bearing, shorter hospital length and low rates of clinical complications must be the priority, although there is a lack of standardization of surgical procedures.

Only a few studies have reported partially functional scores, weightbearing allowance, complications and length of hospital stay.

Indeed, the use of more aggressive surgery, with the aim of more rapid weightbearing, can be a valid option although not yet mentioned in previous studies. However, there is a balance between surgical and clinical priorities, and therefore "personalization" of treatment, which must be taken into account in preoperative planning.

Considering the overall biology and soft tissues, the developing techniques and implants with associated grafting procedures are related to higher success rates. Unfortunately, from the current literature there is a lack of standardization in treatment and management of such injuries. In addition to technical aspects, specific patient factors must be taken into account. Therefore,

treatments should be decided according to a standardized approach tailored to each patient. More studies with higher standardization are needed in order to establish treatment algorithms/guidelines and provide the best possible results.
The prolongation of life expectancy and the consequent increment of joint prostheses implanted worldwide make IFF more frequent and a significant issue for the new generation of orthopedic surgeons. Several papers have reported results on small samples of patients. Despite these limitations, some landmarks have been provided: stress risers must be reduced, intramedullary nails should be avoided and plates should extend for at least two diaphysis diameters beyond the fracture site. Furthermore, less invasive systems and approaches provide better results compared to rigid osteosynthesis systems; revision surgery is needed in case of unstable prosthesis; bone graft and cerclage can aid bone fixation in case of significant bone loss, bone stock preservation are established as landmarks. However, there is still no diagnostic and therapeutic algorithm and the literature is lacking standardized and high evidence level studies. In the future, more studies are needed so that a systematic internationally accepted approach to this type of injury can be reached.
We believe that a standardised approach for the classification and treatment of IFFs should be of great interest for international research societies.

Ethical consideration
Review article, no ethical approval needed.

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Conflict of interest
The Authors declare no conflict of interest.

Author contributions
The Authors contributed equally to the work.

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