Periprosthetic Fractures around the Knee: Update on Therapeutic Algorithms for Internal Fixation and Revision Arthroplasty

Periprotetické zlomeniny v oblasti kolena: nové terapeutické postupy pro vnitřní fixaci a revizní artroplastiku

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SUMMARY

Effective treatment of periprosthetic fractures following TKA continues to represent a surgical challenge. The incidence and frequency of these complicated type of fractures is expected to increase as the number of TKA as well as the activity level of these patients steadily rises. A careful and correct analysis of the fracture pattern, its classification, the quality of the existing bone stock and the fixation / loosening of the underlying prosthetic system has to precede decision making for successful conservative or surgical treatment. Therefore, improved diagnostic radiographic imaging of fracture patterns and reliable assessment of prosthesis loosening progressive development of new implant methods and refinement of soft tissue preserving surgical techniques will hold the key for regaining the functional level prior to the fracture.

INTRODUCTION

During the last decade the number of total knee arthroplasty (TKA) implantations continues to increase and has exceeded the frequency of surgeries performed for total hip arthroplasty in some countries, e.g. the USA. (58). Due to the demographic changes in the western industrial countries with an aging but active popualtion, the continuously prolonged life expectancy and the increasing survival time of the prostheses, the incidence and rate of periprosthetic fractures is expected to markedly increase. (22, 24, 25, 78).

In a systematic study analyzing complications of 415 periprosthetic femur fractures Herrera *et al.*(35) have observed 9% pseudarthroses/non-unions, 4% mechanical complications and 3% infections with an overall revision rate, reaching 13%. To date, the incidence of periprosthetic fractures following TKA is considered to center around 1% (0.3% – 2.5%)(2, 81). With a frequency of 0.3 – 2% the periprosthetic femur fractures are most often observed, followed by corresponding periprosthetic fractures of the tibia (0,3% – 0,5%) (9) and patella 0,6% (4, 9). The rate of postoperative periprosthetic fractures is known to be comparably higher following revision arthroplasty as opposed to primary implantations (81).

Fracture patterns of intra- and postoperative periprosthetic fractures do not resemble the typical rules as known from dia-/metadiaphyseal long bone fractures in general traumatology. For this reasons various authors have developed valid classifications aiming to systematically subgroup different fracture types of the femur, tibia and patella in relation to a fixed or loosened prosthesis. Most of these postoperative periprosthetic fractures result from low energy injuries or stress/fatigue problems. Only few are observed in response to a high energy trauma. As these specific fractures are usually seen in older patients with multiple comorbidities and surgical repair per se is always a revision surgery with implant fixation around prosthetic implants in mostly osteoporotic bone or even revision arthroplasty effective surgical therapy is tremendously complicated. Therefore, adequate treatment of periprosthetic fractures following TKA remains a surgical challenge requiring biomechanical and operative knowledge, experience as well as skills from difficult osteosynthetic techniques to the whole program needed for revision arthroplasty. Consequently, this paper is aimed to systemically review contemporary literature for periprosthetic fractures following TKA in order to unravel the different surgical therapy options and provide corresponding treatment algorithms as guided by the underlying classifications.

Risk factors

Several authors were able to demonstrate the relative importance and impact of underlying, patient specific risk factors known to promoteperiprosthetic fractures. Among others, osteoporosis (10, 56, 75), rheumatoid arthritis (19, 55, 56, 77), enduring steroid/ /corticoid therapy (35, 36, 55, 77), pre-existing neurological disorders such as e. g. cerebral ataxia, Parkinson s disease, myasthenia gravis and many others (19), previous revision arthroplasty (10, 56), arthrofibrosis (due to reduced knee flexion and to increased lever arm forces during walking) (2) as well as progressive local periprostheticosteolysis due to septic or aseptic loosening (65, 72).

PERIPROSTHETIC FRACTURES OF THE FEMUR

Periprosthetic femoral fractures are the most frequent subgroup (0.3% - 2.5%) of periprosthetic fractures following TKA. Apart from the above mentioned general risk factors notching of the anterior femoral cortex is known to increase the risk of periprostheticfemoral fractures (10, 50, 56, 75). Biomechanical studies clearly have shown that femoral notching reduces femoral strength and resistance to fracture (50) while large clinical studies failed to confirm these results, possibly due to ongoing bony remodelling (70, 81).

Several classification for periprosthetic femoral fractures following TKA have been described, which differentially consider and refer to either the fracture line extension or the fixation type/loosening behaviour of the prosthesis (21, 43, 73, 81). For the clinical practice and daily use the classification systems acc. to Rorabeck *et al.* (73) and/or Su *et al.* (81) have found wide acceptance (see table 1). As to the time point of sustained periprosthetic fracture intraoperative fractures can be differentiated from postoperative fractures. Both classification systems are designed and directed towards standardized decision making, reliable guidance of periprosthetic fracture care and establishment of corresponding treatment algorithms.

Tab. 1. Classification of periprosthetic femur fractures acc. to Rorabeck and Su

	Rorabeck-Classification	Su-Classification
Type I	undisplaced fracture with fixed prosthesis	fracture proximal to the femoral prosthesis component (no extension distal to the anterior shield)
Type II	displaced fracture with fixed prosthesis	fracture starts at the level of the femoral prosthesis shield and extends proximal
Type III	loose prosthesis, un-/ displaced fracture	all fracture elements/ lines involve the segment below/ distal the femoral prosthesis shield

The treatment goals of the periprosthetic femoral fractures are as follows (21, 33, 81):
– stable joint without significant malalignment
– uneventful and completed fracture healing (within 6 months)
– „range of motion“ and restored knee function to the level prior to the trauma.

A functionally favourable result is also assumed if a minimum range of motion of 90°, a shortening of less than 1 cm, a varus-/valgus-misalignment of less than 5°, a minimal change in torsion and ante-/retroflexion of less than 10° is reached/accomplished (21, 81). Malalignments exceeding the mentioned limitations compellingly lead to excentric overload of the prosthesis and periprosthetic bone stock, which in turn, typically and rather sooner than later result in early implant loosening (81).

Therapy

Conservative approach

Conservative therapy, which invariably results in reduced knee function, is rarely indicated and exceptionally restricted to undisplaced, stable fractures (10, 19, 20, 56, 59, 77, 79). Long lasting traction treatment is nowadays completely obsolet (21, 58). Exceptional indications are incidentally reported for patients with very reduced general health status and unjustifiable risk of anaesthesia and surgery.

Surgical approach

Concepts of surgical therapy are guided by the underlying fracture type/classification, the type of prosthesis and essentially depend on assessing the loosening behaviour of the prosthesis. Exact and valid analysis of the question whether the prosthesis is loose or not is mandatory and of utmost importance. Preoperative assessment/exclusion of a loose prosthesis component may be difficult and requires detailed clinical analysis and sufficient radiographic/imaging studies. Pain reported to be present already prior to the fracture is sometimes the only sign indicating a subclinical prosthesis loosening, not clearly visible on radiographs. To which extent this pain may have contributed to uncontrolled loss of muscle performance with consecutively increased tendency for stumbling can only be argued and remains speculatory.

Osteosynthetic reconstruction is feasible and indicated only in cases without implant loosening. Difficult situation may arise when e.g., the main fracture zone closely extends to or partly involves the meta-/diaphyseal segment responsible for prosthesis fixation. Periprosthetic fractures with loose components of prostheses require removal of the component according to prescribed rules of orthopaedic revision arthroplasty (54). In most cases, however, the prosthesis is not loose and osteosynthetic reconstruction can be performed using an

- closed reduction and internal fixation (using extra-/intramedullar implants),
- open reduction and internal fixation using extramedullar implants.

The indication for primary bon grafting is still under controversial discussion but in most primary cases not necessary (33, 47, 82, 86). It is mandatory, that performance of different methods for osteosynthetic reconstructions and types of extra-/intramedullar implant fixation need to preserve the soft tissue envelope around the knee. Any „iatrogeneic soft tissue damage", i.e., unnecessarily large approaches, stripping of fragments, are predictors for impeded knee function, susceptibility to infection, hardware failure and non-unions. Concerning soft tissue-preserving, biologicalosteosynthesises with minimal/less invasive approaches and primary restoration of length, axis and rotation rather than anatomic reduction of meta-/diaphyseal, non-articular fractures concepts of classic fracture care do not differ from those for periprosthetic fractures.

Nevertheless, every surgeon needs to be aware of potential, inevitable intraoperative changes in terms of surgical techniques and therefore, should be able to complete any infeasible osteosynthetic reconstruction with a correct revision arthroplasty. Pursuing that approach, however, means also that these surgeries should be performed in Centers which hold availability for all required instruments and implants.

Whenever possible soft tissues around the knee should be preserved and reduction should be performed indirectly. If needed and direct exposure is indispensably necessary an open fracture reduction has to be performed.

– Closed/less open/open reduction and internal fixation

Today, new generations of anatomically preshaped, angular stable implants (angular stable locking plates) which act as an internal fixator, can be combined with percutaneous screw fixation and applied in a minimal/less invasive way, are available (58, 81). Many studies have convincingly revealed the benefits of these types of implants, in particular for osteoporotic bone, when compared to classic conventional plates (1, 45, 46, 53, 63, 66). Among the factors which contribute to the superiority of angular stable implants the preservation of the local periosteal blood flow (internal fixator, no compression to the cortex) together with the opportunity to place unicortical locking screws with biomechanical advantages in terms of stress distribution (particularily in interprosthetic fractures) are thought to be most important (54).

Apart from extramedullar fixation there are also intramedullar techniques like retrograde nailing available that have shown to be useful for treatment of periprosthetic femur fractures following TKA (29, 40, 55, 60, 71, 78, 87). From a biomechanical point of view it could be demonstrated that intramedullar fixation techniques are superior to conventional non-angular stable extramedullar plating techniques (2, 71). Moreover in a cadaver model that simulates a periprosthetic femur fracture Bong et al. were able to show that due to the central loading conditions of the nail the retrograde nailing technique seemed to reach better biomechanical results than angular stable implants like the L.I.S.S.-System (**L**ess **I**nvasive **S**tabilising **S**ystem, Synthes) (7). Retrograde nailing uses the same surgical approach, is minimal invasive and does not expose the fracture zone (no touch). Large reviews, analysing 415 cases of periprosthetic femur fractures following TKA report a decreased risk for evolving non-union of 87%, combined with declined rate of revision surgeries by 70% as opposed to „classic" conventional plate osteosynthesis (35). However, retrograde nailing technique has also some inherent drawbacks as very distal fractures cannot sufficiently stabilized due to the lacking distal interlocking options. Therefore, it is recommended that at least two bicortically fixed interlocking bolts should be placed in the distal fragment. Nevertheless, malalignment of the distal fragment resulting from the impaired ability of the nail to keep the reduction in the metaphysis is a frequently observed phenomenon profoundly complicating the retrograde nailing technique. The more distal the fracture extends the more obvious this problem becomes. Several techniques have been designed to circumvent that problem, as spiral blades for interlocking keep angular stability, poller screws should prevention loss of reduction and angular stable locking bolts may offer multidirectional angular stable fixation(83). Furthermore, retrograde nailing is limited to prostheses with „open box" designs allowing for intercondylar insertion of the retrograde nail. „Closed box designs", „open box designs" with small intercondylar distance or thick nails of certain companies interfering/impinging with the hardware of the femoral prosthesis component are criteria that make retrograde nailing impossible (57).

– External fixation

The external fixation of periprosthetic fracture following TKA as a definitive treatment option is definitely obsolete (27). The external fixation with pin tracks perforating the medullary canal and thereby contacting the prosthesis tremendously increases the risk of prosthetic infections (27). Temporary external fixation of periprosthetic fractures is therefore limited to very rare and exceptional cases like severe open fractures, massive soft tissue damage and polytraumatized patients (6, 38, 76).

Revision arthroplasty

Principal and obligatory indication for revision arthroplasty is a TKA component that shows signs of aseptic/septic loosening prior to the trauma or that became loose in response to the fracture. However, in selected cases of very distal fracture zones (Typ III according to Su, Typ I or II according to Rorabeck) a revision with exchange of the prosthesis may be indicated as there is insufficient space and bone stock for implant/screw fixation in the distal fragment of any type of osteosynthetic reconstruction. Modular prosthesis designs with variable shaft and plateau designs, however, allow sometime exchange of only one component with stable fracture bridging and fixation and direct postoperative full weight bearing (14, 17, 81). According to our experience it seems mandatory and helpful to have alternative options available including also different types of semi- and constrained models in order to be prepared and equipped for any conceivable change, incl. total revision and exchange of the entire system (14, 17, 54, 81).

Differential indication and corresponding treatment algorithms based on the underlying fracture classification

Exact assessment of possible/potential loosening of the prosthesis is a precondition for successful surgical treatment. In addition, information about previous surgeries, other implants in situ (total hip arthroplasty, proximal femur nails, screws and plates) decisively determine the choice of implant and fracture fixation. Based on the accepted classification system by Su *et al.*(81) and the design of the prosthesis together with the fixation/loosening of the prosthesis we developed an algorithm for decision making and treatment planning of periprosthetic femur fractures following TKA.

All fracture types from type I – II acc. to Su as well as proximal type III-fractures are optimum candidates for osteosynthetic reconstructions, preferably using angular stable plates that extramedullary overlap the intramedullar length of the femoral stem. However, encouraging results have also been reported for type I- und II-fractures by various authors using the retrograde intramedullary nail (2, 29, 35, 40, 55, 60, 71, 78, 87). However, unknown prosthesis systems which may only questionably have an open box design or those with closed box design (e.g. PS-variants) angular stable plate fixation techniques represent the recommended treatment of choice (57, 58) (Fig. 1).

PERIPROSTHETIC TIBIAL FRACTURES

Periprosthetic fractures of the tibia following TKA are significantly rarely and infrequently observed when compared to corresponding femur fractures, rating between 0.3 – 0.5% of all implanted TKA (9). Additionally to general above mentioned risk factors specific factors also include varus positioning and malrotation of the tibial component, the forced application of impaction techniques for the tibial head cancellous bone areas as well as large osteolysis (9, 58). The classification of Felix *et al. (Tab. 2)*, published in 1997 has attracted major interest and found wide acceptance as it considers and refers to the time point of fracture (intra- versus postoperative), topography of the fracture to the tibial component as well as the anchorage of the prosthesis (fixed versus loose) (25). Most likely due to the low incidence and the frequency of periprosthetic tibia fractures there is no valid and generally approved treatment regimen available (25, 43, 80). Again, loose and malpositioned prostheses require exchange of the prosthesis and revision arthroplasty. Any extensive dislocation of fragments, or unstable displaced fractures are indications for operative intervention (24). Unstable intraoperative fractures nearly always need immediate fixation (58).

Tab. 2. Classification of periprosthetic tibial fractures acc. to Felix

	Felix-classification
Type I	fracture of the tibial head with involvement of the prosthesis-implant interface
Type II	fracture of the meta-/diaphyseal transition
Type III	fracture distal to the tibial component
Type IV	fractures of the tibial tuberosity
Subtype A	stable prosthesis
Subtype B	loose prosthesis
Subtype C	intraoperative fracture

Therapy

Conservative approach

Intraoperatively caused undisplaced fractures which are stable and first seen/diagnosed at the postoperative radiograph do not necessarily need operative intervention. In those cases, an adaptation of the postoperative weight bearing and radiographic controls are indicated (9). There is sufficient evidence to suggest that undisplaced fractures type II may also be treated successfully in a conservative manner (25).

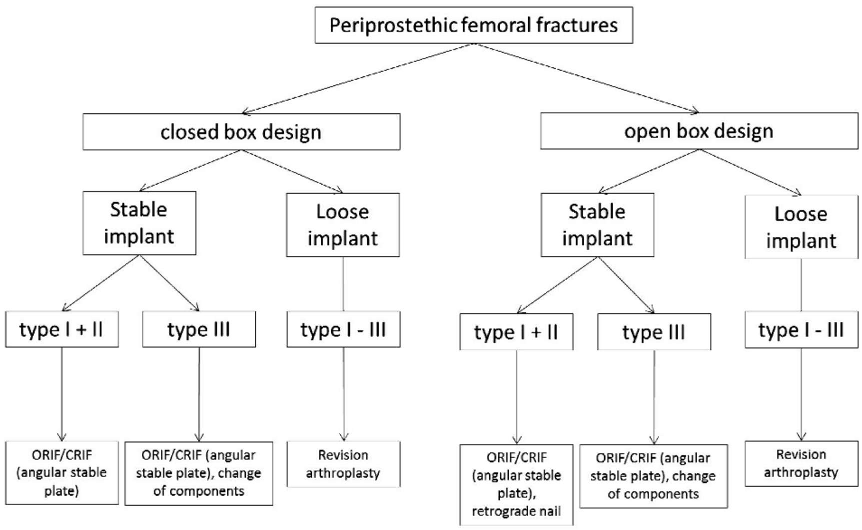

Fig. 1. Treatment algorithm for periprosthetic femoral fractures (modified after [58]).

Surgical approach

Whether the tibial component is tightly fixed or loose is decisively guiding the resulting treatment concept. Similarly to the femoral situation any loose or malpositioned tibial component requires revision arthroplasty with exchange of the component. This may be performed in combination with a osteosynthetic reconstruction or using a long stem revision implant (43, 58). In rare cases with periprosthetic fractures around already implanted revision arthroplasty systems additional augmentation techniques with either auto- or homologous bone may be necessary. In particular patients who already suffer from a longlasting loosening of the tibial component may have large bone defects (43, 64). In analogy to the femoral fractures there are similar techniques and implant systems available for the management of periprosthetic tibial fractures.

Differential indication and corresponding treatment algorithms based on the underlying fracture classification (Fig. 2)

All fracture types (type I - IV) with loose tibial implant (subtype B) are clear-cut indications for revision arthroplasty with exchange of at least the tibial component. Choice of the implant is strictly dependent on the level of the tibial fracture relative to the anchorage zone of the prosthesis. Therefore, type I fractures may be fixed without long stems, whereas type III fractures absolutely need implantation of a long stem revision implant. Periprosthetic fractures around certain types of prosthesis may only be treated by complete removal and exchange of the entire prosthesis system (43, 58, 64).

Intraoperative caused fracture (subtyp C) may be stabilized either with sufficient osteosynthesis (type I/ type III), or may again be treated only using long revision stem systems (type I – III) (43, 58, 64).

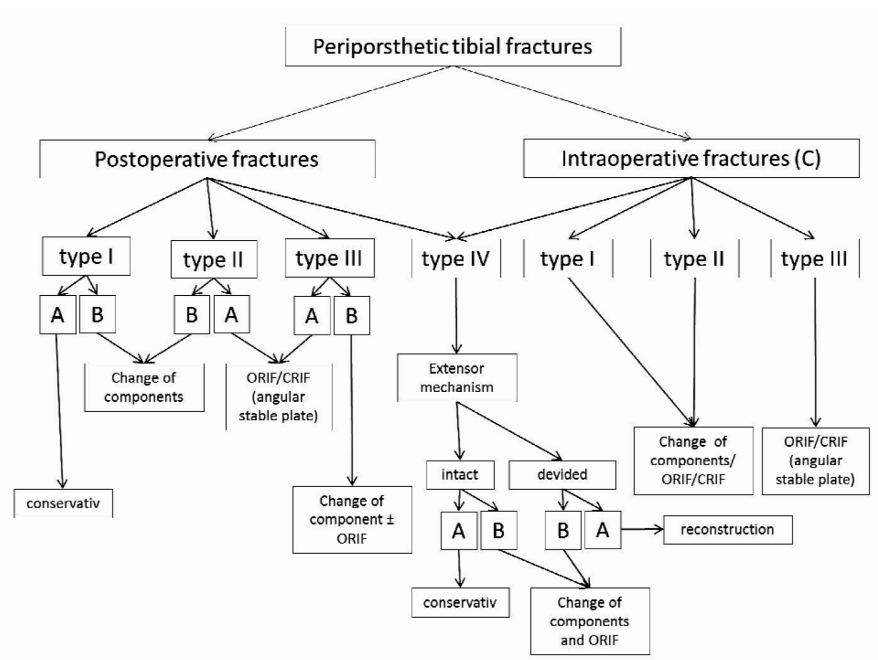

Fig. 2. Treatment algorithm of periprosthetic tibial fractures (modified after [58]).

Displaced type IA fractures which occured postoperatively should be treated by change of the tibial component because this fracture type often shows a varus-/valgus malalignment and therefore leeds to higher stress to the rest of the TKA which again leeds to early loosening. (43, 64). Undisplaced type IA fractures can be treated conservatively. Type IIA fractures are candidates for an individual decision making as depending to the extension of the fracture revision arthroplasty or osteosynthetic reconstruction may be used for adequate stabilization (58).

Treatment of type III fractures is depending on the type of the used prothesis and usually is treated by osteosynthetic reconstruction by the means of angular stable plating (see also figure 7). Only in rare cases an exchange arthroplasty with long revision stems is necessarily indicated. (9, 32).

Adequate management of the rare type IV fractures is essentially depending on a valid assessment of the extension apparatus. Subtype A fractures with functionally intact extension apparatus can be managed conservatively with initial immobilization and early mobilization in a flexion-limited concept (stepwise increase starting from 0° for few days, 30° for further 2 weeks, 45° and 60° for another 2 weeks, respectively) before normal/unlimited range of motion should be allowed. Any impairment or loss of extension function due to the fracture, however, is an indication for either osteosynthetic reconstruction, alone or in combination with revision arthroplasty. In rare cases with pure intraligamentous rupture reconstruction needs to be accomplished with tendon-allografts for augmentation of the extension (58).

PERIPROSTHETIC PATELLAR FRACTURES

Among the periprosthetic fractures following TKA involvement of the patella is quite rare with an Incidence of less than 0.6% (9). However, some new study leed support to the hypothesis that incidence of periprosthetic fractures of the patella will exceed corresponding fractures of the tibia (12). These rare type of fracture occurs in both, the native but also replaced patella (3, 8, 13, 15, 16, 26, 30, 31, 34, 37, 39, 41, 48, 49, 51, 61, 62, 67-69, 74, 85). Many risk factors, such as of axial extremity deformities or malalignment of the prosthesis, design of the patella replacement systems with extensive resections of the patella with thickness less than 15 mm are known to make the patella following TKA susceptible to periprosthetic fracture (8, 9, 11, 26, 30, 34, 58, 61, 67).

In summary, for prevention of periprosthetic patellar fracture sufficient patellar thickness left after

Tab. 3. Classification of periprosthetic patellar fractures acc. to Goldberg

	Classification after Goldberg
Typ I	fractures not involving the implant/cement composite or quadriceps mechanism
Typ II	fractures involving the implant/cement composite and/or quadriceps mechanism
Typ III	A: inferior pole fracture with patellar ligament rupture B: inferior pole fracture without patellar ligament rupture
Typ IV	all types with fracture dislocations

resection together with a meticulous surgical technique and correct implantation of all components seem to be most mandatory (26). Different classification systems for periprosthetic patella fractures have been described in the past (9, 61) with that acc. to Goldberg *et al.* from 1988 being the most commonly used and accepted system (tab. 3). The authors characterized the fracture pattern in a series of 36 periprosthetic patellar fractures (30) and have proposed 4 different types.

Therapy

Integrity and undisturbed function of the extensor apparatus/mechanism along with a stable retropatellar implant is guiding and decisively determining the treatment of periprosthetic patellar fractures (41, 61, 62). In addition, time point of fracture (intra-/postoperative) is also influencing further therapeutic strategy (9, 24).

Conservative approach

Non-displaced longitudinal or also transverse fracture types with functionally intact extensor apparatus and fixed implant without signs of loosening may be managed conservatively (fractures type IIIB, type I, selected fractures of type IV) (41, 61, 62). Usually immobilization for 4 to 8 weeks in an articulated brace seems sufficient. If the brace is fixed in full extension mobilization may be performed/allowed with full weight bearing (58).

Surgical approach

Typical indication for surgical intervention of these rare type of fractures is the dislocated fracture with/without an impaired or partially ruptured extensor mechanism/apparatus (Fig. 3 and 7). As forthe timing of these surgeries a one-stage procedure with simultaneous revision//replacement of the patellar component and anosteosynthetic reconstruction of the fracture is not recommended (9, 24). In cases with insufficient and weak patellar bone stock (revision cases) a „patella plasty“ (32) has turned out to reveal promising results and represents a valuable alternative to patellectomy, which usually is known to result in worst functional outcome (37).

Differential indication and corresponding treatment algorithms based on the underlying fracture classification (Fig. 3)

Periprosthetic patellar fractures with loose implants but good bone stock show successful results when managed with revision/exchange of the retropatellar implant and wire/screw osteosynthesis combined with tension banding/wiring(specifically fractures type II) (12, 58, 61). Without implant loosening anosteosynthetic reconstruction is effective. Type III A fractures with fixed implant are treated according to guidelines for the management of patellar tendon ruptures. Rarely, reconstruction by means of augmentation techniques using tendon- or bone-tendon-allogafts are indicated (18).

OUTCOME OF OSTEOSYNTHETIC RECONSTRUCTION OF PERIPROSTHETIC FRACTURES FOLLOWING TKA

Femoral fractures

The results of osteosynthetic reconstructions of periprosthetic fractures using angular stable implants are promising (see Fig. 4 and 5). In this context, Ehlinger *et al.* report in a retrospective study about 93,8% healing rate after a mean duration of 10 weeks after surgery (23). Similar data are demonstrated by other investigators (5, 44, 89). Corresponding non-union rates are less then 10% (66). Infection rates range between 0–6% (44, 46, 89). In a large metaanalysis by Herrera *et al.* an overall complication rate of 3% infections, 4% implant failure, 9% non-union and 13% revision surgeries was found (35). Interestingly, available studies analysing results of retrograde nailing (29, 57, 58) appear to show similar good results (27, 29, 44, 57). However, this treatment option is only feasible and technically possible in normal prosthesis of the CR-Design. However, retrospective studies with retrograde nailing techniques have also reported implant failure rates of 11% (89). Another

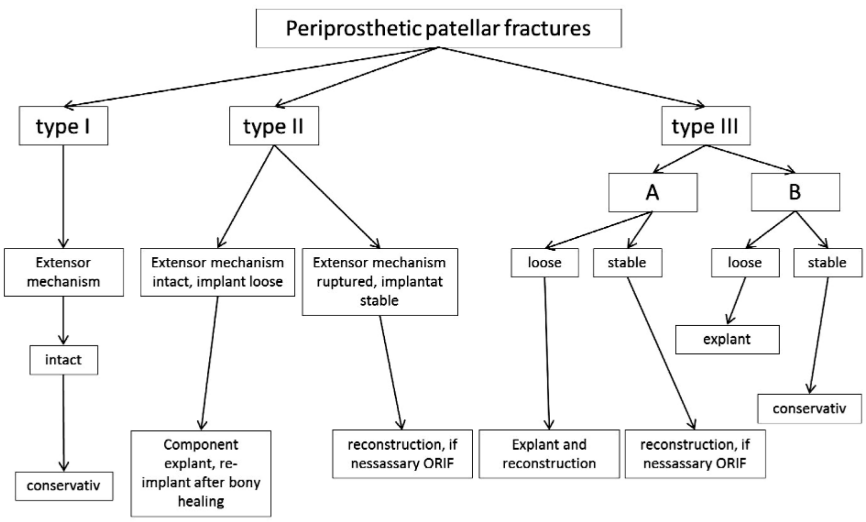

Fig. 3. Treatment algorithm of periprosthetic patellar fractures (modified after [58]).

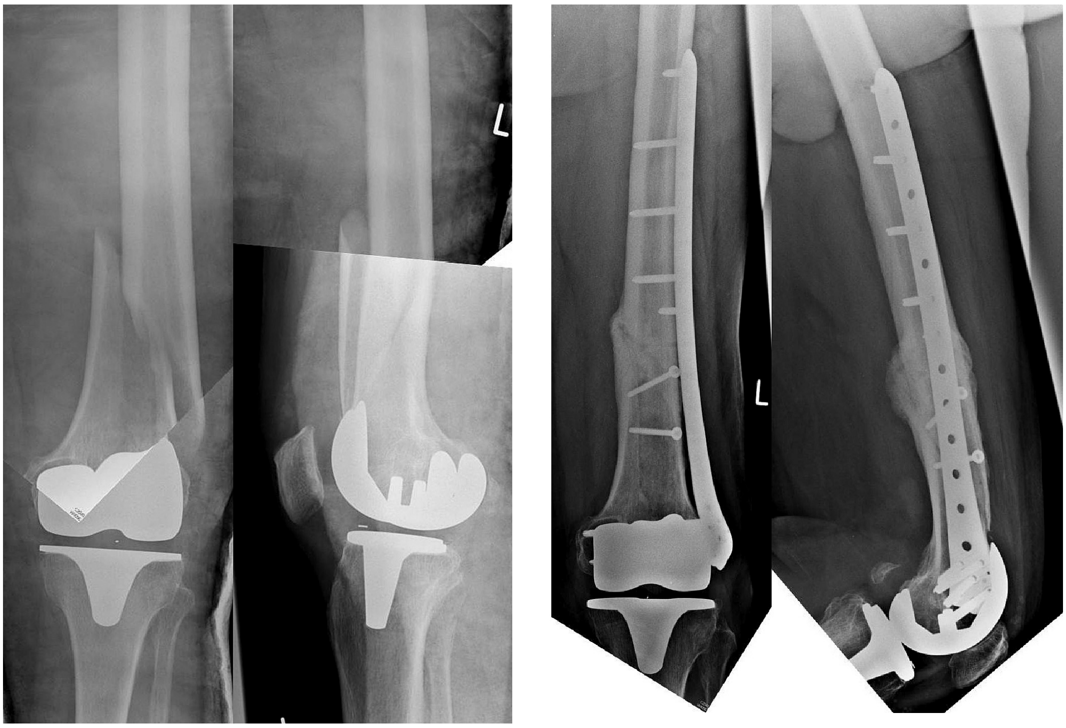

Fig. 4. Type I femoral fracture, treated by MIPO plating (L.I.S.S., Synthes) and additional leg screws, trauma x-ray (left), result after 10 weeks.

problem, frequently coming up during insertion of the nail and reduction of the fracture, is axial malalignment of the distal femur, due to loss of reduction in the funnel-shaped metaphyseal distal femur bone segment (88, 89). As mentioned before, in loose TKAs the revision arthroplasty is the gold standard. In some cases an additional plate osteosynthesis may be required in order to achive stable conditions for early mobilisation (see Fig. 6).

Tibial fractures

To date, for periprosthetic tibia fractures following TKA there are no valid data available. Most likely this is the result of the infrequency incidence of these fractures. Valid data with recommendations for treatment strategies are also lacking (25, 84).

Patellar fractures

Only a limited number of studies have analyzed the treatment results of periprosthetic patella fractures . Ortiguera and Berry present patient data with a healing rate of 82% after conservative management (61). Another study shows with 21 enrolled patients suffering from undisplaced patellar fractures also demonstrates acceptable results following conservative management (37). However, the complication rate for surgical treatment of periprosthetic patella fracture is relatively high, underscoring again the careful decision making for operative indications (30, 37, 61). Some authors go even so far to recommend, whenever possible, conservative treatment should be tried (41).

Revision artroplasty (Fig. 6–8)

Outcome results (17, 19, 42, 52) are reported to be satisfactory. When compared to osteosynthetic reconstructions in MIPO technique revision arthroplasty is always for both - the patient and surgeon - the more time-consuming and larger choice of surgical treatment. The use of cortical strut grafts as used in the Anglo-American areas still has to proof his advantage over the described techniques and should until then only be used in case of huge bone defects (28).

Fig. 5. Approach and range of motion.

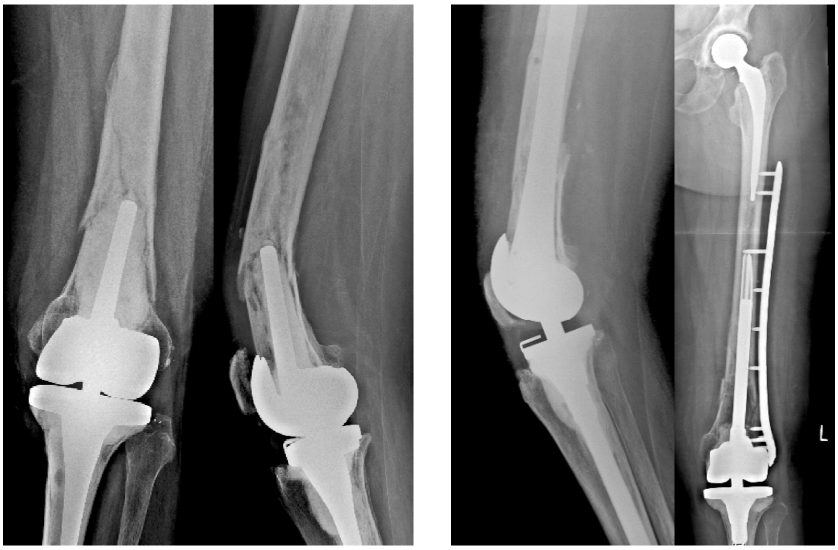

Fig. 6. Type II femoral fracture with loose TKA, pre- and postop result after revision TKA and additional L.I.S.S.

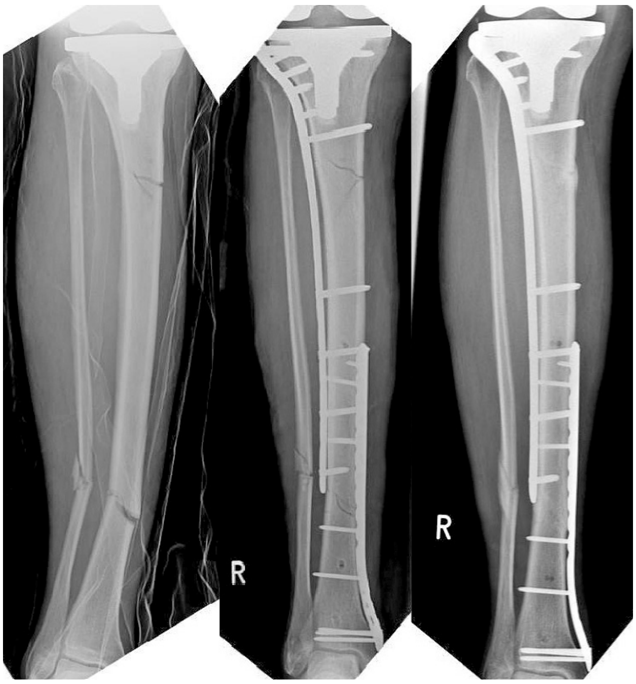

Fig. 7. Type IIIA tibial fracture treated by MIPO plating (L.I.S.S. and low bend tibia LCP, Synthes), trauma x-ray (left), postop x-ray (middle), bony healing 11 weeks after operation (right).

Fig. 8. Pre- and postop X-ray of a periprosthetic patellar fracture.

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