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Tibia periprosthetic fracture management – A 30-year systematic review

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A R T I C L E I N F O

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A B S T R A C T

Periprosthetic fractures are demanding and though uncommon, tibial periprosthetic fractures are furtherly destined to impact clinical and surgical orthopaedics due to the increasing number of arthroplasties performed yearly.

Systematic research focusing on periprosthetic tibia fractures reported beginning 1990 until 2022 was conducted on the following databases: the Cochrane Central Register of Controlled Trials (CENTRAL), MEDLINE/PubMed, Embase, Scopus, the Science Citation Index Expanded from Web of Science, ScienceDirect, CINAHL, and LILACS.

A total of 473 records resulted from the research. Following the exclusion process the studies included were twenty-three (23) with a total of 287 patients and 357 treatments. Periprosthetic tibial fractures prevail in women (72.1 %), in the obese and in rheumatoid arthritis affected patients.

Treatments consist of conservative treatments (22.7 %), osteosynthesis (16.5 %), revision total knee arthroplasty (23.0 %), intramedullary nailing (2.5 %) and other treatments (30.8 %). Stable fractures are treated in various methods, unstable fractures are mainly treated through revision total knee arthroplasty and intraoperative fractures are treated both conservatively and operatively.

Periprosthetic tibial fractures are destined to heavily burden orthopaedics traumatology. Periprosthetic tibia fractures are complex and commonly afflict obese and elderly women with history of rheumatoid arthritis. These fractures may be managed following the ASAP algorithm. Stable fractures are treated using different methods and unstable fractures are mainly approached through revision total knee arthroplasty prior to other treatments. Intraoperative fractures are treated both conservatively and surgically.

Introduction

Due to the rising number of arthroplasties performed each year, the burden of periprosthetic fractures (PPFs) is expected to rise significantly. [1,2] Periprosthetic fractures relevant to total knee arthroplasties (TKA), mainly affect the distal femur (0.8 %), and much less frequently the patella (0.2 %) or the proximal tibia (0.1 %) [3,4]. Due to the scarcity of tibial PPFs, established site-specific guidelines as to their management do not exist.

In 1997, Felix et al. [5] first classified tibial PPFs into four types based on the fracture location as to the tibial components, the timing of occurrence, and the stability of the tibial prosthesis. A fracture in a well-fixed prosthesis is defined as type A, if a fracture is present in the context of a loose implant it is defined as type B, while type C are defined as intraoperative fractures. Illustration follows (Fig. 1).

Although the rationale of the Felix classification is like that of the established classification systems of the more common femoral PPFs, it is supported by less significant published evidence.

Aim of the present comprehensive review is to analyse the existing literature data on tibial PPFs and introduce a clinically relevant algorithm of their management.

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Materials and methods

Systematic research from 1990 until 2022 was conducted by two authors (PG & AA) on the following databases: the Cochrane Central Register of Controlled Trials (CENTRAL), MEDLINE/PubMed, Embase, Scopus, the Science Citation Index Expanded from Web of Science, ScienceDirect, CINAHL, and LILACS. The research was performed using the following keywords in their various combinations: "tibial periprosthetic fractures", "TKA fractures", and "tibia arthroplasty fracture management".

The selection process was based on the participants, intervention, control, outcome, and study design (PICOS).

A total of 473 studies resulted from the research. Duplicate or in vivo animal, cadaveric or biomechanical testing studies, expert opinion manuscripts or studies focusing on fractures around the femoral component were all excluded. Due to the lack of literature addressing this topic, we included all case-series and case reports described in the last three decades.

Controversial records were discussed, and the decision of inclusion was reached with the aid of a third author (AF). Further analysis was conducted in 23 publications referring to 287 patients (Figs. 2 and 3). [5–27]

Fracture patterns (I, II, III or IV) following the Felix classification) and either fracture stability (A – stable, B – unstable), or timing of fracture diagnosis (C – intraoperative) were used for stratification of our analysis and presentation of our findings [5].

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Statistical analysis

Data were extracted and recorded for a stepwise analysis. Basic information of each study including population features, treatment, diagnosis, surgical techniques, implant, time to return to activities and patient-reported outcome measures at latest follow-up, were extracted. All complications including failures, stiffness, infections, and wound complications and amputation were also recorded. Continuous variables were reported as weighted means. Categorical variables were reported as the number of events or percentages. Statistical analysis was conducted using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, N.Y., USA). A P value of less than 0.05 was considered statistically significant.

Study selection

A PRISMA [28] flowchart for study selection was conducted by two different authors (PG & AA) and is illustrated in the following chart (Fig. 2).

Results

A total of 287 patients who were submitted to 357 treatment strategies were included in this analysis based on 23 studies (Fig. 3) [5–27]. A number of patients were managed with more than one treatment options, therefore the discrepancy between the two figures. The

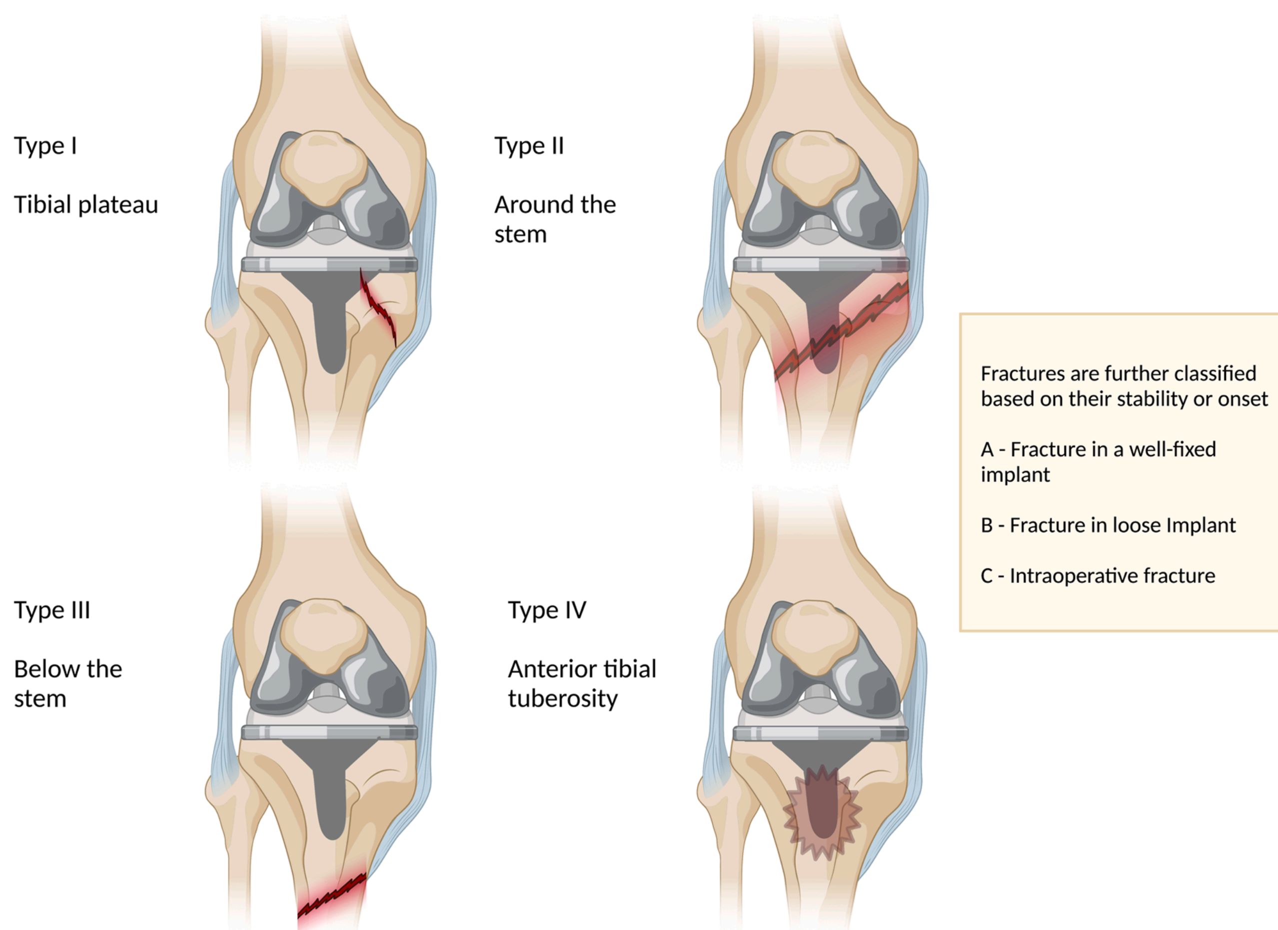

Fig. 1. Felix N. classification for periprosthetic tibia fractures. Additional suffix is added based on component stability (A - well-fixed implant, B – Loose implant, C – Intraoperative fractures).
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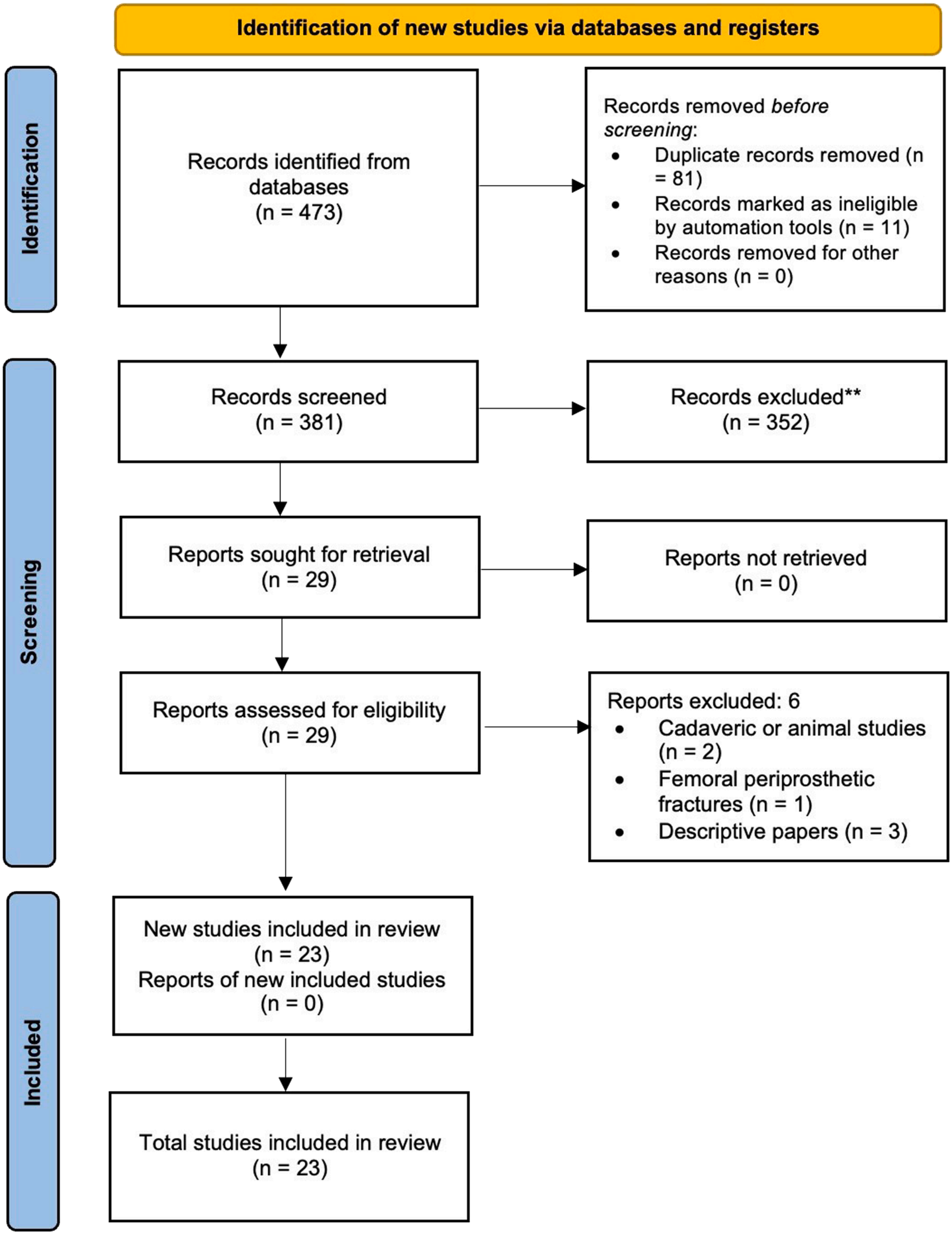


Fig. 2. The PRISMA flowchart illustrating study inclusion process.

distribution of surgical procedures is described in Chart 1.

Specification of patient gender was recorded in 206 (71.8 %) cases, with the majority being females (152, 73.8 %). Patients' age at fracture onset was reported in 207 (72.1 %) patients with the mean age being 70.2 $\pm$ 4.1 years. The mechanism of injury was mentioned in 179, 62.4 % of all cases. High-energy trauma was responsible for 38, 21.2 % of these fractures, with the remaining (141, 78.8 %) presented either low-energy trauma (fall from their height or during normal activities) or no history of trauma. Intra-operative fractures (Type C) were reported in nineteen cases in the mentioned TKA-fracture time frame group (12.83 %).

A comorbidity analysis was performed for the reported 104 (36.2 %) cases. We noted a high prevalence of patients presenting rheumatoid arthritis (14.4 %) and other conditions requiring immune suppressants (1 inflammatory arthritis in Crohn's disease and 4 due to unspecified disorders; 4.8 %) and 3.8 % of patients reported a history of cancer (sarcoma and melanoma), septic arthritis presented a prevalence 2.9 %. Osteochondritis dissecans, osteonecrosis and tuberculous arthritis were reported in less than 1 % of the cases each. Body Mass Index (BMI) was reported in 51 (17.8 %) patients with a mean BMI of 31.36 kg/m^2 per patient.

The time incurred between total knee arthroplasty and fracture onset

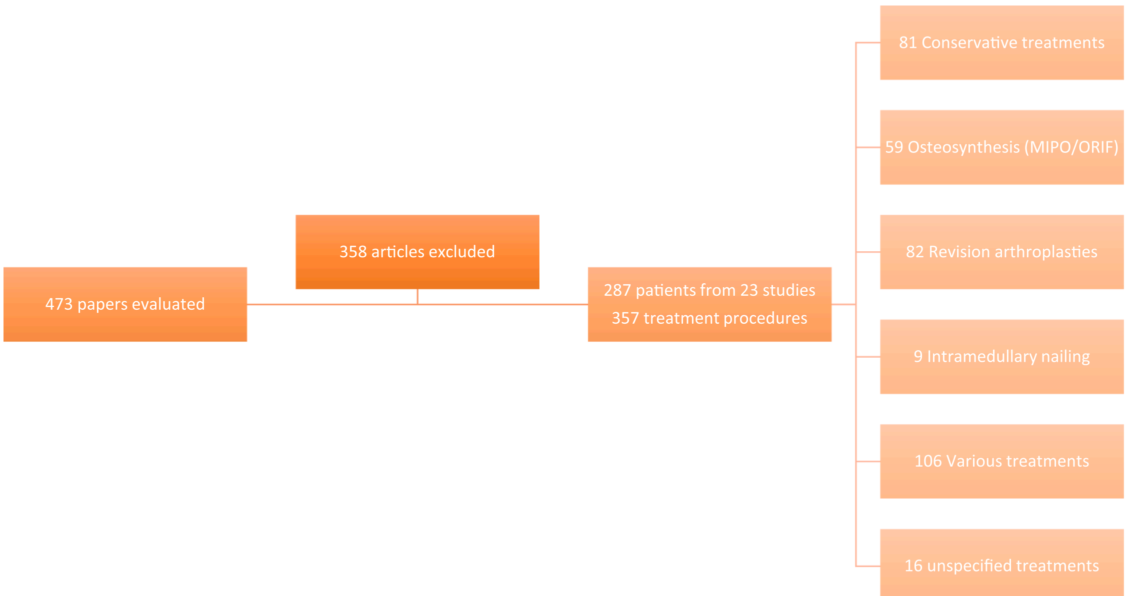


Fig. 3. Illustration of included articles and treatment group distribution.

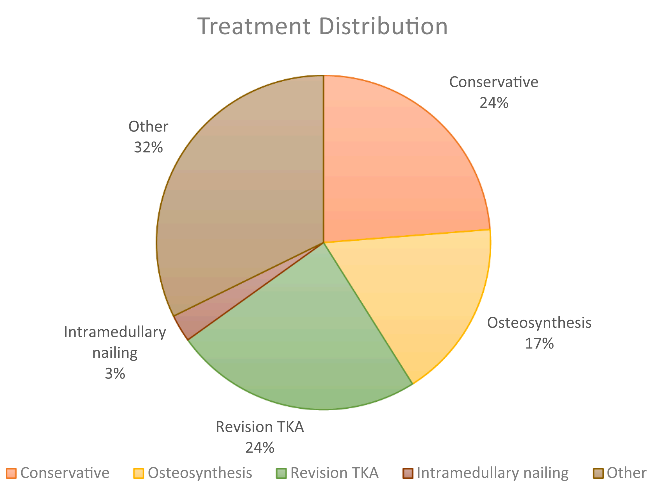


Chart 1. Illustration of treatment distribution.

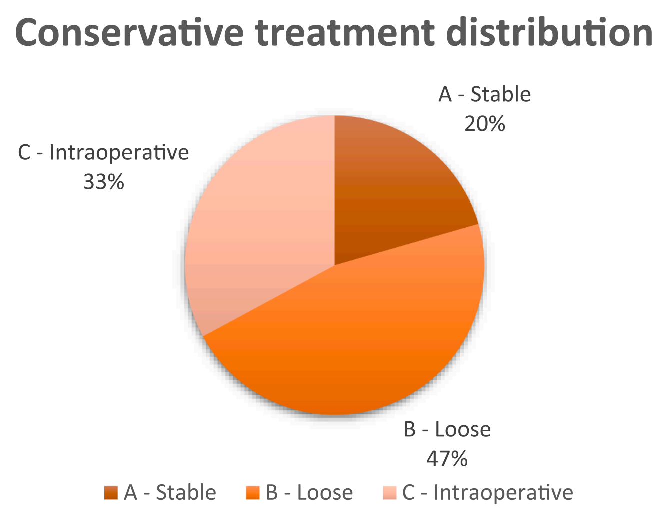


Chart 2. Distribution of fracture stability patterns treated conservatively.

averaged 57.2 months, this interval was reported for 148 (51.6 %) patients. The average hospitalization length was reported for 43 (14.9 %) patients with a mean of 11.3 ± 6.4 (from 6 to 22.8) days. The mean follow-up was 69.0 ± 24.6 (from 4 to 90.7) months. The time to union was mentioned for just 31 (10.8 %) patients and occurred at a mean of 12.7 ± 5.1 weeks. The reoperation rate varied in different studies and ranged from a minimum of 8.8 % to a maximum of 55.6 % with an average reoperation rate of 23.3 %. The postoperative range of motion (ROM) was reported for 50 (17.4 %) patients and ranged from a minimum of 5.9 ± 7.1 degrees in extension to a maximum of 117.3 ± 16.0 degrees in flexion. Postoperative KSS was mentioned in 55 (19.2 %) patients, the mean postoperative KSS was 85.0 points and Knee Society Function Score (KSFS) was reported in 97 (33.8 %) cases and presented a mean postoperative value of 73.1 ± 11.3 points.

Conservative treatment group

This group consisted of 81 treatments of which 15 (18.5 %) were performed on Felix type A fractures, 34 (41.9 %) on type B fractures and 24 (29.6 %) on intraoperative fracture (type C). The distribution of fracture stability patterns is demonstrated in Chart 2.

Apparently, the reporting clinicians opted for conservative treatment in one out of five occasions (22.7 %).

We assume that this approach was chosen in missed intraoperative fractures of partially stable fractures (48.1 %) or due to demanding unstable fractures (41.9 %). One patient was mentioned to have a type IA fracture, four patients a type II fracture, and four patients present a type III fracture (stability pattern was not mentioned).

Osteosynthesis group

Osteosynthesis was performed in 23.0 % of the recorded treatments. Out of 59 osteosynthesis procedures, 24 (40.7 %) fractures had a recorded stability pattern. Type A fractures were reported in 14 (58.3 %) patients, type B in 9 (37.5 %), and type C in one (4.2 %) patient. Stability patterns in the osteosynthesis group are illustrated in Chart 3.

This group underwent either Open Reduction and Internal Fixation (ORIF) or Minimally Invasive Plate Osteosynthesis (MIPO). The MIPO group consisted of 16 patients of which 6 had type II fractures and 10 had type III fractures. Osteosynthesis without specification of the technique was performed in the remaining patients.

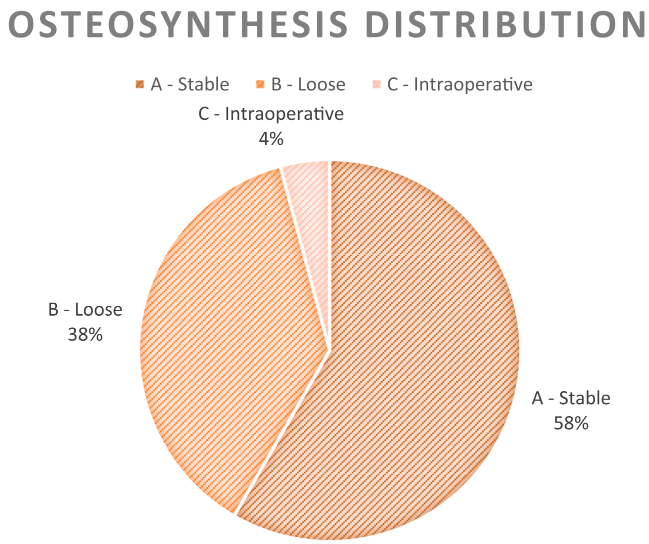


Chart 3. Distribution of stability patterns in osteosynthesis group.

Revision total knee arthroplasty (rTKA)

A clear tendency is noted in this group of 82 procedures. Well-fixed fractures (Type A) were mentioned in 4 (4.9 %) patients, and unstable (Type B) fractures were reported in 69 (84.1 %) of the patients (seventeen of which underwent bone grafting in combination with rTKA) (Chart 4).

Osteoporosis is mentioned in 6 patients only.

Rheumatoid arthritis and diseases necessitating corticosteroid use were mentioned in five patients in this group. Type C fractures were mentioned in 10 (12.2 %) cases. In 23.0 % of all procedures a rTKA is performed.

Intramedullary nailing

Nailing (including pinning) was performed nine times (2.54 % of all procedures), all of which were for type IIIA fractures. No treatment-related complications were reported in this group. Eight out of 9 fractures (88.9 %) united. The average union time was reported to be at 5.5 months of follow-up (from 3 to 6 months), one patient in this group deceased at 4 months due to heart failure.

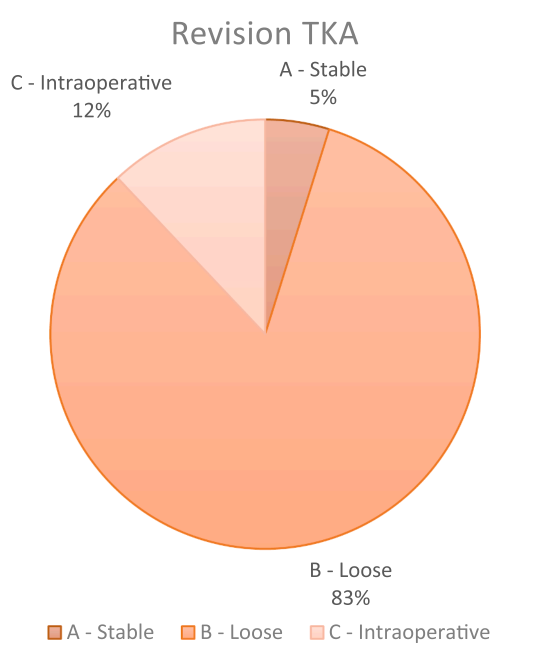


Chart 4. Fracture stability pattern distribution in revision total knee arthroplasty group.

Other treatments

This group included 110 procedures (30.8 %) and represented a variety of methods (Chart 5). Screw fixation and wiring was performed 68 (61.8 %) times, of which 42 for fractures reported as tibial plateau fractures (Felix type I) and 7 as fractures of the anterior tibial tuberosity (Felix type IV). Five patients received suture repair (2 for IV fractures, 3 for Type II fractures). Bone grafting was performed 17 times. Proximal tibial replacement (PTR) was performed in 12 patients and mega-prosthesis in 2 patients (13.2 %; 7 type I, 4 type II, 2 type III). An 100 % revision rate was reported in these 12 PTR (all of which were performed in the same centre) [8].

Out of "Other treatments" group, type I fractures were mentioned in 52 cases. Arthrodesis was performed in four cases (3 IIB due to complications and 1 IIIB as primary treatment). Amputation in 2 cases (1 IIB and 1 IIIB after failed open reduction and internal fixation). Both ORIF failures presented due to infection, implant failure and wound healing disorders.

Type A fractures were mentioned in 7 (6.6 %) treatments, type B in 29 (27.3 %) cases and type C in 70 (66.03 %) cases.

In sixteen (4.5 %) occasions the type of treatment the patients received was not further specified.

Future directions

Since the 1950s, open reduction and internal fixation (ORIF) have been applied to reconstruct the skeletal anatomy, providing optimal stability and enabling early mobilization. This approach requires extensive dissection, devitalization of bony fragments, and evacuation of fracture hematoma with its osteogenic potentials creating biological damage that potentially hinders the fracture healing [29]. All these factors should be carefully considered when approaching a periprosthetic tibia fracture where bone intra-medullary biology is severely altered by metallic implant and bone cement.

The evolution of materials and techniques has developed new plates with more anatomic, low-profile designs and multiple fixation options, different screw sizes with poli-axial locking directions representing an evolution towards biologically favorable internal fixation [30]. These implants can improve fixation strategies in case of periprosthetic tibia fracture in the presence of a metaphyseal stem and could reflect a potential increase in ORIF indication for tibial periprosthetic fractures in the future.

Discussion

Total knee arthroplasty has become the mainstay treatment in the management of end-stage knee osteoarthritis and has markedly improved the patients' quality of life. In USA alone, TKA is estimated to reach 1.3-3.5 million primary arthroplasty procedures per year [31].

Revision arthroplasty is a risk factor for periprosthetic fractures and is predictably and constantly increasing particularly due to aseptic loosening, prosthetic joint infection (PJI) and implant instability [32, 33].

Interestingly, trauma is not the leading cause for tibia periprosthetic fractures, as in our review 108 patients (37.6 %) had no recorded mechanism of injury. Out of the reported cases, 38 (21.2 %) patients presented with high-energy trauma, while the 141 remaining fractures occurred after minimal or no trauma. We believe that metabolic bone diseases including osteoporosis in rTKA group are underreported.

Ebraheim et al. [34] calculated the incidence of trauma-caused fractures based on fracture type. This study concluded that

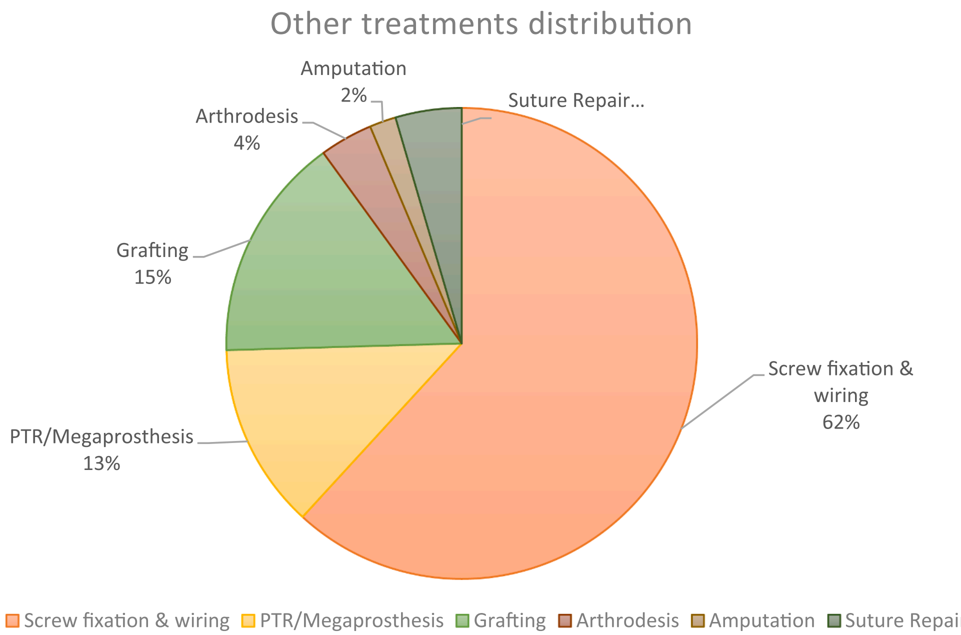


Chart 5. Other treatments group – treatment distribution.

intraoperative fractures (type C according to Felix) often occur during revision TKA or when cementing, while 40 % of postoperative fractures involving the tibial plateau (types A and B – Felix classification) are due to trauma.

Literature proves that periprosthetic fractures mainly depend on two aspects: patient factors (female gender, poor bone stock, inflammatory arthritis, prolonged steroid use) and surgical factors (technical errors, implant malposition, previous implants and under-detected intra-operative fractures) [35].

Periprosthetic fractures were addressed with the aid of the previous unified classification system (UCS) [36] and tibial periprosthetic fractures particularly through the Felix and the Mayo classifications [5,37] yet due to both complexity and scarcity of literature addressing tibial periprosthetic fractures, surgeons necessitate a common, simplified and updated treatment approach through the ASAP algorithm addressing periprosthetic tibial fractures management (Flowchart 1, Fig. 4) and in the tabular format (Table 1).

Fracture stability significantly impacts decision-making between different treatment options. Stable fractures (Felix type A) are treated in a variety of methods; conservative (30.6 %), osteosynthesis (28.6 %), intramedullary nailing (9 cases) and in 4 (4.8 %) cases out of 82 with a revision TKA. Interestingly, nailing represents 2.5 % of all treatments yet 18.3 % of type A treatments. This group consists of type IIIA fractures in all 9 cases with high union rates in 5.5 months.

In a systematic review, out of 63 patients who were treated with rTKA, 40 patients received immediate revision, while the remaining 23 had a delayed rTKA due to complications (34).

Unstable fractures were mainly treated with early revision total knee arthroplasty (rTKA) which further illustrates the importance of considering bone stock before any further treatments. In type B fractures, when other above-mentioned procedures are performed (PTR, grafting, megaprothesis, osteosynthesis, arthrodesis etc) a high complication rate is noted. Thus, if a type B periprosthetic tibial fracture was present, we highly recommend considering an early revision total knee arthroplasty before undertaking further treatments.

We believe that the lack of bone stock in the context of loose implants is to be addressed with rTKA and the aid of other instruments such as bone grafts or cement. The UCS mentions that if an implant is loose (UCS B2), a revision arthroplasty should be performed, yet when the bone stock around the loose implant lacks (UCS B3), a complex reconstruction may be necessary [36]. We suggest that implant instability, severe osteoporosis and certain comorbidities (RA, prolonged steroid use) to be considered as equal indicators for early rTKA in order to prevent further complications.

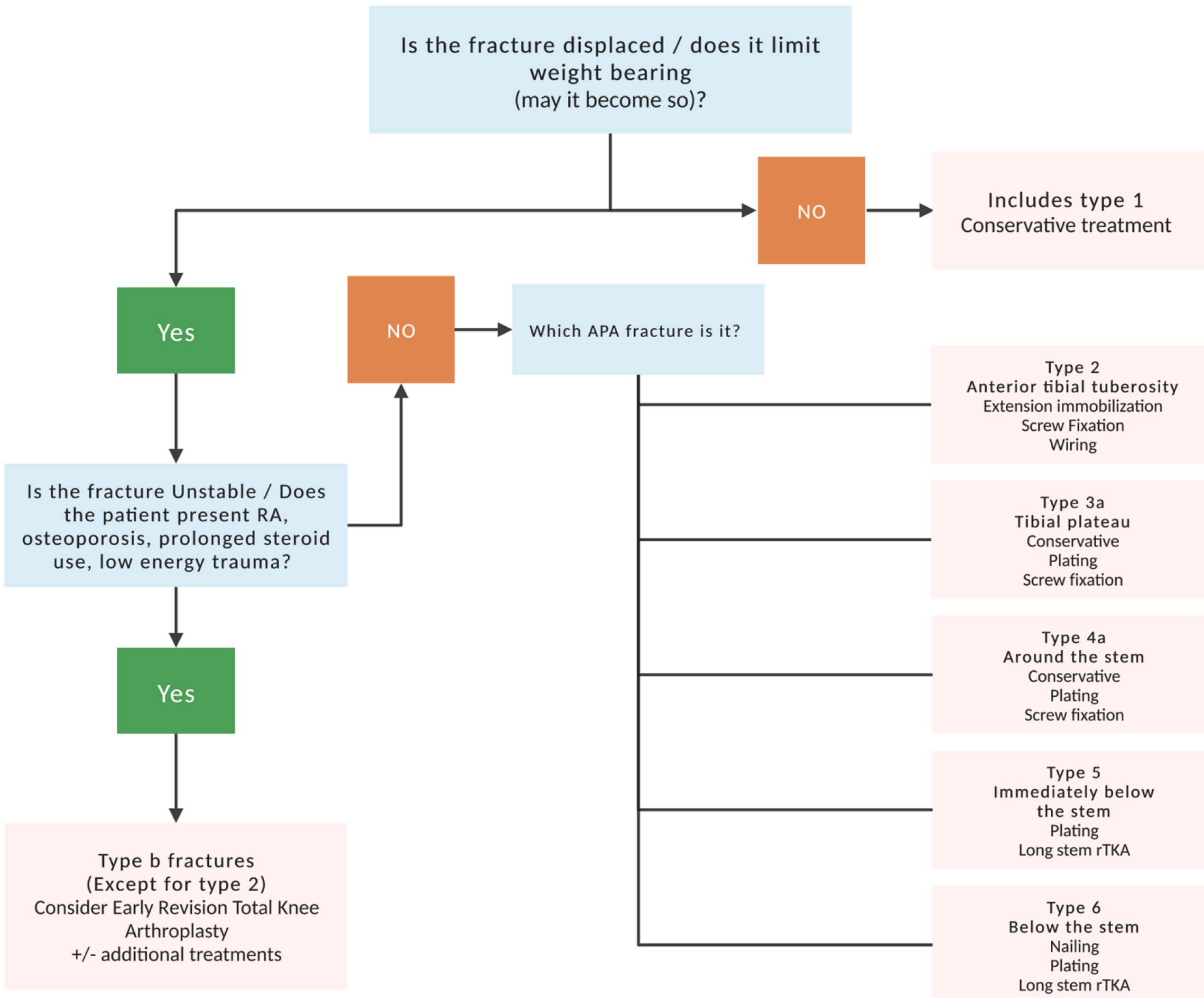
Consistently with other study outcomes, type C fractures (intra-operative) were noted to have either an operative approach consisting mainly of screw fixation or band wiring (66.6 %), or a conservative approach (22.85 %). Less than 1 % of the treatments performed on type C fractures consisted of osteosynthesis and 9.5 % of type C fracture procedures consisted of rTKA. We assume this is due to the fact that not all type C fractures were diagnosed intraoperatively yet when so, are fixed. Although tibial periprosthetic fractures are uncommon, in intra-operative settings they are more frequently encountered compared to femoral periprosthetic fractures [14–16]. We believe type C fractures logically lead "Other treatments group" due to management issues.

Periprosthetic tibia fractures were recorded to have an impressively high rate of adverse events that might affect up to 55.6 % of the patients. Complications range from wound disorders, reoperation with arthrodesis to amputation, thus a careful selection of the initial treatment is of crucial importance [13]. Interestingly, when proximal tibial replacement (PTR) was chosen patients had a 100 % revision rate yet all the described cases of PTR were treated in the same centre [14].

In this review, surgical and clinical complications arose, from soft tissue revisions, repeated osteosynthesis procedures, soft tissue infection, prosthetic joint infection, amputation, arthrodesis, bone grafting, non-union, malalignment, transfusions, prolonged hospital stay, deep vein thrombosis, one case pulmonary embolism and three deaths [5,8].

The reported revision rate for periprosthetic tibial fractures varied in the included studies to this analysis (8.77–55.6 %). The mean reoperation rate was 23.2 %. We believe the heterogeneous revision rate is due to the authors' different definition of revision (from revision due to implant failure to reoperation for soft tissue debridement).

The high prevalence of the female gender (73.8 %) is consistent with other similar studies [38–40]. A study performed on 7 female patients with periprosthetic tibial fractures reported the bone mineral density: 2 cases present osteopenia and 5 (71.4 %) cases exhibit osteoporosis [20]. Consistently with other studies, a high prevalence in rheumatoid arthritis is the morbidity reported study population of 104 (14.4 %). Patients present other autoimmune diseases or necessitate prolonged steroid use in 4.8 %, a history of malignant tumour is mentioned in 2.89



Flowchart 1. The ASAP (the Applied Step Algorithm for Periprosthetic tibial fractures) – Abu-Mukh, Salini, Alessio-Mazzola, Placella. Created with BioRender.com.

% of the patients and septic arthritis in 2.17 % of the cases. Only one study reports the Charlson Comorbidity Index (CCI) without specification of the relative diseases with an average CCI of 4.087 ± 0.498 [8, 41]. We believe that autoimmune diseases present a higher prevalence than the one above reported.

We assume this timeframe is overestimated because intraoperative fractures (Type C) are reported in nineteen cases out of the mentioned TKA-fracture time frame group (12.83 %). Patients affected with periprosthetic tibial fractures were complex and necessitate a long follow-up. The mean follow-up was 69.01 months (4–90.7 months).

Osteoporosis was mentioned in 6 patients only, we believe this parameter is highly underestimated. Poor bone stock and autoimmune diseases or prolonged steroid use are predisposing factors for fracture instability and condition the following fracture management [42].

In the setting of bone stock, loose implants, and certain comorbidities (RA, prolonged steroid use and other autoimmune diseases) early rTKA should be considered prior to other treatments in order to prevent further complications.

Keep in mind, the typical patient is a female above 70 years of age or suffering from rheumatoid arthritis or conditions requiring prolonged steroid use, obese or osteoporotic and not necessarily reporting a history of trauma.

The scarcity of literature and to the relatively small number of cases included limits the study. The included studies offer different outcomes and heterogeneous description of fracture patterns. Unfortunately, this confines the review into a descriptive one without a possible meaningful statistical comparison. The reoperation rate varies significantly due to articles' definition of revision. Some studies consider reoperations as revision surgery due to treatment failure only, other studies define it as any orthopaedic procedure (soft tissue revision, arthrodesis etcetera.) following the primary treatment. This indicates a probably under-reported reoperation rate.

However, the article offers a collective insight into an infrequent yet a demanding and rising challenge in traumatology. A simplified novel algorithm is provided by the authors and illustrates the fracture patterns and treatments performed in the past three decades aiding the clinical decision-making in complex periprosthetic tibia fractures.

Further research is necessary in order to obtain homogeneous study outcomes in order to conclude which treatment is best feasible for each fracture based on effective significance statistical analysis.

Conclusions

Periprosthetic tibial fractures are destined to heavily burden orthopaedics traumatology. Periprosthetic tibia fractures are complex and commonly afflict obese and elderly women with history of rheumatoid arthritis. These fractures may be managed following the ASAP algorithm. Stable fractures are treated using different methods and unstable

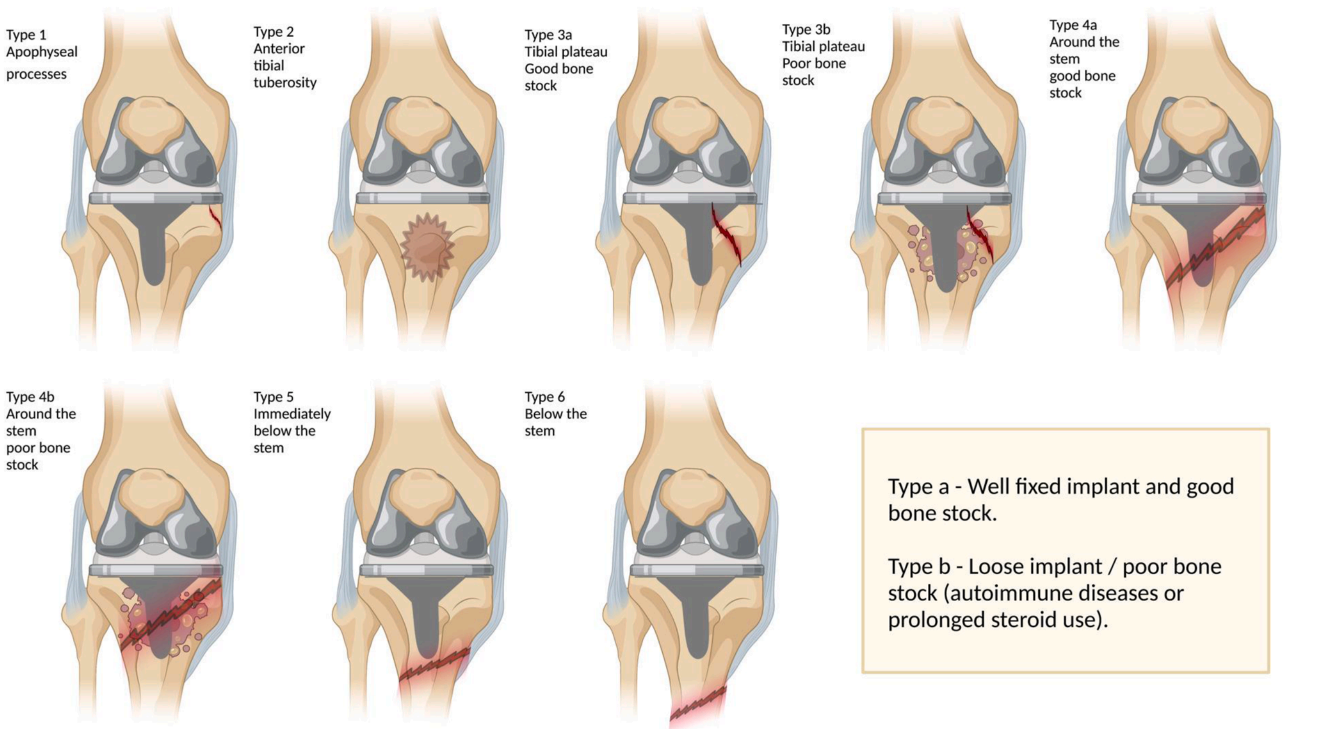


Fig. 4. Illustration of the ASAP fractures. a – good bone stock, b – loose implant/poor bone stock. (b is to be assigned in patients suffering from rheumatoid arthritis, osteoporosis or chronically treated with steroids).
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Table 1
The ASAP (the Applied Step Algorithm for Periprosthetic tibial fractures) – Abu-Mukh, Salini, Alessio-Mazzola, Placella.

ASAP - Applied Step Algorithm for Periprosthetic tibial fractures	Felix Classification / UCS	Proposed treatments
Type 1 apophyseal	Felix 4 / UCS A	• Conservative treatment.
Type 2 Tibial tuberosity	Felix 4 / UCS A	• Conservative • screw fixation/wiring & extension immobilization
Type 3a good BS	Felix 1A / UCS B1	• Conservative • Plating • Screw fixation/band wiring
Type 3b poor BS	Felix 1B / UCS B2	• rTKA in combination with other treatments.
Type 4a good BS	Felix 2A / UCS B1	• Conservative • plating • Screw fixation
Type 4b poor BS • RA • Prolonged steroid use • Severe osteoporosis	Felix 2B / UCS B2-B3	• Revision TKA in combination with other treatments • Mega-prosthesis
Type 5 • Immediately below the stem	Felix 3 / UCS B-C	• Conservative • Plating • Revision long stem TKA
Type 6	Felix 3 / UCS D	• Conservative • Plating • Intramedullary nailing

Table 1 legend: UCS – Unified classification system, BS – Bone Stock, RA – Rheumatoid Arthritis, rTKA – revision total knee arthroplasty.

fractures are mainly approached through revision total knee arthroplasty prior to other treatments. Intraoperative fractures are treated both conservatively and surgically.

Declaration of Competing Interest

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.hsr.2023.100133.

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