The Unstable Total Knee Arthroplasty

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16.1 Introduction

Knee prosthesis instability (KPI) is cited as the third most frequent cause of failure of total knee arthroplasty (TKA), between 10% and 22% of the failure cases and revision surgeries are due to instability [1–3]. Unfortunately, there is confusing information in the literature concerning definitions, risk factors and prevention, and treatment and outcomes. In 2016 Wilson et al. systematically assessed the current evidence available regarding knee instability after TKA [2]. Time to failure between primary and revision TKA was about 3.5 years, and the mean age at time of revision surgery was about 68 years. A gender distribution was identified, with approximately 16% more females revised for instability. This chapter has three purposes: Firstly to define terms, secondly to analyze risk factors and prevention of knee arthroplasty instability, and thirdly to review treatment options and their results.

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16.2 Definition of Knee Prosthesis Instability (KPI)

KPI is defined as the abnormal and excessive displacement of the articular elements that lead to clinical failure of the arthroplasty and is one of the most common causes of aseptic failure following total knee replacement [2] (Fig. 16.1). Instability may be early or late, but also may be in extension, in flexion or global.

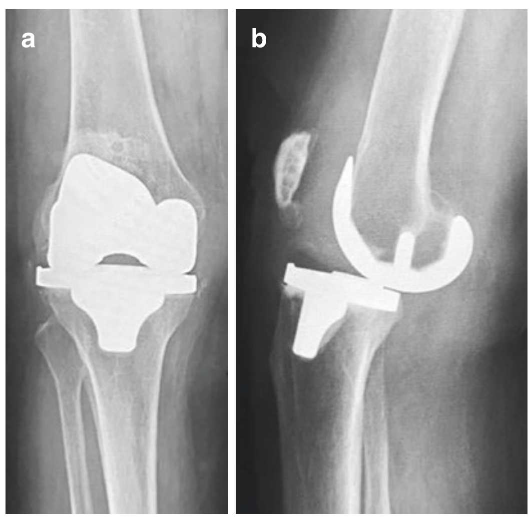

Fig. 16.1 Radiographs of an unstable total knee arthroplasty (TKA) due to ligament insufficiency: (**a**) Anteroposterior view. (**b**) Lateral view

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16.2.1 Early Instability

Instability that occurs relatively early (weeks to months) after TKA. The etiology of these early symptoms are multiple: disalignment of the components, failure of restoration of the mechanical axis of the limb, imbalance of the flexion-extension space, rupture of the posterior cruciate ligament (PCL) or medial collateral ligament (MCL), and tendon rupture or patella fracture.

16.2.2 Late Instability

There are also multiple causes of late instability following TKA. The most common is usually related to polyethylene (PE) wear either alone or in combination with ligamentous instability. PE wear is often a function of disalignment, and it is not unusual to see an asymmetric wear pattern either on the medial or the posteromedial aspect of the implant. This wear pattern can result in a relative lengthening of the MCL and subsequent valgus instability. Furthermore, it is not uncommon for the PCL to elongate or attenuate in cruciate-retaining knees. Depending on the posterior inclination of the tibial cut, a portion of the PCL is injured frequently at the time of surgery. Finally, extensor mechanism problems causing late instability of the knee are similar to those seen early with the exception that they are often secondary to wear of the patellar component.

16.2.3 Extension Instability

Instability in extension may be symmetric or asymmetric. Symmetric extension instability may be due to excessive bone removal from the distal part of the femur or from the proximal part of the tibia. This affects the space between the femur and tibia equally in knee flexion and knee extension. When this is recognized during the operation, the potential instability is corrected by using a thicker tibial insert. Managing excessive bone removal from the distal part of the femur is more challenging. A thicker tibial insert will not solve this problem only elevates the joint line and excessively tightens the flexion space and that adversely affects the kinematics of the knee. Marked elevation of the joint line limits knee flexion, affects patellar function, and contributes to midflexion instability. In this case treatment is based in adding distal femoral augments.

Asymmetric extension instability is much more common it is typically related to a preoperative angular deformity of the knee and is caused by persistent or iatrogenic ligamentous asymmetry. The most common mistake leading to asymmetric instability is poor correction of a fixed angular deformity, often out of tear of creating ligamentous instability in the opposite direction. The disalignment of the femoral or tibial components on the frontal plane and the wear off or change of position can lead to medial or lateral asymmetric instability [1].

16.2.4 Flexion Instability

Is the result of a flexion gap that is larger than the extension gap. Historically, this problem has been underdiagnosed in patients with a cruciate-retaining knee implant where injury or release of the PCL can selectively aggravate an already loose flexion gap. Late insufficiency of the PCL can develop and cause instability symptoms in previously well-functioning cruciate-retaining knees. The manifestations of flexion instability range from a mere sense of instability to frank dislocation (that occurs in approximately 0.15% of knees following total knee replacement). CR (cruciate retaining) ligaments designs require integrity of the PCL for the adequate translation of the femoral and tibial surfaces during flexoextension and anteroposterior stability in flexion. If one of these designs is used in patients who have an insufficient PCL, they will develop instability symptoms.

Using a design that substitutes PCL (posterior stabilization designs or posteriorly stabilized or PS) increases anteroposterior stability in flexion, but does not guarantee stability on flexion, in these it is usually a consequence of an imbalance between the spaces on flexion and extension. An excessive posterior inclination of the tibial component also generates instability on flexion. Moreover, it can be secondary to displacement of the tibial component in varus or valgus or malrotation of the femoral component [1].

In 2015 Kannan et al. analyzed radiologically evident corrections, patient reported outcome and complications associated with revision TKA for flexion instability in a retrospective cohort of 37 patients with minimum 1 year follow-up [4]. Following revision surgery, there was a significant increase in mean posterior condylar offset ratio and a significant decrease in tibial slope while the level of joint line was not significantly altered. Patient reported version of Knee Society score showed significant improvement with surgery and 26 of 37 patient reported perceptible improvement on a 7-point Likert scale.

In 2919 Stambough et al. reported that flexion instability after TKA is caused by an increased flexion gap compared with extension gap [5]. Nonsurgical treatment included quadriceps strengthening and bracing treatment. The mainstays to surgical management of femoral instability involved increasing the posterior condylar offset, decreasing the tibial slope, raising the joint line in combination with a thicker polyethylene insert, and ensuring appropriate rotation of implants. Patient outcomes after revision TKA for flexion instability showed the least amount of improvement when compared with revisions for other TKA failure etiologies [5].

16.2.5 Global Instability

Global instability is a pattern of instability that is clearly detectable in multiple planes, is a combination of loose flexion and extension gaps. There are several causes of global instability including PE wear that results in laxity of the surrounding soft tissue envelope, implant migration, and motor dysfunction, specifically extensor mechanism disruption. The treatment options include revisions with constrained or linked implants can be used successfully and the treatment with insert exchange and bracing tend to produce unsatisfactory results [6, 7].

16.3 Main Causes of Knee Prosthesis Instability

The main causes of knee prosthesis instability are the following: Ligament imbalance, component disalignment, component failure, implant design, mediolateral instability, bone loss from over resection of the distal femur, bone loss from femoral or tibial component loosening, soft tissue laxity of the medial and lateral collateral ligaments, connective tissue disorders (rheumatoid arthritis or Ehlers–Danlos syndrome), inaccurate femoral or tibial bone resection, and collateral ligament imbalance (under release, over release, or traumatic disruption) [8].

16.4 Risk Factors

Some patients are prone to instability. Those who have greater preoperative deformities, especially if compounded by extra-articular deformity or dynamic aberrations of gait, require large surgical corrections and aggressive ligament releases and may be difficult to stabilize [5].

Several factors can produce instability after total knee replacement. Specific patient-related risk factors are a large surgical correction including an aggressive ligament release, general or regional neuromuscular pathology (quadriceps weakness inducing recurvatum or weak hip abductors that impart a medial thrust to the knee), hip or foot deformities typified by tibial posterior rupture, and pes planus induce valgus moments at the knee. Clinical obesity, is also a risk factor because it complicates surgical exposure, jeopardizes the collateral ligaments (8% incidence of avulsion of the medial collateral ligament in obese patients), and makes it difficult to appreciate component position, is often observed in the unstable knee [1, 9, 10].

PS implants should be utilized in those patients with PCL insufficiency and in those with increased risk of posterior instability (rheumatoid arthritis, previous patellectomy or the need to liberate the PCL to correct a ligamentous imbalance, flexion contracture or previous tibial osteotomy). If the choice is made to preserve the PCL, it is important to take special care in maintaining its integrity when the tibial cut is made. In case of doubt it is preferable to convert the arthroplasty to a PS design. Careful attention to the balance of soft tissue and the correct implantation of the components in every plane, including the rotation of the femoral component, is essential to achieve symmetric spaces on flexion and extension. In some patients with marked instability (knee with valgus and complete insufficiency of the PCL, poliomyelitis or Charcot arthropathy) a primary constrained or linked implants can be indicated.

16.5 Prevention

Instability of the knee can be prevented in most cases with an adequate selection of implants and a good surgical technique. Preoperative physical examination allows to evaluate the state of the LCL, MCL, and PCL in order to select the adequate implant for each patient [10].

In patients without significant varus or valgus malalignment and without significant flexion, contracture may be addressed by retaining the PCL, whereas the PCL should be removed in patients with these deformities. Certain diseases are more amendable to PCL sacrifice, such as end-stage degenerative joint disease secondary to rheumatoid arthritis, previous patellectomy, previous high tibial osteotomy or distal femoral osteotomy, and posttraumatic osteoarthritis with disruption of the PCL. The degree of constraint of the articulation in TKA should be dictated by the degree of disease and associated deformity.

16.6 Treatment Options and Results

Most of the patients with KPI require surgical treatment and the use of preoperative planning is very important. An implant with the required constraint can be determined preoperatively. As a general rule, it is recommended that the minimum amount of constraint necessary to achieve stability should be used. With many choices of component designs and levels of constraint, it can be a very difficult process to select the optimum implant for a given patient.

Successful outcomes can be obtained in many of these cases, but without identifying the cause of instability, the surgeon risks repeating the mistakes that led to the instability after the initial TKA. KPI can be prevented in most cases with an adequate selection of implants and a good surgical technique.

16.6.1 Conservative Treatment

Conservative treatment can be useful in a small percentage of patients with knee instability, close reduction, orthotics immobilization is used in patients with acute prosthesis dislocation. Orthotics utilization and rehabilitation programs are effective to strengthen the quadriceps and the hamstring and reduce the symptoms of some patients with mild and moderate instability. However, in many cases it is necessary to turn to surgical treatment, especially if other alterations are noted such as disalignment of the components, deterioration or loosening [2].

16.6.2 Surgical Treatment

In 2016 Luttjeboer et al. recommended three options in revision TKA for instability: (1) hinged implants in cases with severe ligament instability in multiple planes or bone loss, (2) condylar implants with a posterior-stabilized insert in cases with isolated posterior cruciate ligament insufficiency, and (3) condylar implants with condylar constraints in all other cases [11].

16.6.2.1 Polyethylene Exchange

In 2018 Cooper et al. reported that in selected patients, isolated tibial polyethylene insert exchange (ITPEI) was not inferior to component revision at addressing symptomatic instability following TKA [12]. In 2019 Fehring et al. analyzed 1606 revision TKA patients, of which 4% underwent an isolated PE exchange for prosthetic knee instability [13]. The final data set included 41 patients at an average follow-up of 43 months. Of the patients treated with PE exchange only for an appropriate indication (i.e., coronal instability with competent ligaments or global instability), 63% felt their knee was stable, whereas 37% felt they remained unstable after revision. Additionally, only 59% had improvement in their pain, whereas 41% were dissatisfied with their pain relief after revision. Despite the use of this technique when indicated, the results of PE exchange only with regard to pain and instability are unpredictable. Only approximately 50% of patients became stable and had adequate pain relief. Patients and surgeons alike should understand that this low morbidity option does not guarantee a good result regardless of whether it is used for an appropriate indication. Obtaining stability and pain relief in a patient with prosthetic knee instability remains a significant challenge. Therefore, the key to avoiding prosthetic knee instability is through prevention at the time of primary surgery. Prosthetic knee instability remains difficult to manage despite intuitive and appropriate indications for PE exchange only [13].

16.6.2.2 Revision TKA

Most of the patients with KPI require surgical treatment and the use of preoperative planning is very important. An implant with the required constraint can be determined preoperatively [14]. Planning for a stable revision knee arthroplasty must include not only how to “stabilize” the knee but also how to eliminate the forces of destruction: malalignment and gap imbalance. Unchecked, these forces will ultimately destroy any constrained device, hinged or nonhinged by breakage or loosening.

Revision surgery for instability requires: (1) control over the mechanical axis of the limb, (2) equalization of the flexion and extension gaps, (3) assessment of ligament integrity, and (4) access to constrained implants if necessary. As ever, diagnosis precedes successful treatment [9].

As a general rule, it is recommended that the minimum amount of constraint necessary to achieve stability should be used. With many choices of component designs and levels of constraint, it can be a very difficult process to select the optimum implant for a given patient [15].

CR implants designs represent the least amount of component constraint. This translates to the presence of good quality bone with minimal defects, intact soft tissues, and a PCL that remains functional and balanced. In most revisions situations, cruciate-retaining implants are not indicated.

The next level in constraint is cruciate substitution, this design mechanically substitutes for PCL function. Many people find this option easier and more forgiving because all the technical and judgement issues of balancing the PCL are eliminated. There is no gain in varus-valgus stability, and realistically speaking, minimal rotational stability. Thus, for a PS implant to succeed, a functional soft tissue envelope is needed to provide varus-valgus stability. However, the need for good flexion-extension balancing is also important, because a residually loose flexion space can result in posterior tibiofemoral dislocation.

The next level of constraint is nonlinked hinge implant such VVC or CCK. Such components provide a significant degree of rotational control and more significantly a great deal of constraint to varus-valgus angulation. The trade-off is the theoretical disadvantage of increased stress transmission to the component-bone interfaces. Because these implants limit varus-valgus angulation between the femoral and tibial components, it would seem intuitive that they could be used in cases of severe medial or lateral instability. One must not forget that severe flexion instability is still a limitation for these implants [16].

Less constrained components have severe limitations in the absence of collateral soft tissue support or in the presence of gross flexion-extension instability. Unfortunately, going to the highest degree of constraint (a hinged or linked implant) has historically produced disappointing results, predominantly because of implant loosening, significant patellar pain and high infection rates. However, newer designs of rotating hinge have produced more encouraging clinical and radiographic results [16] (Fig. 16.2). In 2015 Rodríguez-Merchán et al. reported that revision arthroplasty with a rotating hinge design provided substantial improvement in function and a reduction in pain in elderly patients with instability following TKA [17].

The indications for the use of a rotating hinge prosthesis are the following: Medial collateral ligament disruption, massive bone loss for the distal femur, proximal tibia (including collateral ligament origin or insertion), comminuted distal femur fracture in the elderly, distal femoral nonunion or malunion, extensor mechanism disruption requiring reconstruction in an unstable knee, ankylosis requiring a femoral peel exposure with moderate or severe residual flexion-extension gap imbalance [10].

Rotating hinge knee implants have a 10-year survivorship in the range of 51–92.5%. Complication rates of rotating hinge knee implants are in the range of 9.2–63%, with infection and aseptic loosening as the most common complications. Although the results reported in the literature are inconsistent, clinical results generally depend on the implant design, appropriate technical use, and adequate indications [8].

In 2018 Boelch et al. compared the clinical and radiographic outcomes after revision TKA for instability with two rotating hinge knee prostheses [18]. Fifty-one patients revised for TKA instability were prospectively randomized to either the Link Endo-Model (N = 26) or the EnduRo (N = 25). Clinical and radiographic outcome scores were compared preoperatively and at 12 months' follow-up. Both prosthetic designs provide significant improvement in pain and function scores after TKA revision for gross instability. Bolech et al. found slight advantages in favor of the Endo-Model; however, no design yielded superior results throughout the study [18]. In 2019 Pasquier et al. reported that rotating hinge implants are very useful in complex cases of TKA revision [19]. They stated that hinged implants continue to have a place in revision surgery to solve major instability.

Barrack et al. found no revision or radiographic failure at longer follow-up [20]. Similar promising results have been reported by Westrich and associates using a different modern hinged implant [21].

The degree of constraint required to get immediate and long-term stability in TKA is frequently debated, with most authors recommending the least degree of constraint possible. According to Lombardi and Berend [22], in patients without significant varus or valgus malalignment and without significant flexion, contracture may be solved by retaining the PCL, whereas the PCL should be removed in patients with these deformities. Certain diseases are more amendable to PCL sacrifice, such as end-stage degenerative joint disease secondary to rheumatoid arthritis, previous patellectomy, previous high tibial osteotomy or distal femoral osteotomy, and posttraumatic osteoarthritis with disruption of the PCL. The degree of constraint of the articulation in TKA should be dictated by the degree of disease and associated deformity. Surgeons should have the option of modifying the degree of constraint at the time of surgical intervention. Nowadays, many TKA implant systems offer such flexibility.

Paradoxical anterior movement of the femoral condyles after TKA often attenuates the extension mechanism and causes a suboptimal outcome. The medial-pivot implant design aimed to confine anterior movement and emulate physiologic knee kinematics. In the study of Fan et al. the medial-pivot TKA provided significant improvement in the postoperative range of motion [23].

Although the design features of the Medial Pivot fixed-bearing prosthesis reportedly improve kinematics compared with TKAs using fixed-bearings, clinical improvements have not been

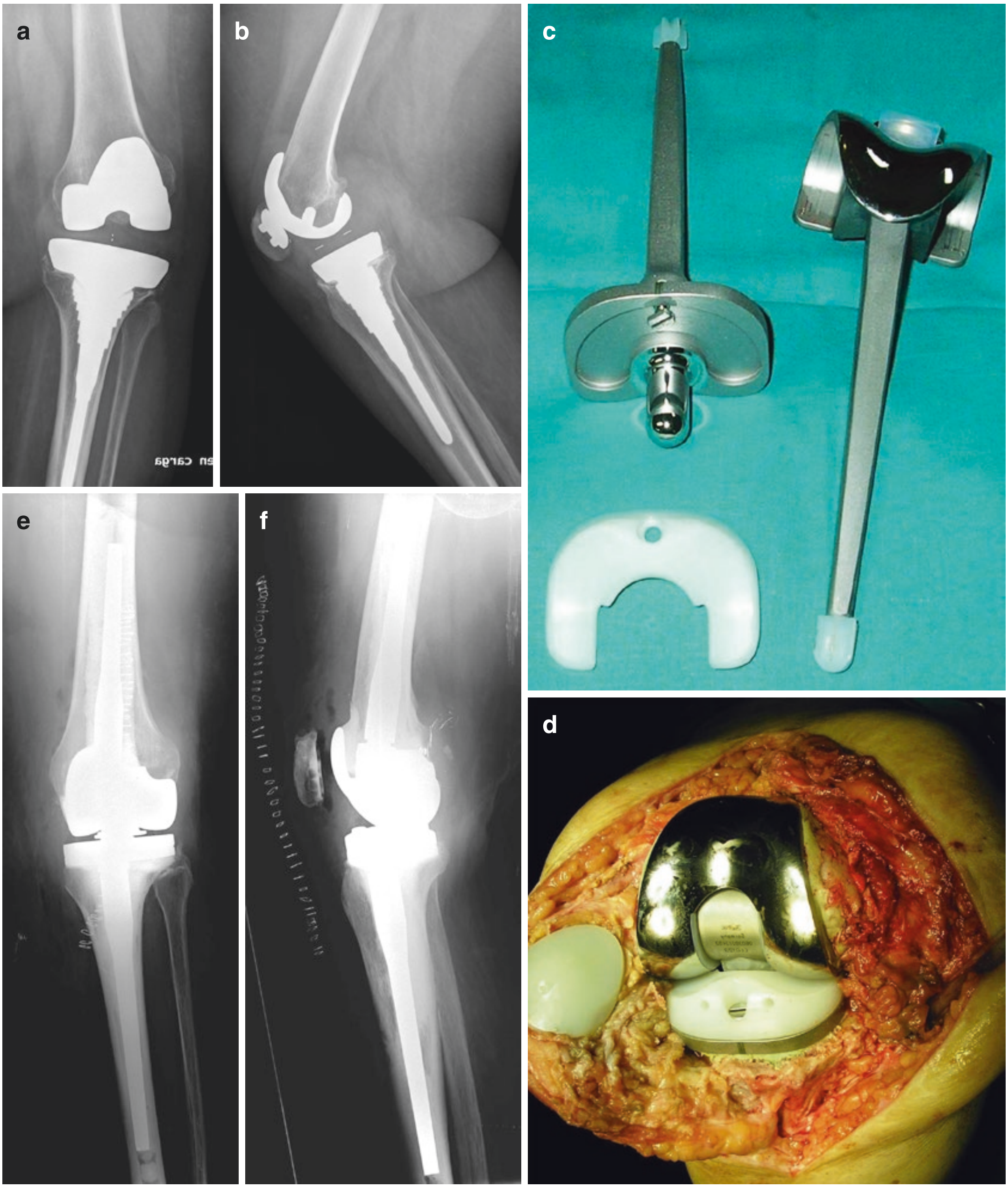

Fig. 16.2 Unstable knee prosthesis which required revision arthroplasty by means of a rotational hinged prosthesis: (**a**) Preoperative anteroposterior radiograph. (**b**) Preoperative lateral radiograph. (**c**) View of the components of the rotational hinge prosthesis to be implanted. (**d**) Intraoperative view of the rotating hinged prosthesis already implanted. (**e**) Anteroposterior postoperative view of the new prosthesis. (**f**) Lateral postoperative view of the new prosthesis

reported. Kim et al. asked whether the clinical and radiographic outcomes, ranges of motion of the knee, patient satisfaction, and complication rates would be better in knees with a Medial Pivot fixed-bearing prosthesis than in those with a PFC Sigma mobile-bearing prosthesis [24]. Contrary to expectations, the authors found worse early clinical outcomes, smaller ranges of knee motion, less patient satisfaction, and a higher complication rate for the Medial Pivot fixed-bearing prosthesis than for the PFC Sigma mobile-bearing prosthesis.

Constrained primary TKA is often required in knees with a severe valgus o varus deformity. Some studies support the use of primary constrained total knee implants in patients with severe deformity or in patients requiring complex reconstructions, particularly if they are elderly and have lower physical demands. Easley et al. reviewed primary CCK (constrained condylar knee) prostheses in older patients with severe genu valgum and reported excellent clinical results with no failure at 8 year follow-up [25].

Another situation in which constraint may be required at the time of primary TKA is in patients with rheumatoid arthritis. However, patients with rheumatoid arthritis have been successfully treated with cruciate-retaining knees in some series.

Intraoperative disruption of the MCL during primary TKA may also require a prosthesis with additional varus-valgus constraint, although this has been addressed by primary ligament repair and use of a less constrained prosthesis in select cases [26].

Finally, there are some other situations in primary TKA in which more constraint (rotating hinge implants) is indicated, for example, in patients with poor neuromuscular control, such as poliomyelitis or neuropathic arthropathy (in which the patients surrounding soft tissues will not confer sufficient stability), or patients who have had a prior high tibial osteotomy or patellectomy [27–29].

16.7 Conclusions

Knee prosthesis instability (KPI) is the third most frequent cause of failure of total knee arthroplasty (TKA). Moreover, the degree of constraint required to achieve immediate and long-term stability in TKA is frequently debated. Specific patient-related risk factors are a large surgical correction including an aggressive ligament release, general or regional neuromuscular pathology, hip or foot deformities typified by tibial posterior rupture, and pes planus induce valgus moments at the knee. Clinical obesity, is also a risk factor because it complicates surgical exposure, jeopardizes the collateral ligaments and makes it difficult to appreciate component position, is often observed in the unstable knee.

Instability of the knee can be prevented in most cases with an adequate selection of implants and a good surgical technique. Preoperative physical examination allows to evaluate the state of the lateral collateral ligament (LCL), medial collateral ligament (MCL), and posterior cruciate ligament (PCL) in order to select the adequate implant for each patient.

Concerning treatment of KPI, most of the patients with KPI require surgical treatment and the use of preoperative planning is very important. Successful outcomes can be obtained in many of these cases, but without identifying the cause of instability, the surgeon risks repeating the mistakes that led to the instability after the initial total knee arthroplasty.

Primary indications for a hinge include medial or lateral collateral loss, massive bone loss, and metaphysis and cortical shell, which includes collateral origins or insertions, and severe flexion gap imbalance requiring a link system for stability. Indications for a hinge in primary TKA include patients with neuromuscular deficits such as polio or flail knee, who require the hyperextension stop. Surgeons should have the option of modifying the degree of constraint at the time of surgical intervention. Currently, many TKA implant systems offer such flexibility. Nowadays there are several levels of implant constraint apart from the classical designs [cruciate retaining (CR), posterior stabilized (PS), constrained condylar knee (CCK), rotating-hinges]: highly-conforming CR designs, post-less cruciate substituting implants, medial-pivot designs, and PS plus components.

The literature neither clarify which design is most appropriate for the KPI nor define the rates of component loosening associated with use of more constrained implants. Future studies should define the rates of recurrent instability after revision using implants with various levels of constraint. As a general rule, it is recommended that the minimum amount of constraint necessary to achieve stability should be used. With many choices of component designs and levels of constraint, it can be a very difficult process to select the optimum implant for a given patient. Surgeons should have the option of modifying the degree of constraint at the time of surgical intervention. Currently, many TKA implant systems offer such flexibility.

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