Periprosthetic knee fractures

A. Maestro[a], L. Rodríguez[b] and J.A. Llopis[c]
[a]FREMAP Medical Services. Cantabria Regional Office.
[b]Cabueñes Hospital. Gijón. Asturias.
[c]FREMAP Hospital. Majadahonda. Madrid.

Fractures around prosthetic knee implants are currently a much debated problem, given the high rates of posterior complications recorded regardless of the treatment employed. This is especially troublesome since it means that the functional result obtained will inevitable be compromised.

A perfect systematization and classification of different fracture patterns will make it possible to make well-founded therapeutic decisions. In addition to the systemic patient-related factors, every case presents other factors, alignment being the most important one.

The types of implants used at present, together with the concept of modularity and the broad therapeutic arsenal available in knee trauma, make it possible to carry out therapeutic planning in a customized way based not only on the patient but also on the fracture type present.

Retrograde nails and the different types of nail-plate fixation play a leading role in the surgical management of these patients. However, orthopedic treatment remains the preferred option on some occasions.

Key words: *knee, arthroplasty, fracture.*

Fracturas periprotésicas de rodilla

Las fracturas alrededor de los implantes protésicos de rodilla continúan aún hoy día como objeto de debate, con importantes tasas de complicación posterior independientemente del tratamiento realizado, por lo que el resultado funcional siempre se verá comprometido.

Una perfecta sistematización y clasificación de los diferentes patrones fracturarios permitirá la toma de decisiones terapéuticas al respecto. Aparte de los factores sistémicos del paciente existen otros factores independientes de cada caso, donde la alineación desempeña el papel más importante.

Los tipos de implantes utilizados en la actualidad con el concepto de modularidad y el amplio arsenal terapéutico existente en la traumatología de la rodilla hacen que la planificación terapéutica sea realizada de una forma individualizada desde el tipo de paciente y, por supuesto, desde el tipo de fractura.

Los clavos retrógrados y los distintos tipos de fijación mediante clavo-placa ocupan un lugar preferente y de actualización en el manejo quirúrgico, pero el tratamiento ortopédico continúa presentando la terapéutica de elección en algunas ocasiones.

Palabras clave: *rodilla, artroplastia, fractura.*

The majority of the published series show a significant incidence of periprosthetic (chiefly femoral) fractures, with percentages ranking between 0.5 and 2.5%[1-9] and with complications further to treatment of up to 75%[10].

Corresponding author:
A. Maestro.
Servicios Médicos FREMAP.
Avda. Juan Carlos I, 1.
33212 Gijón. Asturias.
E-mail: antonio_maestro_fernandez@fremap.es

Received: November 2006.
Accepted: February 2007.

These figures loom large over the results achieved and make this both a clinical and a functional problem, on the basis of the final degree of mobility achieved.

In spite of being a relatively rare complication, the effects of periprosthetic fractures can be devastating for the survivorship of the implant. In fact, implant survivorship is in direct proportion to the stability of prosthetic components, the degree of displacement of the different bone fragments and the degree fracture stability achieved with the therapeutic method of choice.

Obtaining a successful surgical treatment is not impossible, although difficulties must be anticipated given the complexities involved. In any case, a thorough knowledge of the anatomical and biomechanical principles of the knee is required as well as of the fixation methods used in conjunction with prosthetic revision surgery, which is in itself a rather tall order,

Naturally, much better results can be obtained at present than in previous decades given a more in-depth knowledge of fractures, the improvement in Imaging techniques and the existence of specific instruments to fixate and stabilize these types of injuries.

This paper contains a review of the current trends in periprosthetic knee fractures.

BASIC CONCEPTS

Even if from a local or regional point of view there are predisposing factors for fracture, performance of a primary knee replacement requires a meticulous surgical technique to avoid the occurrence of a fracture as a result of: (i) the traumatic management of the bone surfaces (especially in revision surgery); (ii) the third body reaction that takes place because of the wear of the material or the notching or wide resection of the anterior cortex (fig. 1) and (iii) implant malalignment, which affects load sharing between the different compartments and can lower tolerance of varus positions.

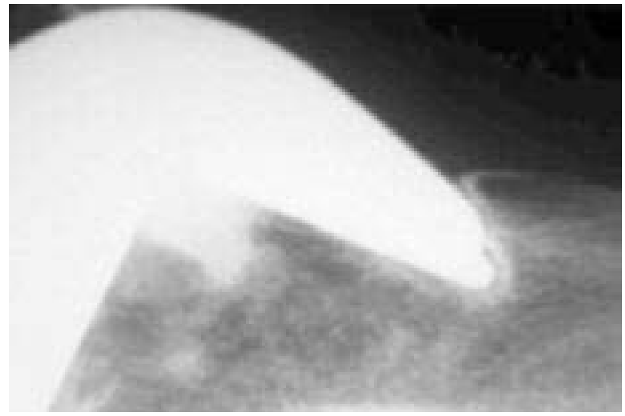


Figure 1. Anterior notch with evident weakening of anterior cortex. There is no scientific evidence of the appearance of subsequent supracondylar fractures. In any case, such notches must be avoided.

Osteoporosis also plays a role in these periprosthetic complications since it tends to affect elderly people, weakening their bone stock. Nonetheless, osteoporosis increasingly affects younger patients, which has led to the use of steroid medication in these patients to prevent a possible systemic involvement. Also, rheumatoid arthritis can promote bone fragilization and cause fractures in patients bearing prostheses[1,2,9]. Neurological conditions such as myasthenia gravis, Párkinson's disease, poliomyelitis or neuropathic arthropathies (syphilis, Charcot), also seem to play a role, both because of their biomechanical effects in terms of distortion of the anatomical axes (and consequently disruption of load sharing) and the alteration of sensitivity, which distorts the reception of propioceptive signals in the knee joint, making these patients more prone to trauma and periprosthetic fractures.

Even if the risk factors In the tibia[10] are similar to those in the femur, injuries in the former are normally fatigue fractures with minimum trauma, associated to a mechanical situation characterized by the presence of stress Rivers caused more often than not by a malaligned implant.

Finally, the third bone component, the patella, is beset by the highest proportion of periprosthetic fractures.

Surgeons themselves may be the cause of some of these fractures since there are some risk factors related to the surgical technique, such as bone overresection, patellofemoral maltracking and the use of a large central peg among others, not to mention the thermal effect of the cement or a vascular deficit, periprosthetic fractures being more usual with posterostabilized prostheses, which permit a wide range of flexion and tend to make the patella impinge on the polyethylene insert. In the case of patellar inset-type implants, avulsions or small marginal fractures can occur at the time of implantation; these problems need to be addressed to prevent patellar pain.

Periprosthetic fractures have been classified into displaced and non-displaced fractures[3,11-13], depending on whether angulation grater than 5° or a displacement greater than 5 mm is present or not, respectively. From a chronological point of view, intraoperative and postoperative fractures have been identified and the latter have been subclassified into two groups, according to the stability of the implant, i.e. with a loose or unviable prosthesis and with a well anchored and stable prosthesis, which is the main variable to be considered.

One cannot forget Neer's[14] classical classification of supracondylar fractures into grade I (undisplaced or minimally displaced fractures); grade II (with a displacement of the femoral shaft, either medially [II-A] or laterally [II-B]) and grade III, with displacement and comminution or with condylar or diapyseal involvement at the level of the femur; in this last group fracture lines could involve the whole of the femur.

More recent classifications[15] divide periprosthetic fractures into the following categories: grade I, extraarticular or undisplaced fractures (the degree of displacement is identical to that in Neer's classification); grade II, also extraaarticular fractures but with moderate displacement; and grade III, fractures with significant displacement whereby contact is lost between the cortices and intercondylar lines may be found.

Following the Mayo Clínic classification[11], tibial fractures have been classified into 4 groups from an anatomical point of view, depending on the location of the fracture line: metaphyseal (grade I), metaphyseal-diaphyseal (grade II), purely diaphyseal (grade III) and, lastly (grade IV), involve-

A B C D

Figure 2. *Post-traumatic supracondylar fracture (A and B) with significant displacement. (C and D) Result following orthopedic treatment by means of traction and subsequent functional immobilization.*

ment of the tibial tuberosity. These are in turn divided into three subgroups, depending on the stability of the implant and the chronology, since it is not infrequent for these fractures to occur intraoperatively.

Patellar fractures may occur both with or without a prosthesis[16], with a reported incidence ranking between 0.05 and 6.3%. In what follows we review femoral, tibial and patellar periprosthetic fractures.

FEMORAL FRACTURES

It has been shown that 83% of patients with a type I fracture had satisfactory results, whereas only 63% of type II and II fractures obtained good results[4], which means that the degree of displacement is the most significant variable to be taken into account from the point of view of the fracture, and the implant's viability is the most important variable to be considered when it comes to the functional recovery of the knee.

In undisplaced or extraarticular fractures (grade I), or in situations where the patient's general condition is weak with a high surgical risk, treatment of choice must be reduction and immobilization by means of a toe-to-groin cast (fig. 2) and functional casts later on[17].

Weight bearing of the limb is strictly contraindicated; rest or orthopedic traction should be mandated[18,19]. Traction must limit the mobility of the involved joint; 4-6 weeks is sufficient to achieve fracture healing[18].

As will all cases of periarticular involvement, accurate periodical and serial x-ray follow-up is necessary to assess any displacements and be able to act promptly and with minimal manipulations should they occur; if they are too large a surgical reduction can be performed, followed by one of different fixation methods.

The criteria for surgical treatment are determined by cases in which it is impossible to keep the limb immobilized, as is normally the case with obese or multi-trauma patients, or patients intolerant of immobilization or offloading of the limb (geriatric patients), who require either wedges to be made in their casts to improve alignment or fixation devices to be used prophylactically.

Use of pins or thin Zickel or Rush-type nails with minimal extraarticular incisions or minimally invasive surgery have proven themselves to be highly satisfactory techniques in these injuries[18,20-24], although osteoporosis could require more aggressive approaches.

Authors who claim that immobilization for longer than three weeks is associated with significant mobility losses[25] consider this surgical indication their primary treatment[19,23].

It should be considered that in these types of fractures the chances of success are determined by the degree of fracture healing and by a good clinical and functional result with at least 90° of flexion, these functional and clinical pain-related criteria being in direct proportion to the degree of alignment obtained; shortening of up to 2 cm, varus/valgus of up to 5° and flexion-extension of up to 10° are considered acceptable.

Likewise, the presence of some of the potential complications of immobilization, such as pressure or decubitus ulcers on the heel and sacral areas[2,6,14], could force the surgeon to change his initial criteria and perform a more aggressive surgery.

Within grade I, full or marginal epicondylar avulsions can occur chiefly as a result of hyperpressures in a flexed position. These avulsions cannot be maintained in the fracture site and require surgical treatment by fixating and stabilizing the fragment; it is normally enough to use a screw with a washer (fig. 3). As regards marginal (extra- or intraarticular) avulsions, can be left untreated, provided that they do not interfere with the load sharing pattern and that they are not affected by the movements of the joint.

In grade II fractures, alignment is not normally satisfactory and surgery is required to achieve a stable fixation and allow early joint mobility. The presence of a stable prosthetic implant that is well anchored to the distal bone fragment or with the metaphyseal region is an indispensable requirement.

When determining the type of fixation required, it is fundamental to consider the distal bone fragment, i.e. the fragment attached to the femoral component, in terms of its size, the length of the fracture line and the degree of osteoporosis present (if any). If screw-plate or threaded plate fixation is used, bone grafting may be necessary or, as has recently been proposed, cement can be introduced through the screw holes[26,27].

The use of external fixators has very limited indications in these types of fractures, since the idea is to permit early mobilization and the use of pins in the distal bone fragment may be complicated by the proximity of the implant. In ad-

Figure 3. *Intraoperative fracture-avulsion of the medial epicondyle treated with screw and washer osteosynthesis with no functional repercussion.*

dition, the fixation of the pins in the proximal fragment could interfere with the quadriceps muscle, which constitutes two limitations to their use, one from the point of view of controlling the fragments and the other represented by the intolerance of nails, especially if we take into account the friction that occurs between the mails and the muscle as soon as there is some mobilization.

Recently, the use of retrograde intramedullary mailing has been advocated through the patellar tendon and the distal femur, with good clinical and functional results. The procedure can be carried out with a minimal incision thus allowing percutaneous locking at the proximal level of the nail. This technique requires a good alignment (especially as far as rotation is concerned) and a knowledge of the distance or the intercondylar slot of the implant that has been placed[28], which will be the nail's entry point (table 1).

This technique cannot be used in posterostabilized implants since access to the medullary canal is blocked by the implant. This requires the use of other fixation methods.

In grade III fractures, the treatment of choice will depend on whether the implant is stable or not. In these types of periprosthetic fractures, frequently characterized by intercondylar lines that initially go unnoticed, given the severity of the displacement of the large fragments, it is indispensable to achieve a solid fixation between implant and distal bone, diaphyseal —or rather metaphyseal-diaphyseal— stability being less important. Therefore revision prostheses with intramedullary stems allowing endosteal locking (associated with different fixation methods) are the safest and most reliable procedure. Most manufacturers offer these possibilities with femoral valgus of 5°, which means that once the Joint has been restored, the extraarticular area can be addressed.

Compacted bone grafting techniques[29] have obtained very good results. Moreover, avoiding the use of cement in the endosteal area or at the fracture site will facilitate the repair process and prevent complications such as bone necrosis or nonunion of the fracture because of cement excess or interposition.

Finally, the use of bulk grafts, tumoral implants or both has been proposed. This requires an extremely laborious technique since success will depend on the amount of bone stock that needs to be retained to allow effective load sharing and, once satisfactory stabilization is obtained, joint mobilization can be performed.

TIBIAL FRACTURES

These are normally perioperative fractures that go unnoticed at the time of surgery or stress fractures, which are normally closely related to poor implant placement, especially in a varus position, since with this residual deformity of the axis there is a certain level of tolerance of valgus.

Table 1. Minimum intercondylar distance of different prosthetic models

Model	Intercondylar distance (mm)
Advantim (Wright Medical®)	19
AGC (Biomet®)	17
AMK (DePuy®)	14
Anakine (Lafitt®)	16
Apollo (Centerpulse®)	18.5
Ascent (Biomet®)	14
Axiom (Wright Medical®)	14
CKS (Biomet®)	16
Columbus (Aesculap®)	18
Duracon (Stryker®)	18.5
Genesis (Smith & Nephew®)	20
Genesis II (Smith & Nephew®)	16.5
Hermes (Ceraver®)	20
Interax (Stryker®)	18
LCS (DePuy®)	13.6
Maxim (Biomet®)	13
MBI (Biomet®)	17
Natural knee (Centerpulse®)	14
Nex-Gen CR (Zimmer®)	12.1
Nex-Gen LPS(Zimmer®)	13.7
Optetrack (MBA®)	15.3
PCA (Stryker®)	12
Performance (Biomet®)	20.3
Performance CR (Biomet®)	14
PFC Sigma (DePuy®)	17.4
Scorpio (Stryker®)	17
Vanguard (Biomet®)	18
Whitesides (Dow Corning®)	20

As regards post-traumatic fractures, depending on the degree of stability of the implant and the type of trauma present, they may be more or less serious, with predisposing factors identical to those of femoral fractures; the potential implication or the need to have performed a previous tibial osteotomy are factors to be taken into account.

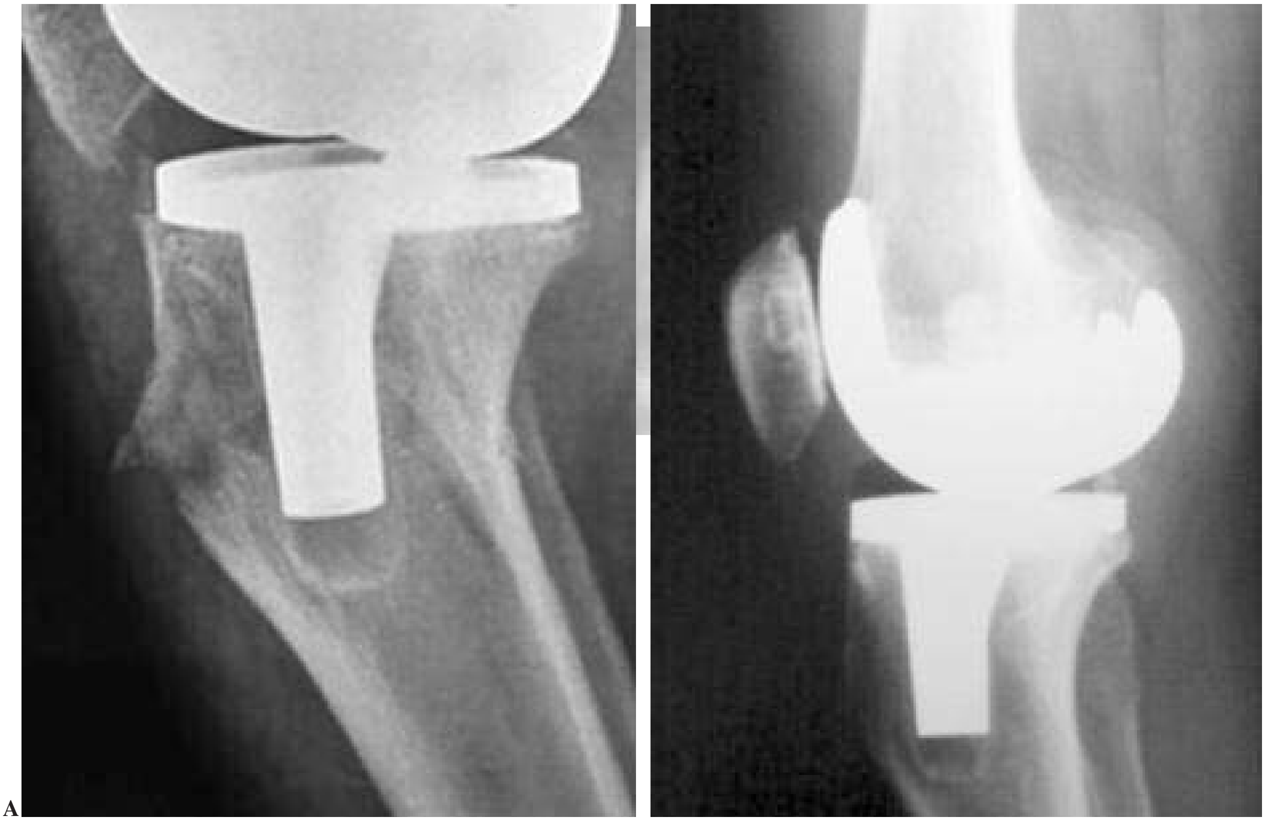
Type I

These types of fractures are often associated with the loosening of the tibial component, and it is necessary to restore the bone surface in order to provide adequate support.

For the surgical technique to be successful, the type of bone defect present (cavitary or peripheral) must be identified, as well as the amount of remaining bone stock. For this purpose, use of bone graft or cement-filled augment blocks, or of a custom prosthesis, is necessary to address the existing defects and promote correct load transmission.

Type II

Unlike fractures in the previous group, these fractures can be associated to either a stable or a loose implant (fig. 4), which may or may not comprise a stem, which may or not in turn be cemented.



A B

Figure 4. *(A) Tibial type II fracture. (B) Result of orthopedic treatment by means of a toe-to-groin cast in extension with complete resolution.*

In terms of treatment, apart from aligning the limb in the case of a loose implant, revision surgery is mandatory in order to obtain an accurate fixation of the component, which should be attempted with an intramedullary stem that delivers a satisfactory level of stability. Resting the fracture line on an implant with a cemented stem complicates the situation since it makes it necessary to withdraw the remainder of the cement in order not to interfere with fracture healing and make it necessary to use bone grafts.

In fractures on a stable implant, always baring in mind the importance of a good alignment, immobilization and non-weight-bearing of the limb, followed by progressive and assisted bearing of weight could be enough to achieve healing.

On some occasions, intramedullary instrumentations and intramedullary stems in primary surgery could lead to cortical perforation with the ensuing weakening and malpositioning of the implant (fig. 5) since the end of the latter rests on the weakened bone area.

Type III

In these situations the prosthesis normally remains stable. Fractures should be treated as ordinary tibial shaft fractures, i.e. with satisfactory alignment, healing being achieved through the usual orthopedic means. However, when trauma leads to the loosening of the implant, a revision will be necessary with a long intramedullary stem or some other device whose effect is similar to that of intramedullary nailing with endosteal fixation.

Type IV

The avulsion of the tibial tuberosity, and therefore the interruption of the extensor mechanism, Could signal the inception of a severe and difficult-to-resolve injury, which means that an attempt to use simple and low-risk methods would be the most reasonable option.

Therefore, in cases with or without minimal displacement, immobilization with a toe-to-groin cast in extension could be a viable solution. On the other hand, more or less aggressive fixation strategies in conjunction with an assessment of the integrity of the tendon (which may require additional maneuvers or the use of grafts including the patellar tendon), could result in either great successes or catastrophic situations that could require surgical palliative treatment to relieve pain, without taking into consideration the mobility of the joint and forgetting about the knee's function.

Figure 5. Intraoperative tibial fracture (of the lateral cortex) that occurred as a result of misguided use of the alignment rods. Orthopedic treatment by means of non-weight bearing with full recovery of mobility with no repercussions for implant survivorship.

PATELLAR FRACTURES

This infrequent complication accounts for most periprosthetic fractures. Although its incidence has decreased in recent years (2-3.6%)[31,32], some published series report levels of up to 21%[30]. This decreased incidence is due to the greater surgical skills acquired, the improvement in patellar implant design and materials and the betterment of instruments, which has made cuts of the patellar bone more straightforward.

The involvement of this bone in the context of knee arthroplasty, as mentioned above, occurs both in knees with and without a patellar implant, with a published incidence of 0.05% in patellas without a patellar implant and 0.33% in those with an implant[33].

As is the case with the femur and the tibia, these fractures can be classified from a genetic point of view into traumatic or genetic injuries. The first group is clearly random-based, but in the second there is a multifactorial situation with elements that could determine or cause the injury, such as excessive postoperative mobility[34], associated or not with technical defects, excessive bone resection or an inappropriate correction of patellofemoral tracking[30,35-38] with concomitant hyperpressure, which has made it advisable to respect a minimum of 15 mm.

Likewise, they are associated to biomechanical factors related to the design of the implant, such as a large central peg or a residual patella which, in posterostabilized implants, can give rise to repetitive impingement or repetitive microtrauma.

Other factors are using cement or not[35,37] (cement triggering a thermal effect), or the section of the retinaculum that causes a deficit in blood supply, or the resection of Hoffa's fat pad with factors favoring bone weakening[8,35,37,39-41].

These fractures can be grouped chronologically into intra or postoperative fractures; pathologically into displaced and undisplaced fractures; and anatomically into vertical, horizontal or comminute fractures[18,42]. From a practical and prognostic viewpoint, the following classification could be deemed more simple[43]: type I, integrity of the extensor mechanism or non-involvement of the implant's stability; type II, either of the conditions above does not obtain; type III, breakage of the inferior pole, subdivided in turn into type III-A, patellar tendon is torn, and type III-B, patellar tendon is intact; and finally type IV, with an associated patellar dislocation.

Treatment of marginal or undisplaced fractures, those with displacement of less than 2 mm, is normally orthopedic with immobilization at 5° flexion[44], followed by progressive physical therapy and occasionally, in cases of selective peripatellar pain that require visualization of fragments, a surgical procedure, which will normally involve the resection of the fragments.

Conversely, fractures that are displaced or accompanied by extensor mechanism insufficiencies require restorative surgery with lever arm reconstruction by means of different fixation methods, cerclage wiring being the most common one. If patellar reconstruction is unviable, a partial or complete patellectomy should be performed, preserving the function of the quadriceps tendon and the retinacula. These are nevertheless complicated techniques that do not guarantee full recovery or the functional integrity of the knee's extensor mechanism.

Therefore the resolution of patellar fractures depends mostly on the therapeutic success of the reconstruction of the extensor mechanism, which means that orthopedic treatment should always be attempted, except in special situations in which the implant is loose or unviable, where there are displaced fractures or in cases where extension is functionally impossible. In these instances reconstruction of the extensor mechanism is mandatory.

On the basis of the authors' experience, fractures with minimal or no displacement must be treated orthopedically, with special emphasis on restrictions to weight-bearing, with active mobilization always contingent on the fracture pattern.

In cases where surgery is indicated, where immobilization is not tolerated or when regular follow-ups reveal that displacement has occurred, usual fixation methods by means of condylar plating or retrograde nailing should be the most favored option.

If the comminution present or the existing bone quality are such that the stability of the implant cannot be guaranteed, revision surgery is required, always taking into account the significant stabilizing role to be played by the use of a long stem that crosses the fracture site as well as the potential need to use bone allografts.

Finally, as regards the patellar fracture, the degree of involvement of the extensor mechanism will be the determining factor for the choice of either reconstructive or protective treatment.

To conclude, even if periprosthetic fractures are a rare complication, it is essential to reduce them and get them to heal in order to achieve both the clinical and functional recovery of the patient. The therapeutic approach to this complication requires, in the first place, an assessment of the viability of the implant so that the surgeon can fixate the fracture with the method that he knows best[45]. We should not forget that knee periprosthetic fractures are a constantly evolving challenge given the technological progress achieved in the field of trauma surgery; common sense and scientific evidence should never be lost sight of.

REFERENCES

1. Aaron RK, Scott R. Supracondylar fracture of the femur after total knee arthroplasty. Clin Orthop. 1987;219:136-9.
2. Bogoch E, Hastings D, Gross A, Gschwend N. Supracondylar fractures of the femur adjacent to resurfacing and MacIntosh arthroplasties of the knee in patients with rheumatoid arthritis. Clin Orthop. 1988;229:213-20.
3. Cain PR, Rubash HE, Wissinger HA, McClain EJ. Periprosthetic femoral fractures following total knee arthroplasty. Clin Orthop. 1986;208:205-14.
4. Chen F, Mont MA, Bachner RS. Management of ipsilateral supracondylar femur fractures following total knee arthroplasty. J Arthroplasty. 1994;9:521-6.
5. Culp RW, Schmidt RG, Hanks G, Mak A, Esterhai JL Jr, Heppenstall RB. Supracondylar fracture of the femur following prosthetic knee arthroplasty. Clin Orthop. 1987;222: 212-22.
6. Figgie MP, Goldberg VM, Figgie HE, Sobel M. The results of treatment of supracondylar fracture above total knee arthroplasty. J Arthroplasty. 1990;5:267-76.
7. Hirsh DM, Bhalla S, Roffman M. Supracondylar fracture of the femur following total knee replacement. Report of four cases. J Bone Joint Surg (Am). 1981;63:162-3.
8. Merkel KD, Johnson EW. Supracondylar fracture of the femur after total knee arthroplasty. J Bone Joint Surg (Am). 1986;68:29-43.
9. Mooney V, Mickel VL, Harvey JP, Snelson R. Cast brace treatment for fractures of the distal part of the femur. J Bone Joint Surg (Am). 1970;52:1563-70.
10. Booth RE. Revision total knee arthroplasty. Supracondilar fractures: all or nothing. Current Concepts in Joint Replacement. December 15-17 Orlando; 1994.
11. Clayton ML, Thirupathi R. Patellar complications after total condylar arthroplasty. Clin Orthop. 1982;170:152-5.
12. Felix NA, Stuart MJ, Hanssen AD. Periprosthetic fractures of the tibia associated with total knee arthroplasty. Clin Orthop. 1997;345:113-24.
13. Degoia AM, Rubash HE. Periprosthetic fractures of the femur after total knee arthroplasty. Clin Orthop. 1991;271:135-42.
14. Neer CS, Grantham SA, Shelton ML. Supracondylar fracture of the adult femur. J Bone Joint Surg (Am). 1967;49:591-613.
15. Chmell MJ, Moran MC, Scott RD. Periarticular fractures after total knee arthroplasty: Principles and management. J Am Acad Orthop Surg. 1996;4:109-14.
16. Grace JN, Sim FH. Fracture of the patella after total knee arthroplasty. Clin Orthop. 1988;230:168-75.
17. Moran MC, Brick GW, Sledge CB, Dysart SH, Chien EP. Supracondylar femoral fracture following total knee arthroplasty. Clin Orthop. 1996;324:196-9.
18. Kayler DE, Lyttle D. Surgical interruption of patellar blood supplied by total knee arthroplasty. Clin Orthop. 1988; 229:221-7.
19. Ritter MA, Keating EM, Faris PM, Meding JB. Rush rod fixation of supracondylar fractures above total knee arthroplasties. J Arthroplasty. 1995;10:213-6.
20. Barker LG, Ryan WG, Paul AS, Marsh DR. Zickel supracondylar nail to treat supracondylar fracture of the femur in patients with total knee replacements. Internat J Orthop Trauma. 1993;3:183-5.
21. Delport PH, van Audekercke R, Martens M, Mulier JC. Conservative treatment of ipsilateral supracondylar femoral fracture after total knee arthroplasty. J Trauma. 1984;24:846-9.
22. Ortega M, Rodríguez-Merchán EC, Agüera M, Alonso G. Fracturas periprotésicas en artroplastia de rodilla. Rev Ortop Traumatol. 2000;2:149-58.
23. Roffman M, Hirsh DM, Mendes A. Fracture of the resurfaced patella in total knee arthroplasties. Clin Orthop. 1980;148: 112-6.
24. Scott RD, Turoff N, Ewald FC. Stress fracture of the patella following duopatellar total knee arthroplasty with patellar resurfacing. Clin Orthop. 1982;170:147-51.
25. Digiora A, Rubash H. Periprosthetic fractures of the femur after total knee arthroplasty. Clin Orthop. 1991;271:135-42.
26. Ayers DC, Dennis DA, Johanson NA, Pellegrini VD Jr. Common complications of total knee arthroplasty. J Bone Joint Surg (Am). 1997;79:278-311.
27. Harrington KD. The use of metylmetacrylate as a djunt in the internal fixation of unstable comminuted intertrochanteric fractures in osteoporothic patients. J Bone Joint Surg (Am). 1975;57:744-52.
28. Rosenfield AL, McQueen D. Zickel supracondylar fixation device and Dall-Miles cables for supracondylar fractures of the femur following total knee arthroplasty. Tech Orthop. 1991;6:86-8.
29. Healy WL, Siliski JM, Incavo SJ. Operative treatment of distal femoral fractures proximal to total knee replacements. J Bone Joint Surg (Am). 1993;75:27-34.
30. Cameron HU, Fedorkow DM. The patella in total knee arthroplasty. Clin Orthop. 1982;165:197-9.

31. Healy WL, Wasilewski SA, Takei R, Oberlander M. Patellofemoral complications following total knee arthroplasty. J Arthroplasty. 1995;10:197-201.
32. Windsor R, Scuderi G, Insall J. Patella fractures in total knee arthroplasty. J Arthroplasty. 1989;4:563-7.
33. Hanks GA, Mathews HH, Routson GW, Loughran TP. Supracondylar fracture of the femur following total knee arthroplasty. J Arthroplasty. 1989;4:289-92.
34. Fipp G. Stress fractures of the femoral neck following total knee artrhoplasty. J Arthroplasty. 1988;3:347-50.
35. Figgie HE, Goldberg VM, Figgie MP, Inglis AE, Kelly M, Sobel M. The effect of alignment of the implant on fractures of the patella after condylar total knee arthroplasty. J Bone Joint Surg (Am). 1989;71:1031-9.
36. Rolston LR, Christ DJ, Halpern A, O'Connor PL, Ryan TG, Uggen WM. Treatment of supracondylar fractures of the femur proximal to a total knee arthroplasty. A report of four cases. J Bone Joint Surg (Am). 1995;77:924-31.
37. Scuderi G, Scharf SC, Meltzer LP, Scott WN. The relationship of lateral release to patella viability in total knee arthroplasty. J Arthroplasty. 1987;2:209-14.
38. McLaren AC, Dupont JA, Schroeber DC. Open reduction internal fixation of supracondylar fractures above total knee arthroplasties using the intramedullary supracondylar rod. Clin Orthop. 1994;302:194-8.
39. Ritter MA, Stiver P. Supracondylar fracture in a patient with total knee arthroplasty. A case report. Clin Orthop. 1985;193: 168-70.
40. Tria AJ, Harwood DA, Alicea JA, Cody RP. Patellar fractures in posterior stabilized knee arthroplasties. Clin Orthop. 1994;299:131-8.
41. Insall J, Haas BH. Complicaciones de la artroplastia total de rodilla. En: Insall J, editor. Cirugía de la rodilla. Buenos Aires: Panamericana; 1994. p. 910-54.
42. Hozack WJ, Goll SR, Lotke PA, Rothman RH, Booth RE Jr. The treatment of patellar fractures after total knee arthroplasty. Clin Orthop. 1988;236:123-7.
43. Goldberg VM, Figgie HE, Inglis AE, Figgie MP, Sobel M, Kelly M, et al. Patellar fracture type and prognosis in condylar total knee arthroplasty. Clin Orthop. 1988;236:115-22.
44. Zehntner MK, Ganz R. Internal fixation of supracondylar fractures after condylar total knee arthroplasty. Clin Orthop. 1993;293:219-24.
45. Rodríguez-Merchán EC. Fracturas periprotésicas de rodilla. Patología del Aparato Locomotor. 2005;3:260-70.

Conflict of interests

The authors have declared not to have any conflict of interests