

Using Sensors to Evaluate Revision TKA: Treating the “Looks Good; Feels Bad” Knee

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Abstract

Despite long-term success rates associated with total knee arthroplasty (TKA), a large proportion of patients continue to report dissatisfaction with their surgical outcomes. Complications such as pain, stiffness, or instability can reduce a patient's quality of life and may be attributed to soft-tissue imbalance. The cause of imbalance related complications is often difficult to diagnose, but if unresolved may lead to early total revision surgery. However, these procedures are associated with a higher risk of post-operative complications, elicit longer rehabilitation regimes, and can become a financial burden to the patient and healthcare provider. Therefore, the purpose of this study was to determine if the use of intraoperative sensors during revision TKA led to a decreased need for all-component revision. In this review, 88% of intended total component revisions were changed to partial revisions based on the surgeons' interpretation of the sensor feedback. This sparing of components saved an estimated \$4,990 in healthcare provider implant costs, per case.

Keywords: Sensor-Assisted Surgery; Total Knee Arthroplasty; Revision Knee Arthroplasty; Soft-Tissue Balance

Introduction

By 2030, orthopedic surgeons in the United States will perform over 200,000 revision total knee arthroplasties (TKAs) annually [1]. While advancement in diagnostic techniques and implant component design have improved, complications resulting in revision TKA are still highly prevalent, with significant cost both economically and to the health of the patient [2]. Patient reported outcome measures (PROMs) report 20-30% of patients who undergo TKA are not satisfied. Patients often complain of pain, instability or poor range of motion post-operatively. These complications may be due to soft-tissue imbalance, which account for over half of early reasons for revision [11,12,13]. Commonly, radiographs and physical exams may seem normal and cannot explain the underlying etiology (Figure 1).

This frustrated, “Looks Good; Feels Bad” patient cohort has historically been very difficult to treat, often because the exact pathology is not fully appreciated pre-operatively or even during surgery. If the patient is returned to surgery, the prosthesis may be revised to a different type with the hope of solving the problem. However, removing a stable prosthesis results in bone loss, often requires implant-

ing a new prosthesis with more internal constraint, increases the risk of complications (e.g. infection or fracture), and may make the post-operative rehabilitation regime more difficult. Surgeons often adopt the “change everything” mentality with respect to component exchange because they do not have specific quantifiable data to analyze knee kinematics and soft-tissue balance of the problem joint. They may also identify a gross problem at time of revision surgery (e.g. a loose component) but not recognize a subtler problem (e.g. malposition, malrotation, soft-tissue instability) as a root cause. It is clear that more empirical methods for evaluating the painful TKA are needed.



Figure 1: Despite pain and stiffness for this patient, these AP and Lateral radiographic views show satisfactory alignment and component sizing with no evidence of malrotation.

The purpose of this retrospective evaluation was to determine if the integration of intraoperative sensing data, during revision TKA, leads to a decreased need for all component revision.

Materials and Methods

Sensors

Intraoperative sensors have been developed to measure real-time kinetics and intercompartmental loading during TKA (VERA-SENSE™ Orthosensor Inc., Dania Beach, FL). A computer microchip and load sensors are incorporated into trial polyethylene inserts with matching geometries of the standard original equipment manufacturer (OEM) components. These sensor trials can be placed into the tibial tray both during the “trialing phase” and after the final components are implanted for “final trialing.” As the surgeon takes the knee through a range of motion (ROM), dynamic load measurements are generated for the lateral and medial tibial compartments. A reference location of the load in each compartment throughout the ROM can also be used to evaluate knee kinematics. Armed with this data, the surgeon can determine if compartmental loading and knee kinematics are desirable or if further resection or soft-tissue releases are indicated.

Patients

For the purposes of this review, seven arthroplasty-trained surgeons have provided data regarding their patient presentation, intraoperative plan, intraoperative findings and post operative outcomes.

A total of 58 patients received a sensor-assisted revision TKA. All patients reported with idiopathic pain, instability and/or stiffness. All patient radiographs exhibited acceptable component alignment with symmetrical joint gaps, and all patients reporting pain had culture-negative aspiration findings.

Results

Nearly 70% (n = 41/58) of all cases were intended to be total revisions (Figure 3). Despite the highly varied presentations and severity of pain, stiffness, and instability, 91% (n = 53/58) of these revision cases were corrected for soft-tissue imbalance and/or component incongruity, which resulted in only partial revision (tibial component and/or liner exchange). All patients have since reported back to

the surgeon for post-operative follow-up (intervals ranging from 3 months to 1 year), and all surgeons have evaluated their patient’s condition to be “excellent” (an average score of 4.8 out of 5). None of the patients collected for this review have returned with any further complications.

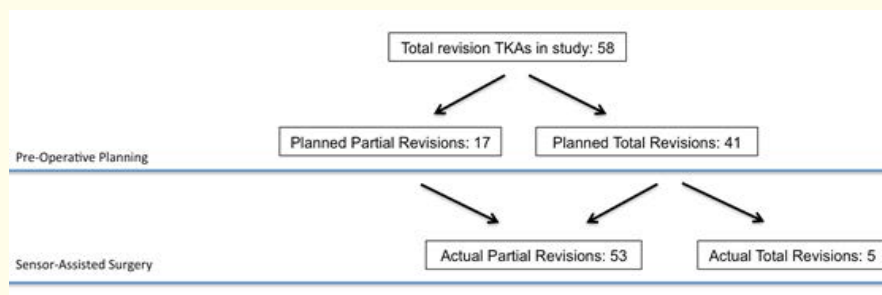


Figure 3: This flowchart demonstrates that, of 58 revision TKAs, 41 were planned for total revision. Based on intraoperative sensor data, 36 of the 41 planned total revisions became partial revisions, sparing total component replacement in approximately 88% of the intended total revision cohort.

Discussion

In this study, it was shown that the incorporation of sensors was associated with a decrease in planned total revisions. A large proportion of operating room cost during revision surgery is associated with the implanted revision TKA components and their associated specialized tools. In fact, total charges for revision TKA are nearly double the charges for primary TKA [8]. While this may seem somewhat favorable for hospital revenue, MEDPAR data from 2013 provided by the Centers for Medicare and Medicaid has shown that 90% of hospitals lose revenue for every revision procedure performed, at an average of -\$9,539 [9]. Therefore, money saved in the operating room may help hospitals to recover or avoid revision-associated financial losses.

Total revision implant costs are approximately \$6,770 [10,14]. However, if the surgeon only needs to replace the tibial component or polyethylene liner, the average implant charges drop precipitously to \$2,880 and \$980, respectively [10,14]. Therefore, there is a financial value to providing surgeons with empirical data that may help them avoid having to replace all primary components. This was seen in the current analysis. Intraoperatively, 88% ($n = 36/41$) of expected total revisions were converted to partial revisions based on surgeon interpretation of sensor output: 10 tibia-only procedures (with liner exchange) and 26 polyethylene liner exchanges only. As follows, the theoretical cost savings to the hospitals involved in data collection were \$179,640 (or approximately \$4,990/case).

The results of this retrospective review serve to demonstrate that complex revision procedures do not have to result in increased intraoperative risk. Using sophisticated sensor technology, surgeons can empirically evaluate soft-tissue balance through the range of motion with the joint capsule closed. This method of assessing ligament balance most naturally recreates the native motion of each patient’s joint and allows the highly specific mal behavior of each revision TKA to be accounted for and corrected.

When used in a revision TKA scenario, surgeons do not have to rely exclusively on exploratory surgery. Instead, the surgeon is able to reference the specific kinetic signature of each patient to help inform intraoperative decisions. In performing individualized corrections during each revision TKA, surgeons may avoid unnecessary soft-tissue or bony corrections, with the potential of avoiding unnecessary total revision surgery (Figure 2).

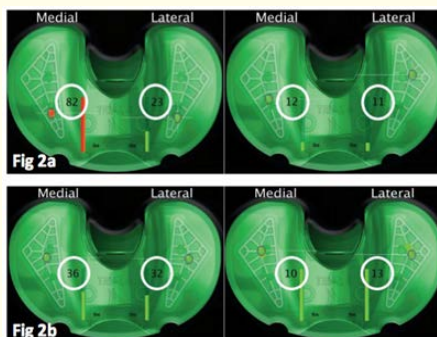


Figure 2a: At the time of revision surgery, VERASENSE was inserted and instability was identified as excessive medial tightness in extension (left) while the medial and lateral pressures were tensioned appropriately in flexion (right).

Figure 2b: A pie-crusting technique of the posterior medial collateral ligament was used to selectively correct the coronal imbalance and restore complete extension (left) while the knee remained balanced in flexion (right).

The limitations of this study include

1. This was a retrospective review without a null hypothesis. However, because this analysis did not compare revision protocol of two groups - only the paired pre-operative plans and intraoperative execution of surgeons - there is no risk of over-claiming in a manner similar to a type I error.
2. The cohort size is relatively small. However, we did include data from several surgeons and noted consistent trends in the proportion of partial revision performed.
3. There was no non-sensor assisted control group to compare the relative proportion of partial revision conversions to. However, pre-operative plans confirmed that most of the cases presented were intended to be total revisions. Partial revisions were made based on surgeon interpretation of sensor output. A prospective revision study will be conducted to further examine post-operative patient outcomes and cost-analyses of sensor-assisted revision TKA.

This novel intraoperative sensor data provided to the surgeon may help to spare implanted primary components, which not only saves patient bone stock and rehabilitation time, but may also preclude unnecessary operating room spending. In this analysis the utilization of intraoperative sensors during revision TKA lead to decreased total component revision, yielding excellent post-operative results for patients, and potential incremental profit to the hospital.

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