Intraoperative Medial Instability During Total Knee Arthroplasty

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KEYWORDS

• MCL • Intraoperative • Injury • Total knee replacement • Repair • Outcomes

KEY POINTS

- The incidence of intraoperative medial collateral ligament (MCL) injury is likely under-reported and there is a paucity of research on the subject.
- There are pre-operative risk factors that increase the likelihood of having a MCL injury during total knee arthroplasty (TKA).
- Care must be taken during the approach and surgical steps of TKA to prevent inadvertent injury to the MCL.
- MCL injury must be fully assessed when it does happen, and a plan to manage should be undertaken with a focus on obtaining a balanced knee through the range of motion.
- Missed MCL injury or postoperative medial laxity can lead to an increased rate of revision and TKA complication.

INTRODUCTION

Total knee arthroplasty (TKA) is a successful and increasingly commonly performed procedure in the United States. Growth models project up to almost 1 million procedures annually by the year 2030 with an American pool of potential operative candidates growing up to 3 million people by that time.[1] There are several techniques and alignment goals employed during TKA and there is conflicting data as the best approach. However, a common denominator to all these approaches is stability, and the profound importance that maintaining stability through the range of motion has on a successful TKA outcome.

The medial collateral ligament (MCL) is the major supporting structure during valgus and rotatory stress. Injury and/or laxity to the static and dynamic medial stabilizers of the knee after TKA can have a significant impact on the balance and stability of the TKA throughout the range of motion. Prevention and timely identification of medial instability when it does occur is critical to having a successful outcome. The incidence of medial instability during TKA is hard to quantify; studies have shown rates from 0.43% to 3%.[2] However, the incidence is likely underreported and is managed at the time of surgery without additional notation or documentation.[2] These medial instability events have been shown, even when properly managed, to lead to a concomitant increase in revision rates.[2]

Risk factors to medial instability can be multifactorial including both anatomic and surgical. Preoperative evaluation should identify the

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degree of deformity, integrity of the MCL, and anatomic considerations, which may influence the surgical plan and implant choice.[3,4] Iatrogenic injury to the MCL may also occur during the surgical approach, bone preparation, soft tissue release for a fixed varus deformity, or accidental transection.[5–7]

Management of intraoperative medial instability during TKA can be addressed in several different ways depending on the nature of the injury and the type of implant system. The options include, but are not limited to, primary repair, repair and augmentation with autograft/allograft or synthetic product, fixation with screws and washer constructs, increasing polyethylene thickness, or increasing prosthetic constraint.[4,8–14] Each of these options has advantages and disadvantages and depends on the type of injury and degree of instability.

ANATOMIC CONSIDERATIONS

The medial soft tissue supporting structures, which contribute to the stability of the knee, are composed of both dynamic and static stabilizers. The static stabilizers include the extra-articular ligamentous structures, the deep and superficial medial collateral ligaments, the posterior oblique collateral ligament (POL), and the joint capsule. Dynamic stabilizers to the medial knee include multiple muscular structures. The semimembranosus tenses the posteromedial capsule of the knee at its attachment just proximal to the superficial MCL on the tibia. Its tension changes throughout active range of motion of the knee both passively and actively contributing to medial stability. The medial retinaculum, as an extension of the vastus medialis aponeurosis, can dynamically stabilize the knee as well. As the vastus medialis contracts the distal fibers of the aponeurosis, which are affixed to the anterior portions of the medial capsule, are tightened and the anteromedial knee is stabilized while the knee extends from the pull of the quadriceps.[15]

The MCL is divided into deep and superficial ligaments. The superficial MCL is the largest structure over the medial knee with 1 femoral attachment and 2 tibial attachments. It inserts proximal and posterior to the medial epicondyle of the femur then courses distally to the tibia. The first attachment is to the soft tissue envelope over the anterior arm of the semimembranousus, which is attached to the tibia.[16] The inferior medial geniculate artery and vein runs between the tibia and the superficial MCL at this level. At its second insertion more distal, the superficial MCL has a broad-based attachment just anterior to the posteromedial crest of the tibia forming the floor of the pes anserine bursa approximately 6 cm distal to the joint line.[16,17]

The deep MCL structure is fundamentally a thickening of the medial capsule of the knee with a distinct density at the anterior border where it runs parallel to the superficial MCL. Posteriorly the deep MCL blends into the central arm of the POL. Proximally and distally the deep MCL directly connects to the femur and tibia through a soft tissue confluence with meniscofemoral and meniscotibial attachments. The meniscotibial connection, of the deep MCL, inserts directly on the medial tibial plateau at edge of the articular cartilage. The attachment continues distally below the joint line where it is also intimately intertwined with the capsule and the medial meniscus. The superficial MCL lies directly superficial to this structure at this level. This exposes the deep and superficial MCL fibers to potential injury during the resection of medial meniscus and any medial tibial bone resection during TKA.

The POL connects the semimembranosus tendon to the femur as well as attaching to the tibia and the capsule of the posteromedial knee. The POL merges with the posterior fibers of the superficial MCL and is primarily at risk during resection of the posterior medial portion of the medial meniscus and saw cuts to the posteromedial corner of the tibia.[16]

ETIOLOGY OF INJURY, RISK FACTORS, AND PREVENTION

Injury to the medial structures can occur at any time during surgery. Meticulous surgical technique should be undertaken during surgical dissection, soft tissue release, and bone resection. Care should be taken during exposure of a stiff knee, forceful manipulation of the knee, or during retractor placement and retraction, may cause injury or avulsion of the MCL. Tibial avulsions of the MCL most commonly occur during hyperflexion for exposure of the knee[9] but can also occur from the femoral attachment on osteoporotic bone. The MCL is also susceptible to direct injury from the excursion of the saw blade during bone resection of the tibia and femur.[3,7]

Both modifiable and nonmodifiable factors can increase the risk of damaging the medial structures during TKA including preoperative limb alignment, joint contractures, and patient habitus. Patients with preoperative tibiofemoral alignment in severe varus (>7°), medial instability with a valgus deformity, morbid obesity, and preoperative flexion contracture have been reported as a risk of MCL injury.[4,18,19] A cup and saucer morphology where the distal femur is articulating over a proximal tibial bone defect leads to a relative increased slope has also been described as an independent risk factor.[20]

There are several intraoperative factors that also need to be understood. Use of larger oscillating saw blades, which are wider than the femoral condyle, has been shown to be a risk factor for MCL injury.[3] In correcting a fixed varus deformity, the appropriate sequence of steps in soft tissue release should include osteophyte removal followed by medial soft tissue release. The late removal of osteophytes has also been implicated in creating too much medial laxity during TKA.[3] Extensive early soft-tissue releases, overly strenuous testing of varus valgus stability of the knee with trials in place, aggressive hyperflexion or forced subluxation of the tibia with trials in place for visualization, abrupt forceful retraction, and placing overly tight trials in while in flexion are all controllable risk factors for causing medial injury.[3–6,18,19]

As we can see from this long list, there are many potential ways to injure the medial stabilizing structures of the knee during the procedure. The key to minimizing any unintentional injury to these structures requires taking a consistent stepwise approach to performing TKA, having knowledge of the above-described anatomy, and taking an active role to protect them throughout the procedure.

The approach to the knee during a standard medial parapatellar approach to the knee involves elevating the retinaculum and capsular attachments to the medial proximal tibial plateau. A careful evaluation of the preoperative ligamentous balance of the knee is paramount to completing any approach to the knee in such a way as to not excessively release any medial tissues from the tibia which will affect the future balance of the TKA. A general rule of thumb is to start with a minimal release of the medial soft tissues and to remain at the level of the parameniscal soft tissue and the joint line.[3] Release along the joint line to the level of the mid-coronal plane will preserve the more posterior, capsular, deep MCL, and POL attachments to the tibia. Stopping at the mid-coronal plane has been advocated in patients with neutral or minimal varus deformity to prevent overreleasing these structures prematurely and affecting the ultimate balance.[12] In a more severe varus deformity and knees with significant medial soft tissue contracture this joint line release may be taken around the posteromedial corner with subperiosteal elevation, sharp dissection, or electrocautery. Care must be taken to stay on bone when releasing around the posteromedial corner and it is possible to encounter the inferomedial geniculate vessel at this level when deep to the superficial MCL[16] (Fig. 1).

The release of the medial capsule during the initial approach may be accomplished by sharp dissection or electrocautery with care taken to maintain integrity of the soft-tissue envelope and to always remain on bone during subperiosteal elevation. Transverse disruption of distal periosteum can lead to difficulties with later closer of the arthrotomy. This can affect medial stability as well as preventing watertight closure of the arthrotomy.

Minimally invasive surgical techniques including subvastus and midvastus approaches have limited evidence of increasing the risk of MCL injury during TKA[21–23] Regardless of the approach taken to perform the TKA, the location and careful placement of retractors is paramount to protecting the medial knee. Retractors placed on the medial side of the knee during TKA serve 2 primary goals. The first goal of retractors is to improve the visualization of the necessary anatomy to complete the surgery. The second goal is to protect structures from unintentional injury. There are many different retractors to choose from on the market and they come in various shapes and sizes, with both blunt and sharp tips.

During subperiosteal dissection of the medial capsule it is important to keep the tissues retracted medially to allow the surgeon to visualize the soft tissue to bone interface; this can be accomplished with various types of retractors

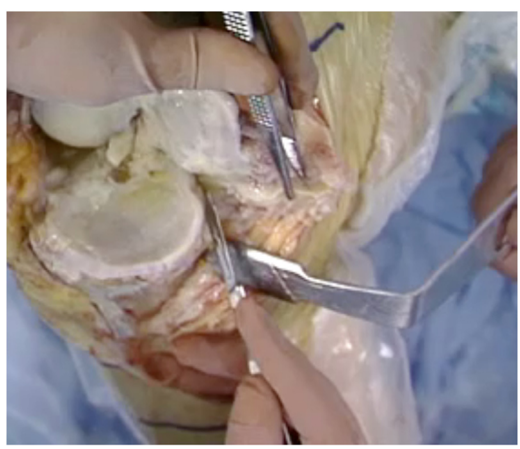

Fig. 1. Posteromedial release of soft tissue off of tibia.

Without appropriate visualization it is possible to inadvertently skive into the soft tissue envelope, which could lead to transection of the capsule or other deeper structures as described above.

The position of deeper medial retractors may change depending on the patient's anatomy and existing soft tissue balance/alignment.

Medial Retraction During Tibial Preparation

Medial retraction during tibial preparation should be designed to protect the skin, retinaculum, deep and superficial MCL. When there is a fixed varus deformity and a medial soft tissue release is performed from the proximal tibia, the tip of the retractor can be seated on the proximal tibial bone extending around the posteromedial joint line. A retractor is placed horizontally deep enough to stop the saw blade excursion into the soft tissues at the level of the planned tibial resection (Fig. 2). In the case of a valgus deformity, it is important that the MCL is protected during tibial resection. Although the placement of these retractors is crucial for protection, they are also a potential source of injury, as this location is just deep to the remaining intact deep MCL and superficial MCL fibers. If the medial retractor is pulled too hard to obtain visualization it is possible to cause an avulsion to the distal attachment of the deep and superficial MCL footprints described above. Surgeons using mobile window incisions, mini-incisions, or with certain robotic platforms may alternate between placing lateral tibial and medial tibial retractors during resection of the tibia. Additional superficial soft tissue retractors or self-retainers may also be used during the tibia resection to prevent damage to those tissues by saw blade oscillation. Retraction and protection of the lateral structures and the patella tendon are also key to a successful tibial resection. A detail orientated approach to protecting these structures is paramount, but outside the scope of this current review.

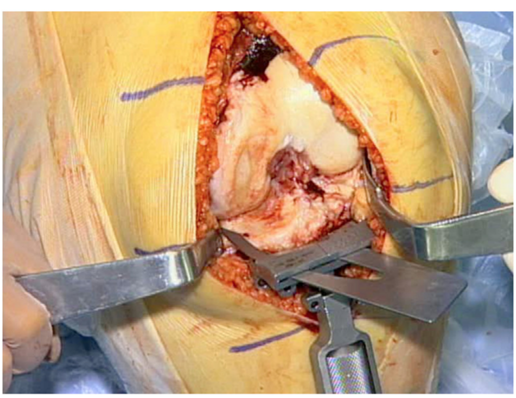

Fig. 2. Medial retractor placement prior to tibial resection.

Medial Retraction During Femoral Preparation

The medial soft tissue also needs to be protected during preparation of the femur including during osteophyte resection and bone resection. The retractor is placed deep to the deep MCL at the level of the joint line. This will retract the deep MCL, the superficial MCL, and the capsule as these structures insert more posteriorly behind the medial epicondyle. It is important that all these structures are retracted adequately to visualize the soft tissue insertions and remove osteophytes. During the resection of medial femoral osteophytes, it is important to carefully dissect them off from any soft-tissue attachments to avoid unintended injury to the MCL.

Once the resection guide is in place or the robotic saw is ready for femoral resections, the medial retractor should be double checked to ensure it is deep to the deep MCL. The position of this retractor should be reassessed throughout femoral resection. It may become necessary to change the angle of the retractor when transitioning from distal femur, posterior femur, and posterior chamfer cuts to have the retractor in line with the saw blades excursion path and maintain protection. The MCL appears to be at the highest risk during the resection of the posterior femoral condyle.[9]

MANAGEMENT OF MEDIAL INSTABILITY

Once a discrete injury or medial ligamentous instability is identified during a TKA, there are several options for how to address the issue. In the setting of a sharp transection of the MCL whether caused by an errant saw blade, knife, or electrocautery, the first step is a careful evaluation of the extent of the injury, if operating through a minimally invasive approach it may be necessary to extend the incision to fully visualize the injury. Once the injury is fully assessed a decision needs to be made as to the extent of the injury and the method of managing it.

Authors have advocated a myriad of techniques for addressing unanticipated medial instability during TKA.[4,8–14] In the setting of mid-substance MCL injury, usually the fibers of the MCL are disrupted and a direct end-to-end repair has been suggested. Several studies show that primary repair of a sharp dissection can be achieved without negatively affecting the balancing of the TKA.[8,10] However, this finding may be difficult to generalize to all surgeries as the majority of patients in these cohorts used cruciate retaining (CR) components with preservation of the PCL, which contributes to medial stability. Several authors describe the importance of completing any remaining bony preparation of the knee prior to repairing the injury.[8,12] This is important as overtightening of the MCL during the repair procedure could detrimentally affect the balance of the medial side of the TKA. After the preparation is completed for the TKA, the knee is brought into extension and a spacer block equal to the size of the completed construct is inserted or the trials are retained. The repair of the ends of the torn ligament is brought together with either a Krakow, Kessler, or barrel stitching style technique using nonabsorbable high strength suture (Fig. 3). The goal is to tension the soft tissues to the space created by the spacer block or trial. When the injury is not complete, this technique has also been applied, with repair of the injured fibers being accomplished in a similar manner with the spacer block or knee construct in place with the knee between 30° of flexion and full extension. It has also been advocated to evaluate the injury before the end of the case and wait to complete the full repair until after final components are in. This will help prevent damage to the repair during final implantation of TKA components.

Fig. 3. End-to-end repair of lacerated medial collateral ligament (MCL).

When the injured MCL is not able to be approximated end to end authors advocate for several other potential options. One option is to augment the repair with a woven high strength nonabsorbable commercial product, autograft, or a cadaver allograft tissue[8,12,24] (Fig. 4). This technique also requires careful tensioning of the repair with regard to the future balance of the total knee. A more technically demanding aspect of these types of repairs is in the setting of tibial avulsion. Repair in the setting of avulsion has been described with suture anchors or screw and spike washer[8,11,12] (Fig. 5A, B). The repair can be challenging due to the positioning of the bone anchor used to attach the MCL or augment to the femur or tibia. This positioning is critical to provide consistent medial tension throughout the arc of motion, and careful attention must be paid to achieve balance through the range motion. Soft tissue bone anchors are also described for use in setting of avulsion of the periosteum when the MCL proper remains intact.[8] A femoral avulsion of the MCL can be reattached with nonabsorbable sutures secured to the medial femoral condyle through transosseous tunnels or secured with a screw and spiked washer (Fig. 6A–C). With repair of the MCL it may be necessary to increase the level of prosthetic varus/valgus constraint.

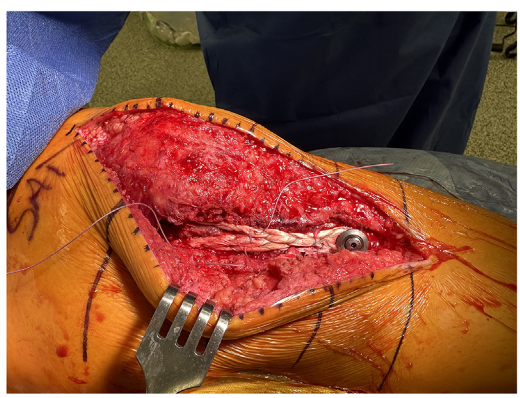

Fig. 4. Repair of the MCL with medial hamstring autograft and semitendinosus allograft. (Photo courtesy of Drs Sam Taylor and Fred Cushner.)

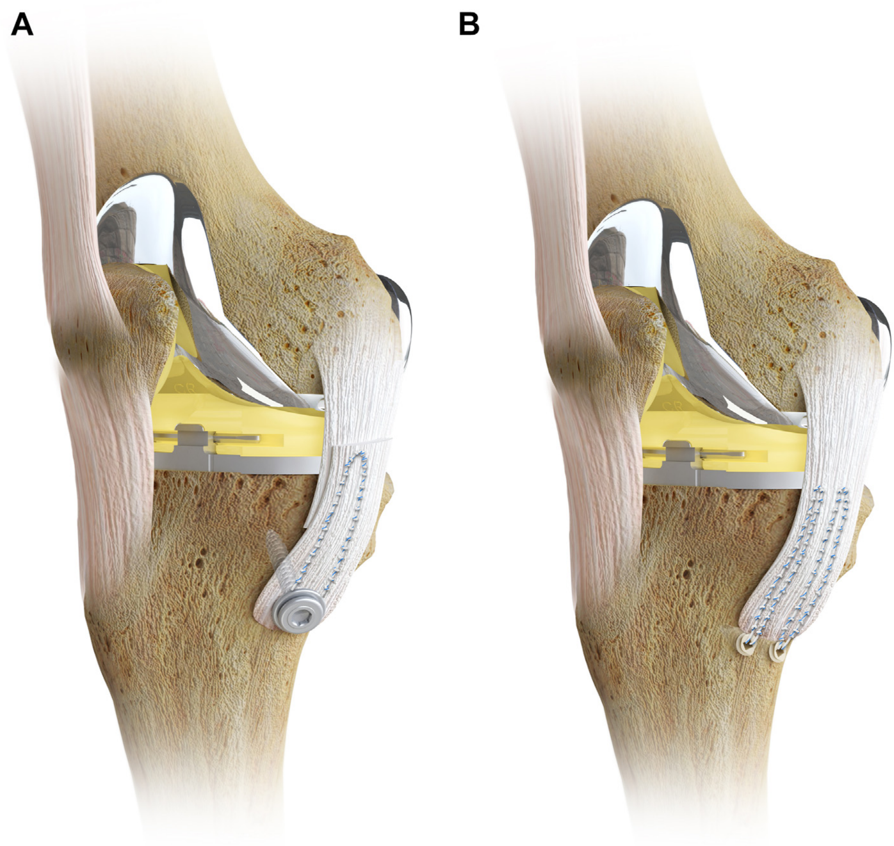

Fig. 5. (*A*) Avulsion of the MCL reattached to tibia with nonabsorbable suture tied over a screw. (*B*) Avulsion of the MCL reattached to tibia with nonabsorbable suture secured to the tibia with suture anchors.

Other authors suggest increasing the constraint level of the implant may be a simpler and more consistent way of managing this issue. Siqueira and colleagues[10] reviewed a series of patients who had intraoperative MCL injury managed with various techniques. In their study of 23 MCL injuries, 10 were managed with no change in implant constraint and had a direct repair, 8 were converted to more constrained implants, 3 received a constrained implant and a repair, and 2 had no change in implant constraint and were left unrepaired. At 5 years postoperatively, these patients had lower overall scores compared to patients with no injury, but between the 4 groups there was no significant difference in outcome or knee function scores. This suggests that repair without constraint and just increasing constraint are both feasible options in this small retrospective study. Caution should be used in situations when considering no repair or increase in constraint. The decision should be based on the level of instability caused by the MCL injury. Choi and colleagues[11] reviewed patients who had an overrelease of the tibial insertion of the MCL and were repaired with suture anchor. He found no difference in clinical outcomes compared to patients who had no injury in this cohort of patients with posterior stabilized (PS) implants.

Although in many cases simply increasing constraint may be a good option, it is not always a simple conversion. In the setting of a primary CR TKA, conversion to increased constraint is generally more difficult. CR TKA systems have limitations on the ability to convert components to increase varus/valgus constraint. This means that increasing varus/valgus constraint during a CR TKA would require switching components to a PS TKA. Many implant systems use the same tibial component for both systems but do require a change in femoral components. Several major companies have the same internal geometry of the CR and PS femoral component. Since the basic distal femoral bone preparation is the same, conversion to a PS design may be

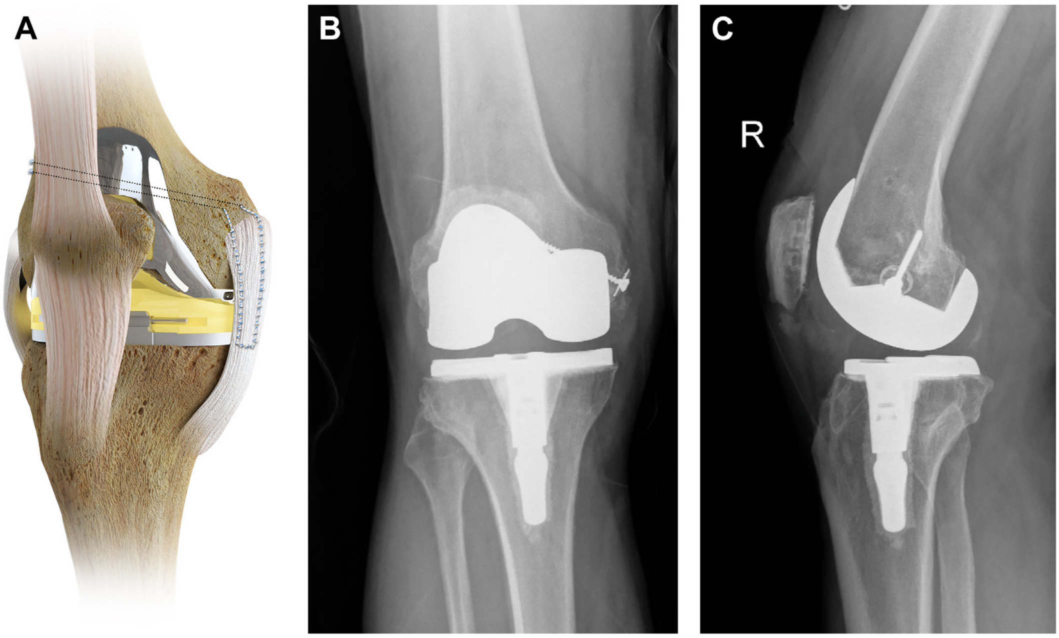

Fig. 6. (*A*) Avulsion of the MCL reattached to the femur with nonabsorbable suture passed through transosseous tunnels and tied over the lateral femoral cortex. (*B*, *C*) AP and lateral radiographs showing avulsion of the MCL reattached to the femur with a screw and spiked washer. The tibial component was a constrained posterior stabilized (CPS) articulation.

as simple as cutting an intercondylar box and inserting the PS tibial articulation.

When the primary implant is a PS TKA construct, several systems allow seamless conversion to a mid-level constraint (MLC) option, without changing implant system at all (Fig. 7). These MLC components allow for increased varus/valgus constraint with primary femoral PS components. These designs have been shown to successfully manage intraoperative instability without affecting clinical outcomes and without increasing any risk of aseptic loosening or causing accelerated wear.[25,26]

The decision to repair, augment, increase constraint, or a combination is multifactorial and depends on the type of implant being used. During CR TKA with a preserved PCL, there is some existing internal medial stability provided by the PCL. In this situation a repair with or without augmentation can provide enough stability to the knee without needing to increase constraint. During a PS TKA with partial MCL injury or overrelease medially, the literature supports increasing constraint to an MLC component. When complete disruption of the MCL occurs MLC implants are not constrained enough to establish stability and in this situation conversion to full varus/valgus constrained knee (CCK) systems is required (Fig. 8). Additionally, some systems do not have MLC options, which would also require switching to a revision style CCK implant. Hinged knee implants may even be needed in extreme situations with complete loss of medial integrity (Fig. 9). The intricacies of the implant systems and the subtle differences between the components play a major role in successfully managing this predicament. It is critical that surgeons know their primary implant systems' unique features well and have working relationships with their company representatives to assist with options in these situations.

POSTOPERATIVE MANAGEMENT

When more constrained implants are used to manage laxity/injury, there may not be any need to alter postoperative protocols.[4,9] However, in the setting of soft-tissue repair, internal fixation of augmentation, without an increase in constraint, there may be a role for postoperative bracing or immobilization. There are many static and hinged immobilization devices available. The benefits of open style hinged stabilization devices are that the patient may continue with their postoperative rehabilitation and continue to move the knee without restrictions. However, there have been studies, which show that using a hinged

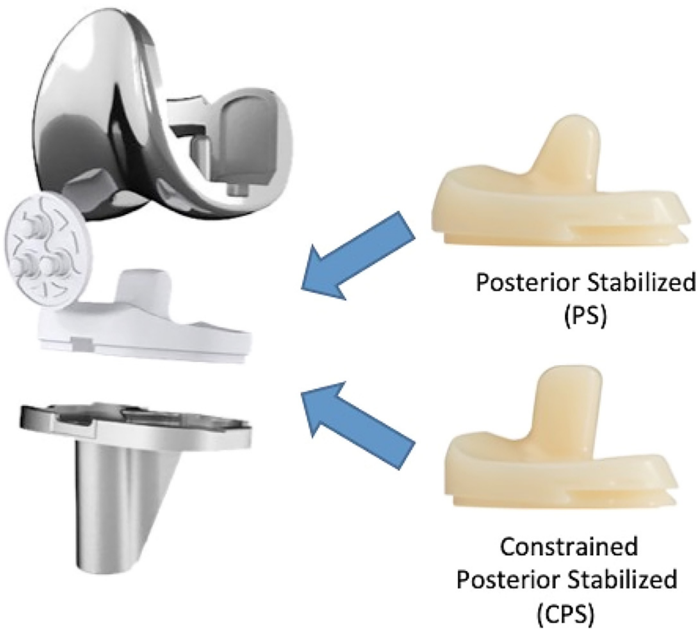

Fig. 7. Primary femoral component can accept either a PS or CPS tibial articular component.

knee brace after TKA with a repaired MCL injury without increasing implant constraint may lead to an increase rate in postoperative stiffness.[14]

There is a wide range of postoperative protocols described in the literature. Lee and Lotke[9] based the postoperative rehabilitation program on the etiology of the injury and how the injury was managed. Patients who were managed with a constrained implant were allowed early motion and immediate full weight bearing without restrictions or brace. Patients who were managed with repair or augmentation of the MCL and had a PS implant were divided into 2 groups: one group was immobilized for 4 weeks prior to initiating their rehabilitation program and the second group had no immobilization and was allowed immediate full weight bearing without restrictions. The authors found, as expected, that all patients had lower overall outcome scores compared to patients without an injury to the MCL, and the patients managed

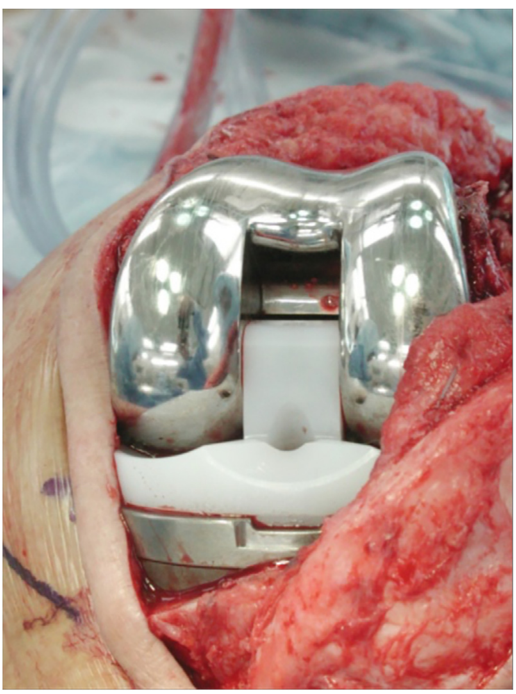

Fig. 8. Constrained condylar knee (CCK) with varus/valgus constraint.

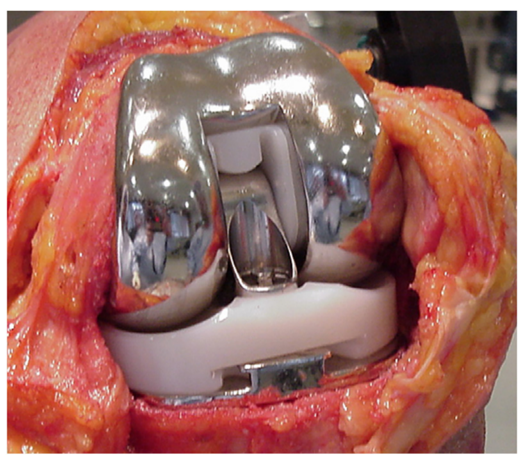

Fig. 9. Rotating hinge knee (RHK).

with a constrained implant had better stability, less revisions for instability, and a better outcome compared to patients managed with MCL repair or augmentation and a less constrained implant.

Leopold and colleagues[8] managed their injuries with direct repair or suture anchor fixation and no change in the type of TKA implanted (12 CR, 4 PS). They braced their patients in a hinged knee brace unlocked for 6 weeks with no reported failures or revisions for instability at 45-month follow-up, with only one case requiring manipulation for stiffness. Shahi and colleagues[12] treated medial instability with synthetic augmented primary repair and maintained a CR TKA using a hinged knee brace for 2 weeks postoperatively. They reported no residual instability in their cohort of 15 patients.

The decision to brace should be made on a case-by-case basis with regard to the type of implant being used, the quality of the repair, and the subjective "feel" of the knee at the end of the surgery. There is a theoretical increased risk of stiffness when postoperative bracing is employed; however, the limited existing literature supports the argument that it may be necessary when preserving CR implants to allow time for the soft tissues to heal. Management of intraoperative medial instability with varus/valgus constraint, with either an MLC for limited instability, CCK for moderate instability, or RHK for severe instability, allows for initiation of postoperative rehabilitation without bracing.

DISCUSSION

The rate of intraoperative medial instability is likely underreported in the literature. Physicians may address these issues intraoperatively and postoperatively without any documentation of iatrogenic injury, by changing their implant choice or using postoperative bracing without any discrete reference as to why those decisions were made. This makes this topic inherently difficult to study and objective data with large cohort numbers difficult to find. The risk factors for medial soft tissue injury are multifactorial and their interplay is complex. Many of the risk factors are potentially avoidable and iatrogenic in nature. A careful examination of the patient preoperatively and reducing any modifiable risk factors may help alleviate the risk. A large factor to this injury, however, is intraoperative and directly related to surgeon experience and skill. Retractor placement and bone resection during TKA has been shown to have a large learning curve with senior residents graduating from residency in one study still not considered fully proficient in retractor placement during TKA.[27]

Preoperative planning and implant choice can be useful in reducing risk and having alternative options when considering surgery in patients with more severe disease, such as using PS components with options for MLC.

Postoperative Outcomes

Medial instability during TKA can have a profound impact on the outcome when missed or not adequately addressed during primary TKA. Patients with these injuries have worse outcomes compared to matched TKA patients regardless of fixation or treatment technique. Pooled data show significant drops in knee function scores, lower postoperative range of motion, and significantly increased rates of revision and complications.[2] Pooled outcomes presented by Li and colleagues[2] showed more than a 6-fold increased rate of complications and need for revision with complications including instability, aseptic loosening, and infection. These findings reinforce the importance of prevention of MCL injury to reduce the risk of potentially catastrophic complications.

There does not appear to be a consensus in the literature on the best management strategy for intraoperative MCL injury. Regardless of the repair or constraint approach the goal is generally consistent, obtain a TKA, which is balanced medial-lateral and maintains that stability through the arc of motion. Most surgeons appear to lean towards increasing the level of constraint as the most consistent solution with or without repair as the solution to this problem.[9,10,28]

SUMMARY

Maintaining medial stability is critical to a successful TKA regardless of the implant type or system used. Careful attention to the medial soft tissue envelope during TKA will help prevent unnecessary injury and improve patient outcomes from the procedure. An in-depth knowledge of knee anatomy and the use of well-placed retractors will help reduce the risk of injuring the medial side of the knee during TKA. When soft tissue injury does occur, a full evaluation of the injury and treatment with the goal of maintaining stability through the full arch of motion can help prevent poor patient outcomes.

CLINICS CARE POINTS

- Carefully assess the preoperative soft tissue balance before TKA.
- Approach the knee in such a way as to limit unintended overrelease of the medial soft tissues of the knee.
- Take care to place retractors during TKA to protect structures from injury during surgery.
- Assess the integrity of the medial knee soft tissues consistently throughout surgery to allow timely identification of any potential injury.
- Address the injury with either repair, augmentation, or alteration in component constraint, or a combination of these options.
- Assess the integrity and balance of the repair/alteration prior to completion of the TKA.
- Decide on the necessity of changing postoperative protocols and immobilize or protect with bracing when necessary.
- Management of intraoperative medial instability with varus/valgus constrained implants may be necessary.

DISCLOSURE

The authors have nothing to disclose related to the content of this article.

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