Rev esp. cir. ortop. traumatol. 2009;**53(2)**:113-119

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Revista Española de Cirugía Ortopédica y Traumatología

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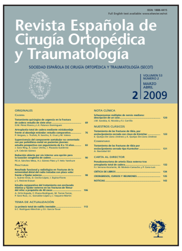

REVIEW ARTICLE

The unstable knee prosthesis

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Received July 7, 2008; accepted September 3, 2008
Available on the internet from 24 February 2009

KEYWORDS
Knee:
Prosthesis;
Total;
Instability;
Treatment

Abstract
Prosthetic instability is the third most frequent cause for the failure of total knee replacement (TKR), which leads to between 10% and 22% of surgical revisions. In addition to individual factors such as previous instabilities or deformities, an associated neuromuscular condition, rheumatoid arthritis or obesity, the main causes for prosthetic instability are related to errors in selecting the primary prosthesis or mistakes in the surgical technique, i.e. inadequate bone resections, failure to obtain an appropriate joint balance with symmetrical flexion and extension gaps, causing a iatrogenic laxity, etc. —all of them easily preventable. In order to successfully correct these instabilities, it is indispensable to identify its causes so as to be able to address and thereby avoid repeating the same mistakes that provoked them in the first place. As, the majority of cases will require surgical treatment and prosthetic revision, in this study we carry out an analysis of the different models available. As a general rule, we recommend the use of a prosthetic model with the minimum constraint necessary to achieve stability, taking into account that a posterostabilized prosthesis may be able to address a flexion instability, although it cannot compensate for a medial-lateral instability, and that even if a highly constrained prosthesis can compensate for both instabilities initially, in the long term it can lead to mechanical complications.

PALABRAS CLAVE
Rodilla;
Prótesis;
Total;
Inestabilidad;
Tratamiento

La prótesis total de rodilla inestable

Resumen
La inestabilidad protésica es la tercera causa más frecuente de fallo de una prótesis total de rodilla (PTR). Entre el 10 y el 22% de las revisiones quirúrgicas se deben a esta causa. Además de factores individuales, como inestabilidades o deformidades previas, afección neuromuscular concomitante, artritis reumatoide u obesidad, las principales causas se

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deben a errores en la selección de la prótesis primaria o a defectos en la técnica quirúrgica, como inadecuadas resecciones óseas, no obtener un apropiado balance con espacio simétrico en extensión y flexión o producir una laxitud iatrogénica, por lo que pueden ser prevenibles. Para obtener un buen resultado en su corrección es imprescindible identificar la causa de la inestabilidad a fin de actuar sobre ella y no repetir los errores que la produjeron. La mayoría de los casos requerirán tratamiento quirúrgico y recambio protésico, por lo que en este artículo realizamos un análisis de los distintos modelos disponibles. Como regla general recomendamos utilizar un modelo de prótesis con la mínima constricción necesaria para lograr la estabilidad, teniendo en cuenta que una prótesis estabilizada posterior puede solucionar una inestabilidad en flexión, aunque no compensa una inestabilidad medio-lateral, y que si bien una prótesis altamente constreñida compensa inicialmente ambas inestabilidades, a largo plazo pueden producir complicaciones mecánicas.

Introduction

An unstable knee prosthesis is defined as an implant characterized either by significant insufficiency of the primary knee stabilizers or by inappropriate ligament balance, which result in symptoms or a displacement of the two parts of the joint with respect to each other. The main factor for the mechanical survivorship of a knee prosthesis is correct tibiofemoral alignment and appropriate component positioning. Nevertheless, to obtain a satisfactory clinical result it is essential to endow the prosthesis with an appropriate ligament balance, both in flexion and in extension. Instability has been cited as the third most frequent cause of failure following total knee replacement and it is estimated that between 10 and 22% of revision surgeries are due to an unstable knee.[1-3]

Even if most cases result from errors in the surgical technique or in the selection of the prosthetic model, some patients may possess intrinsic characteristics that make them prone to this complication.[4] Although many cases can be resolved favorably, in order to avoid repeating old errors it is essential to identify the cause for instability and carry out an exhaustive clinical and radiographic analysis that determines the pattern of the instability.[3] Unfortunately, the literature provides little information about the diagnostic criteria, the therapeutic options and the prognosis associated with knee prosthetic instability.[5,6]

Predisposing factors

Many factors are known that could lead to instability following total knee replacement (table 1). The specific risk factors associated with the patient are diverse and include prior lesions in the knee ligaments, rheumatoid arthritis (usually resulting in an insufficiency of the Joint stabilizing structures), general or regional neuromuscular involvement (weakness of the quadriceps indoor weak abductors that impart a medial thrust to the knee), or hip or foot deformities characterized by ruptures of the tibialis posterior tendon leading to pes planus, which in turn causes the knee to shift into valgus. Obesity is also a risk factor, both because it complicates the surgical approach and because it hinders intra-operative examination of ligament balance. Also, overload produces laxity and a chronic insufficiency of the knee stabilizers, especially in the medial compartment.

Evaluation

Clinical findings are the first step toward confirming a diagnosis and understanding the underlying cause of prosthetic instability. It is necessary to put together a complete and appropriate clinical record that includes the diagnosis leading to the primary arthroplasty, any deformity or preoperative contracture, previous surgical procedures on the knee joint, as well as specifications of the knee replacement surgical technique, the type of prosthesis used and the postoperative rehab program indicated and whether the patient sustained any kind of trauma following surgery.

Initial patient assessment following knee arthroplasty should include an exhaustive physical examination of the

Table 1 Main causes for prosthetic knee instability

Ligament imbalance
Component malalignment
Component failure
Implant design
Medial-lateral instability
Bone loss resulting from an excessive resection of the distal femur
Bone loss resulting from femoral or tibial component loosening
Laxity of the soft tissues of the medial or lateral collateral ligaments
Connective tissue disorders (rheumatoid arthritis or Ehlers-Danlos syndrome)
Inadequate femoral or tibial bone resection
Imbalance of the collateral ligament (insufficient release, excessive release or traumatic tear)

Joint in order to identify any varus/valgus exion or extension laxity; a distance greater than 10 mm between the 2 joint surfaces should be considered signi cant. In addition, the existence of anteroposterior laxity must be determined by means of the drawer test. Radiologic evaluation should include a measurement of the mechanical and anatomic axes on a weightbearing anteroposterior teleradiograph and lateral knee views in full exion and extension in order to detect potential displacements or subluxations. A stress radiograph may also be of use. In addition to tibiofemoral alignment, it is necessary to identify whether prosthetic components have been placed correctly. This can be done by means of computerized tomography, which makes it possible to assess the components' rotational position. It is also important to identify the stability and the wear of such prosthetic components, especially of the tibial polyethylene component.[3,7] Finally, a deep infection must be ruled out since this would be a contraindication for surgically revising the instability.[1]

Types of instability

With a view to diagnosis and treatment, instability following total knee replacement can be classi ed chronologically as early or late and, in terms of its direction, as extension and exion instability. Extension instability may be symmetrical or asymmetrical and may have valgus or varus effects; exion instability – the most usual kind – normally has an anteroposterior clinical effect.

Early instability

Early instability manifests itself relatively soon, a few weeks or months following TKR. It is usually characterized by failure, locking or "giving way" of the knee joint, whose function becomes unsatisfactory. It may be attributable to different causes, although it is normally related to trauma caused by prosthetic implantation. It is normally dif cult to identify patient-related instability prior to knee replacement, reestablish the limb's mechanical axis or poor placement of the prosthetic components. Other causes may be technical errors in trying to produce appropriate exion and extension ligament balance (inadequate bone resections, poor component sizing or inappropriate tibial component thickness), an inadvertent rupture of the posterior cruciate ligament following implantation of a PCL-retaining prosthesis or an inadvertent injury or excessive release of the collateral ligaments, the PCL or the popliteal tendon. Some of the other causes for early knee prosthesis instability are related with injury to the extensor mechanism, including tendon ruptures and patellar fracture.

Late instability

The most common cause of late instability is wear, which causes the tibial polyethylene component to break; this may occur in isolation or in conjunction with ligament instability (g. 1). The result of this is generally an asymmetric extension gap, with the leg oriented in the direction in which the wear has occurred, and laxity in the said compartment. Finally, the extensor mechanism problems producing late instability are similar to those occurring early, except that they tend to be secondary to patellar component wear.[5]

Symmetric extension instability

This kind of instability is due to excessive distal femoral or proximal tibial bone resection, so that a wide extension gap is created. If the instability is caused by an excessive tibial resection, which would also affect the exion gap, it can be resolved with a thicker tibial polyethylene insert. If it is caused by excessive distal femoral bone resection, a thicker insert will not solve the problem; even if it would admittedly

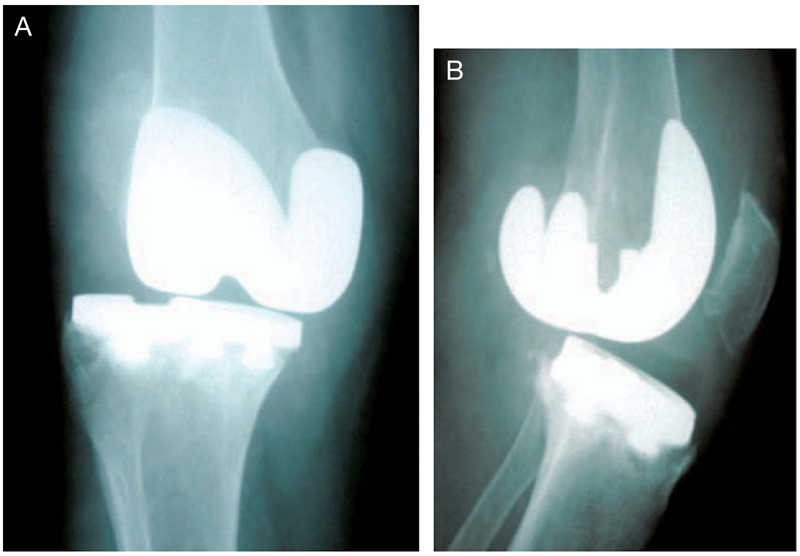

Figure 1 X-rays of an unstable total knee prosthesis caused by ligament insuf ciency. A: anteroposterior view. B: lateral view.

compensate for the wider extension gap, it would also bring about an elevation of the joint line and would excessively constrain the flexion gap. Joint line elevation could limit knee flexion and affect patellar function (patella infera) contributing to mid flexion instability. Flexion gap constraint would affect knee kinematics and limit flexion. For that reason, recommended treatment in this case would be to use distal femoral augments to compensate for the existing bone defect.

Asymmetric extension instability

Asymmetric instability is more common than symmetric instability and is typically related to a preoperative angular deformity of the knee. It is usually caused by some surgical error during primary arthroplasty, such as failure to bring about an appropriate ligament balance, failure to carry out a release in severe deformities, carrying out an excessive release that leads to a deviation in the opposite direction or causing a iatrogenic injury of one of the main knee stabilizers, especially the medial collateral ligament.

Varus angulations tend to be caused by an excessive release of the medial collateral ligament or by an attempt to compensate for a tibial bone defect with an exaggerated bone resection. In the majority of cases, even in severe deformities, adequate ligament balance can be obtained simply by means of posteromedial capsulotomy and posterior osteophyte resection, without acting on the medial collateral ligament. Valgus deviations may require release of the lateral compartment ligaments, which must be careful and gradual to avoid an excessive release, which could lead to extension instability.

Malalignment of the femoral or tibial component (fig. 2) on the frontal plane as well as wear and micromotion could also lead to medial or lateral asymmetrical instability.

Figure 2 Anteroposterior x.ray of an unstable knee prosthesis caused by tibial component loosening.

Flexion instability

Flexion instability results from discrepancy between the flexion and extension gaps arising further to the bone resections required to implant the prosthesis. It tends to present early, when a PCL retaining prosthesis has been used in a patient whose PCL has some kind of prior insufficiency or sustained an intraoperative injury, which may happen when tibial resection is excessive or in cases of genu recurvatum when a posterior release has been performed, especially if the popliteus tendon was also damaged. Nonetheless, there may also be a late secondary insufficiency of the posterior cruciate ligament. Symptoms are a feeling of instability in the knee, although it can also present more severely as a subluxation or a downright tibiofemoral dislocation.

As mentioned above, the first cause reported for flexion instability was placement of a PCL-retaining prosthesis in patients with ligament insufficiency, which can be resolved by conversion to a posterostabilized implant with satisfactory results in most cases. Nevertheless, it must be borne in mind that, in order to provide effective stabilization, posterostabilized models require the existence appropriate balance between the flexion and extension gaps. Other potential causes of flexion instability are component malposition, malrotation or loosening of the femoral component and late displacement of the tibial component.

General instability

General instability is an instability pattern that can be detected clearly on multiple planes; it is a combination of lax flexion and extension gaps. There are various causes for general instability: polyethylene wear, which results in surrounding soft tissue laxity, implant migration, motor dysfunction and, specifically, extensor mechanism rupture.

Patients present with significant instability symptoms ranking from knee failure or locking to recurvatum in cases of a poor extensor mechanism since these patients often have marked quadriceps weakness. Treatment options include revision with a constrained implant, which normally yields good results. However, treatment with grafting and orthosis tends to produce unsatisfactory results.[2,8,9]

Treatment

Conservative treatment

Conservative treatment may prove effective in a small percentage of patients with knee instability; closed reduction and orthotic immobilization could be of help in patients with acute prosthetic dislocation. Indication of orthosis and rehabilitation programs to strengthen the quadriceps and the hamstrings could improve symptoms in certain patients with mild or moderate instability. Nevertheless, in most cases, it will be necessary to resort to surgical treatment, especially if other disorders are detected, such as component malposition, wear or loosening.[1,10]

Surgical treatment

Most patients with prosthetic instability will require surgical treatment; preoperative planning is of great importance and it includes selecting an implant with the right degree of constraint.[11] In Knee revision surgery for instability, surgeons must: *a)* have an adequate mechanical axis of the limb; *b)* achieve a balance between the exion and extension gaps; *c)* verify ligament integrity make sure both compartments are well balanced, and *d)* have at their disposal prosthetic models with different degrees of constraint. As usual, diagnosing the cause of instability must precede successful treatment.[4]

As a general rule, we recommend using a prosthetic model that incorporates the minimum degree of constraint necessary to achieve stability. With the multiple component design options and degrees of constraint available in the market, it may be challenging to select the optimal implant for each patient.[5,12,13]

On some occasions it is possible to act directly on excessively lax ligaments, by advancing one of their 2 extremes, although results have been controversial. If a decision is made to address the ligament structures, it is in general preferable to release one compartment rather than tighten the opposite one. As excessive relaxation could result in severe ligament insuf ciency, it is better to moderately release the said compartment and compensate for the laxity of the other by means of a constrained prosthesis.

Posterior cruciate ligament retaining implants

Posterior cruciate ligament (PCL)-retaining designs are the implants with the least constriction between their components. In order to be effective, they require appropriate medial-lateral ligament balance and PCL suf ciency. For that reason, they are not indicated in most cases of prosthetic instability. Their use in revision surgery is reserved for patients with extension instability, where a thicker polyethylene component or revision of the femoral component are required, either because they are malpositioned or because distal augments are needed: All of this can only be done if the knee stabilizing ligaments are competent.

PCL-substituting implants

The next degree of constraint includes the posterostabilized models, which substitute for the function of the PCL: this is why they are normally indicated in cases of exion instability.

Nonetheless, it should be remembered that these models provide no medial-lateral and little rotational stability. Therefore in order to use them those ligament structures must be fully competent or, if this is not the case, carry out a repair of the joint spaces to produce an appropriate ligament balance.

Moderately constrained implants

The next degree of constraint is contributed by the VVC (varus valgus constrained*)* or CCK (constrained condylar knee) models, whose femoral and tibial components are not linked to each other; rather, stabilization is created at the expense of the femoral design and of the polyethylene insert. Such designs provide signi cant rotational control and an acceptable degree of stabilization for varus-valgus angulation. Their theoretical disadvantage is their load transfer pattern, whereby the component-bone interface tends to be overloaded. Because of the stabilization between the femoral and tibial components, these models can be useful in cases of severe medial or lateral instability, although it must be remembered that severe exion instability is a limitation for these types of implants.[12,14]

Highly constrained implants

These are the models where the femoral and tibial components are linked to each other. They include rotational hinge implants, which provide knee stabilization during extension (valgus/varus) and exion (PCL insuf ciency)[5,14] (g. 3). The drawback is that load transfer occurs axially through the link mechanism between both components, which increases the load they must withstand and favors loosening (in spite of the fact that both components have extension stems).

Their use should be restricted to speci c cases. These include severe valgus deviations where, in order to obtain ligament balance, an excessive release of the lateral compartment would be required. In these situations, it is preferable to create a moderate release, which causes the medial collateral ligament to advance, keeping the joint well-tensed. A constrained prosthesis can also be implanted. Another indication would be cases of generalized combined exion and extension instability that cannot be resolved with ligament balancing: the alternative in these cases could be knee arthrodesis. Current potential indications for the use of rotational hinge prostheses are shown in table 2.[16]

Indications for constrained implants in primary arthroplasty

Constrained prostheses also have their indications in primary surgery. It is better to use them that to fail as a result of severe instability, although cases must be selected with great care. Constrained knee arthroplasty designs are used usually in primary arthroplasty in cases of knees with severe varus or valgus deformities, resulting both from ligament insuf ciency that requires releases or complex reconstructions and from severe bone defects, especially in elderly or low-demand patients.

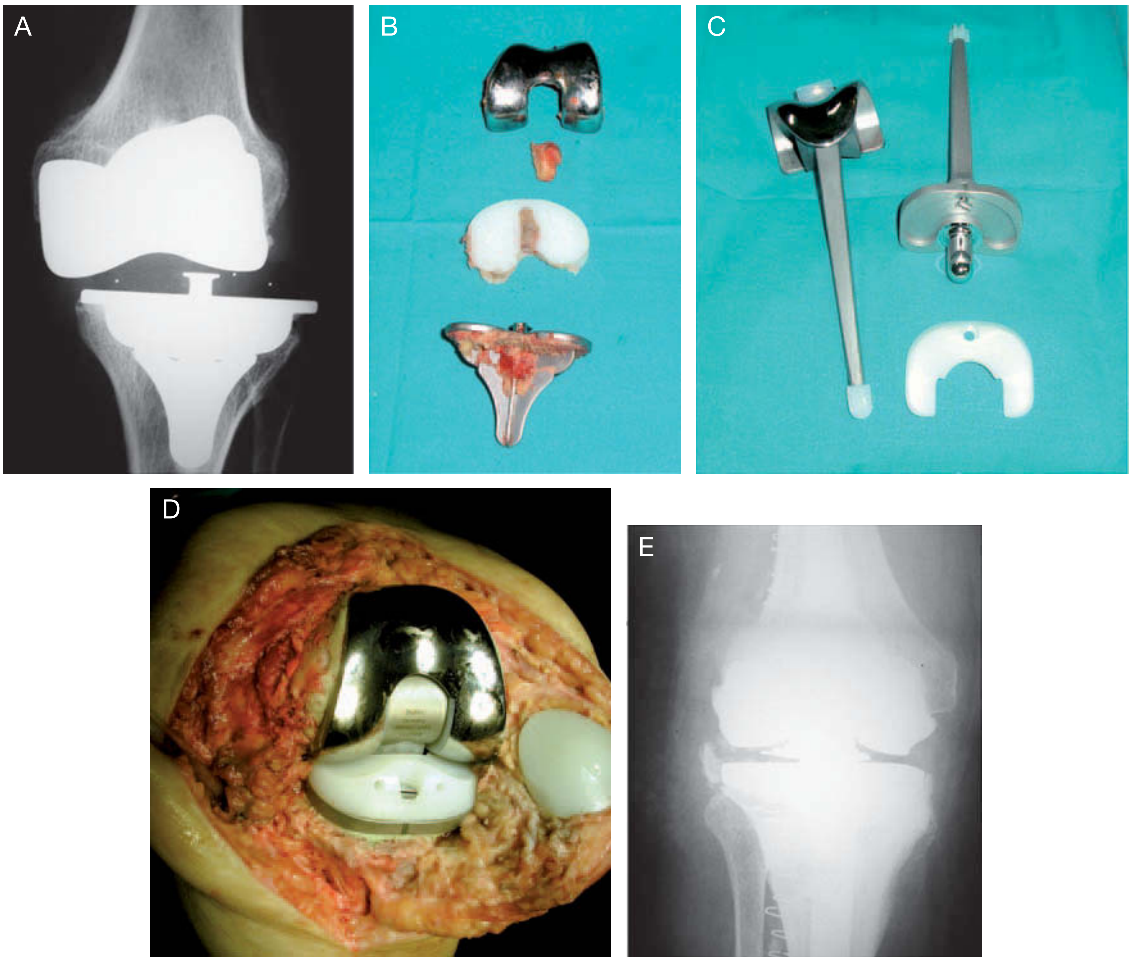

Figure 3 Unstable knee prosthesis that required revision arthroplasty by means of a rotational hinge implant. A: Preoperative x-ray. B: Intraoperative view of the removed components. C: View of the rotational hinge prosthetic components about to be implanted. D: Intraoperative view of the implanted rotational hinge prosthesis. E: Anteroposterior view of the new prosthesis (satisfactory result).

Table 2 Current indications for primary constrained prostheses

1. Tear of the medial collateral ligament
2. Massive bone loss of the distal femur or the proximal tibia (including the origin or attachment of the collateral ligament)
3. Comminuted distal femoral fracture in the elderly
4. Pseudoarthrosis) or malunion in the distal femur
5. Rupture of the extensor mechanism requiring reconstruction in an unstable knee
6. Ankylosis requiring extensive femoral exposure with moderate or severe residual imbalance of the exion/ extension gaps

Easley et al[14] reviewed 44 CCK prostheses in elderly patients with severe genum valgum, with excellent clinical results and no failures at 8 years' follow-up. Lachiewicz et al[15] reported 87%good or excellent results in a group of 25 patients with a primary arthroplasty, where they used constrained prostheses for complex knee reconstructions. Another scenario where constraint may be required during primary arthroplasty is in patients with rhemuatoid arthritis. Nevertheless, these patients have also been treated satisfactorily in the past with posterior cruciate ligament-retaining prostheses.

Medial collateral ligament injury in the course of primary arthroplasty could also require a constrained prosthesis in order to minimize stresses on the repaired ligaments. However, favorable results have also been described with primary repair of the ligament and the use of less constrained prostheses in specific cases.[16,17]

Finally, there are some situations in primary arthroplasty where greater constraint is indicated, as in patients with poor neuromuscular control resulting from poliomyelitis or neuropathic arthropathy, where the surrounding soft tissues do not provide enough stability, or in patients with a previous patellectomy.[18-20]

Conclusions

The majority of patients with prosthetic knee instability will require surgical treatment and revision of their primary implant. An adequately constrained prosthesis may be selected preoperatively. As a general rule, it is advisable to use a prosthetic model with the least constraint possible in order to contribute the required level of stability. Satisfactory results may be obtained in many of these cases. However, if the cause for the instability is not previously identified, the surgeon runs the risk of repeating the same errors that causes the instability following the primary surgery. Given that most cases of instability result from errors in the surgical technique or an ill-advised selection of the prosthetic model, we can conclude that, in most cases, instability following knee replacement can be prevented by carrying out the bone resections appropriately (so as to obtain a suitable balance between the flexion and extension gaps), promoting optimal medial-lateral ligament balance, and compensating for potential posterior cruciate ligament insufficiencies. Furthermore, causes leading to mechanical failure and polyethylene insert wear must be prevented. This is achieved by correct limb alignment and careful prosthetic component placement.

Conflict of interests

The authors have declared that they have no conflict of interests.

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