Sensor guided unicompartmental to total knee arthroplasty revision: Surgical technique

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Abstract

Unicompartmental Knee Arthroplasty (UKA) is an effective surgical option for managing unicompartmental knee osteoarthritis; it represents 10% of all knee arthroplasties worldwide, increasing 32.5% annually in the United States alone. Despite evolution in surgical technique and implant design, success rate and long-term survivorship of UKA have been historically lower than Total Knee Arthroplasty (TKA). The most common causes of UKA failure leading to revision are polyethylene wear, progression of arthritis, aseptic loosening and patella-femoral symptoms due to poor patient selection in many cases. Historically, UKA revisions have presented technical challenges mainly related to managing residual bone defects and ligament insufficiency ultimately leading to knee instability: the fear of instability has often pushed surgeons to lower the threshold for an increase of the intra-articular level of constraint. Unfortunately, the use of more constrained implants requires sacrificing bone stock and has been related to higher rates of re-revision secondary to recurrence of aseptic loosening. Because of these challenges, the authors developed a surgical technique that could combine balancing the knee during revision surgery with the use of the less constrained polyethylene option. To achieve this, we started evaluating a novel device (VERASENSE, Orthosensor, FL) designed to support soft tissue balancing during primary TKA. This intraoperative sensing technology dynamically quantifies intra-articular loads during TKA trial with the goal of correcting any residual imbalance in real time. Herein we propose a novel surgical technique, which might allow use of a primary TKA design characterized by a lower level of constraint, instead of a constrained or hinged revision knee system, during UKA revision. A key aspect of this technique is the use of sensing technology during intraoperative stability testing.

Introduction

Unicompartmental Knee Arthroplasty (UKA) is an effective surgical option for managing unicompartmental knee osteoarthritis; it represents 10% of all knee arthroplasties worldwide, increasing 32.5% annually in the United States alone. Despite evolution in surgical technique and implant design, success rate and long-term survivorship of UKA have been historically lower than Total Knee Arthroplasty (TKA). The most common causes of UKA failure leading to revision are polyethylene wear, progression of arthritis, aseptic loosening and patella-femoral symptoms due to poor patient selection in many cases. Historically, UKA revisions have presented technical challenges mainly related to managing residual bone defects and ligament insufficiency ultimately leading to knee instability: the fear of instability has often pushed surgeons to lower the threshold for an increase of the intra-articular level of constraint. Unfortunately, the use of more constrained implants requires sacrificing bone stock and has been related to higher rates of re-revision secondary to recurrence of aseptic loosening. Because of these challenges, the authors developed a surgical technique that could combine balancing the knee during revision surgery with the use of the less constrained polyethylene option. To achieve this, we started evaluating a novel device (VERASENSE, Orthosensor, FL) designed to support soft tissue balancing during primary TKA. This intraoperative sensing technology dynamically quantifies intra-articular loads during TKA trial with the goal of correcting any residual imbalance in real time. Herein we propose a novel surgical technique, which might allow use of a primary TKA design characterized by a lower level of constraint, instead of a constrained or hinged revision knee system, during UKA revision. A key aspect of this technique is the use of sensing technology during intraoperative stability testing.

Surgical technique

An accurate preoperative plan is mandatory before any UKA revision: all patients undergo extensive preoperative radiological evaluation, which includes anterior-posterior and lateral weight-bearing radiographs, a weight-bearing pagnogram, and a patella view. A CT study is often required to quantify bone loss following aseptic loosening of the implant, and in all cases of painful UKA to evaluate component malalignment. Note that a Posterior-Stabilized (PS) primary system (Persona, Zimmer-Biomet, USA) and a semi-constrained revision system (Persona Revision Knee System, Zimmer-Biomet, USA) are always available at the time of surgery since the final level of constraint is intraoperatively selected. With the patient in supine position, a standard midline incision following the previous approach and a medial para-patellar capsulotomy are performed. The first intra-articular surgical gesture is represented by removal of any scar tissue usually present in the suprapatellar pouches and behind the patellar tendon; the fat pad is then removed. The tibial insert is usually removed using a 1/4 inch osteotome slid between the polyethylene and the metal.
component. At this point, all the visible osteophytes are removed from the patella, the distal femur and proximal tibia; the anterior and posterior cruciate ligaments are then removed.

Before removing the other components, the entry point for the intramedullary alignment guide is determined (usually 1cm proximal and 1cm medial to the top of the femoral notch), the guide is inserted and the distal femur cutting gig is secured at an angle according to the preoperative plan. The femoral component (medial or lateral) is addressed first and removed with the subsequent use of straight and flexible osteotomies, oscillating and reciprocating saws, paying extreme attention to conserving the femoral bone-stock. Once the femoral component has been removed, femoral bone loss is quantified. The femoral component is then repositioned on the femur after removal of the tibial component in order to protect the femoral bone stock from iatrogenic damage while working on the tibia (Figure 1). The tibial component is then removed with the subsequent use of flexible osteotomies, stacked osteotomies and oscillating saw, paying extreme attention to conserving the tibial bone stock. Once the tibial component has been removed, tibial bone loss is quantified (Figure 2). When all components have been removed, the level of constraint (primary PS or semi-constrained system) is determined. The general rule followed by the authors is that if the distal femoral and proximal tibial bone loss is no more than 15 mm on each side, a primary PS design is intraoperatively chosen, making the final decision on the stability of the implant and the integrity of the collateral ligaments at the time of sensor-guided trial testing.

The distal femoral cut is then completed and the femoral sizing guide is placed on the distal femur: the rotational alignment of the component is determined in accordance with the surgical trans-epicondylar axis to avoid excessive internal or external rotation of the femoral component due to bone loss, a typical error if the posterior condylar axis is used as a reference. The final, four-in-one, cutting jig is then placed on the distal femur after sizing and the final cuts (anterior, posterior, chamfers) are performed. The Persona PS size specific trial femoral component is placed on the femur and the PS box cut is then completed. It must be considered that mild distal condyle bone loss can be present and tolerated, since it will be filled during cementation (Figure 1). Attention is then paid to the tibia. After exposure of the tibial plateau, the initial resection level is set such that the sawblade just fits on top of the area characterized by bone loss, which should be only “refreshed” with an oscillating saw (Figure 2). The varus-valgus alignment of the final tibial cut is determined by an extramedullary rod set at the center of the ankle. The alignment of the knee is checked by placing a 10-15 mm spacer block, keeping the knee in extension. If the alignment is satisfactory, the tibial component size and rotational alignment according to the middle third of the tibial tuberosity are determined; the final preparation of the tibial component is then completed. Please note that this included reaming the tibial canal in order to accept a 30 mm, cemented tibial stem (“stubby”). At this point (Figure 3), the femoral and tibial component trials are inserted and the Postero-Stabilized (PS) Verasense tibial sensor is inserted, the knee is brought to extension (not hyperextension) and the extensor mechanism is temporarily closed with a clamp. Please note that the trial is routinely inserted and then removed so that it can be re-zeroed due to the small plastic deformation of the trial that occurs with initial implantation which may alter the load measurements. With the patella relocated in the trochlear groove, load measurements are...
Expected outcomes

UKA is a very appealing procedure when compared with TKA because it results in less postoperative pain, less peri-operative blood loss and faster discharge. The surgical technique proposed here makes conversion to TKA a more precise salvage procedure for failed UKA. The aim of this technique is to create a standardized UKA to primary TKA revision protocol based on a load scoring system able to suggest accurate surgical steps, setting a specific level of constraint for a specific range of load values. Secondarily, this technique allows surgeons to follow objective and intra-operatively determined parameters, which, when correlated with the standard intra-operative exam, could help surgeons choose the appropriate polyethylene thickness. Finally, this technique might help knee surgeons during complex revisions at the time of deciding on bone loss management and implant fixation; trabecular metal cones, titanium sleeves and stems might be necessary in the scenario of an unbalanced knee with high intercompartamental load differences.

Interestingly, revision of UKA to TKA has been associated with poorer clinical outcomes when compared with primary TKA; patients are usually less satisfied in terms of pain, joint stiffness and physical function. Being a symptom rather than a clinical finding, TKA instability represents a challenging entity to quantify; our technique combines an increase in the polyethylene thickness and an increase of the level of constraint as methods to guarantee the stability of the final, primary implant; it must be noted that, when a final insert with greater than 17 mm thickness is required, the authors recommend the use of a CCK system. The use of this sensing technology has also been proven to intraoperatively help the surgeon select the appropriate thickness of the insert and increase the degree of constraint addressing major instability during regular, primary TKA.

A decision-making algorithm on the level of intra-articular constraint during UKA to revision TKA has been published. Posterior-stabilized components showed superior clinical outcomes in patients with minor bony defects and intact metaphyseal bone; semi-constrained implants showed better outcomes in the setting of an aseptic loosening with major bone defects while a rotating-hinge was preferred to address major bone defects due to septic causes.

The clear advantage of using this sensor-guided technology is to allow an intra-operative evaluation of the medial and lateral compartmental load pressures, tracking soft-tissue balance throughout the entire range of motion arc with trial implants in place, and accordingly, modify any residual imbalance: to the authors knowledge, there are no other reports on this technique and its theoretical advantages.

Complications

Being a surgical technique based on a single-use, non-implantable testing device, no major complications are expected. First,
we recognize that being an operator-dependent technique represents a limitation as the learning curve of one experienced surgeon may not immediately translate to surgeons in general. Second, sensor readings are influenced by limb position and rotation; surgeons are invited to use a similar testing technique in their cases. Third, the authors apply this sensing technology to trial components, which may reproduce more instability as they are not cemented to bone as are actual components.

Finally, the authors recognize that this surgical technique has the major limitation of extrapolating intraoperative data from a non-loading situation and may not duplicate \textit{in vivo}, weight-bearing kinematic of the knee.

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