



Sensor-Assisted Total Knee Arthroplasty: A Narrative Review

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Wireless intraoperative load sensors have been used to improve the quality of soft-tissue balancing during total knee arthroplasty (TKA). Recent studies using the sensors have demonstrated reductions in gap imbalance, as well as early improvement of patient-reported clinical outcomes and low rates of arthrofibrosis. However, well-designed prospective studies are needed to determine whether the application of the sensor technology for TKA will have clinical benefits and improve the survival of prosthesis. Knowledge of the load-sensing technology (advantages and disadvantages, potential pitfalls, and future prediction) is crucial to apply this new TKA technique successfully. Herein, we conduct a narrative review of previous studies on this technique.

Keywords: *Knee, Arthroplasty, Computer-assisted surgery, Sensor, Load*

The primary goal of total knee arthroplasty (TKA) is to improve the function of the knee and eliminate pain in the knee joint. To achieve this goal, we have to obtain a stable knee through optimal alignment and deformity correction.¹⁻⁶⁾ In particular, soft-tissue balancing is known to influence the functional results and survival of the prostheses.^{7,8)} Despite its importance, soft-tissue balancing has been primarily based on subjective assessment by surgeons; it typically depends on training, surgical experience, and overall skills of surgeons.^{7,8)} A tensiometer can be used to overcome the limitation of subjective evaluation, but it may still be inaccurate or have inconsistent reliability.⁹⁾

Wireless intraoperative load sensors were introduced to measure medial and lateral compartmental loads separately on trial or real implants during TKA, and they have been used in hopes of improving the quality of soft-tissue balancing.⁸⁾ These instruments can provide real-time feedback regarding the quantitative load at femorotibial contact points in medial and lateral compartments, as well as information regarding tibiofemoral kinematics. Several

recent studies using intraoperative sensors have shown clinical benefits.^{1,10,11)} However, well-designed prospective studies are needed to determine whether the application of the sensor technology for TKA will increase patients' satisfaction and improve the survival of prostheses.^{9,12)} Because of the short history, this technique appears to be less frequently evaluated and more controversial than other computer-assisted techniques in TKA, such as navigation, patient-specific instruments, and robotic surgery.

Here, to help readers apply sensor technology in an appropriate manner, we provide a narrative review of the published literature regarding sensor technology, as well as its advantages, disadvantages, modes of operation, potential pitfalls, and clinical efficacy.

HISTORY AND TECHNOLOGY OF LOAD SENSORS

Historically, various experimental methods have been used to evaluate femorotibial contact areas and compartmental loads in prosthetic knees, with varying degrees of success.¹³⁾ These methods have been based on stereophotogrammetry, dye injection, silicone rubber, Fuji pressure-sensitive film, piezoelectric transducers, micro-indentation transducers, and computer models.¹³⁾ Fuji pressure-sensitive film does not allow real-time measurement and feedback; it also has relatively low accuracy. The K-Scan sensor (Tekscan Inc., Boston, MA, USA) uses piezoresistive strips

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and measures load distribution over a grid of small elements; it carries a risk of discretization errors in contact pressure measurements and requires many wires to be attached to the load sensor arrays for acquisition.^{13,14} An implantable tibial component has been developed with multiple load cells and a passive telemetric transmission system.¹⁵ Crottet et al.¹⁶ introduced a small load sensor for TKA, which can precisely measure the loads real-time with the patella in its anatomical position. This device has several plates, and each plate contains 3 deformable bridges with thick-film piezoresistive sensors. As the reaction forces are measured through deformation of the bridges, the location and amplitude of the compartmental loads can be computed. Nicholls et al.¹⁷ used a customized device with 3 sensors embedded in the medial and lateral compartments of a base plate with identical dimensions of standard tibial components.

Newly developed intraoperative load sensors provide numerical values of dynamic load pressure visualized through a graphical user interface display. There are currently 2 commercial disposable devices that measure loads during TKA: the VERASENSE (OrthoSensor, Dania Beach, FL, USA) and the eLIBRA Dynamic Knee Balancing System (Synvasive Technology, Reno, NV, USA). The VERASENSE with thin film piezo strain Micro-Electro-Mechanical Systems type pressure sensor is compatible with Zimmer-Biomet, Stryker, and Smith & Nephew prostheses. Compressive loads are displayed in pound (lb). In contrast, the eLIBRA is only compatible with Zimmer knee systems and allows for measured and balanced resection along with an adjustable device of femoral component to accomplish a symmetric flexion gap. The compressive forces across the joint are displayed in units, which can range from 1 through 20; each unit represents approximately 15 N (3.4 lb).

Roth et al.¹⁸ proposed that 6 major design criteria should be satisfied to maximize the utility of sensors for TKA. (1) The sensor must be interchangeable with a standard tibial base plate (i.e., identical thickness, size, and shape). (2) The sensor must be able to determine the location and force of femorotibial contact points over the full articular surface of the tibial insert because femorotibial contact points are near the posterior edge of the tibial insert during high flexion of the knee. (3) The sensor must be able to separately determine the location and force of contact points in the medial and lateral compartments. (4) Force of contact points must be measured with sufficiently low error margins to detect clinically meaningful imbalances that restrict postoperative function. (5) Location of contact points must be computed with sufficiently low

error margins to detect abnormal femorotibial kinematics (e.g., > 5 mm pathologic roll forward). (6) The sensor must be able to withstand contact forces in each compartment up to 450 N in order to detect contact force imbalance adequately after TKA.¹⁶ Roth et al.¹⁸ stated that their sensor designs overcome the limitations of previous sensors because the VERASENSE does not fulfill the 6 major design criteria, particularly No. 2.

ADVANTAGES

Intraoperative load sensors have several theoretical advantages. They can measure medial and lateral compartmental loads at peak contact points or triangular points for trial or real TKA implants.^{19,20} Surgeons can intraoperatively evaluate intercompartmental loads during range of motion and correct soft-tissue imbalances, based on dynamic real-time feedback.^{10,21} Sensors can also track the femorotibial contact points with peak pressure separately in the medial and lateral compartments. Therefore, the sensors can determine targets for ligament balance and compartmental load distribution for physiologic kinematics after TKA.²²

The patella is lateralized or everted during the assessment of femoral rotation with the transepicondylar axis or symmetric balancing of mediolateral gaps in TKA procedures. It affects intraoperative compartmental gaps or loads because the extensor mechanism may act as a lateral tether; balancing may be inappropriate when the patella is everted.²³⁻²⁵ In addition, the femorotibial contact points cannot be tracked accurately when the patella is dislocated.¹⁹ The sensor enables the measurement of medial and lateral compartment loads and the evaluation of tibiofemoral kinematics without patellar eversion to make a tight lateral gap.^{12,23} Closure of the retinaculum can also affect the measurement of compartmental loads; the wireless load sensor can predict the load change after closure of the retinaculum when loads are measured with towel clips or temporary sutures.^{12,20}

In a cadaveric study with 7 knees,²⁶ the tensiometer failed to achieve gap balance for 3 of 7 TKAs; the sensor was able to guide final soft-tissue balancing to equilibrate compartmental loads through the full range of motion. The rectangular flexion and extension gaps may be achieved by modern distraction tensiometers; however, they only measure soft-tissue behavior at 2 points of motion and are very easily influenced by rotational malposition of the femoral and tibial components.^{26,27} In addition, gap equivalence during distraction does not necessarily equate to a balanced load,⁹ unless there are equivalent Young's moduli for the medial and lateral soft tissues.^{26,28}

Sensors can overcome the limitations of the distraction tensiometer in terms of femorotibial incongruence and Young's moduli.⁹⁾ When compared with other computer-assisted techniques such as navigation, patient-specific instruments, and robotic surgery,¹²⁾ sensor-assisted TKA using the VERASENSE does not fundamentally change the surgical workflow.

DISADVANTAGES

It is important to conduct cost-benefit analyses when new medical devices are introduced. The VERASENSE sensor adds approximately \$500 (estimated cost of the trial sensors in the USA) in the TKA procedure.²²⁾ Some clinicians consider this sensor to be a low-cost and high-benefit instrument, compared with other computer-assisted TKA techniques.¹²⁾ The sensor is expected to more strongly improve physical function during the recovery period, while shortening rehabilitation period and decreasing overall costs for TKA patients.¹⁰⁾ OrthoSensor, the manufacturer for VERASENSE, published a multicenter study, which showed a nearly 75% lower rate of revision TKA compared to the average rate within postoperative 2 years in the United States; the company claims that this reduction represents clinical and financial benefits for both patients and providers.²⁹⁾ However, other studies have raised concerns regarding the cost-benefit issue for the load sensor.^{8,12,26)}

There are also controversies in terms of reliabilities and practical benefits of sensor-assisted gap measurement.³⁰⁾ It was reported that the intraclass correlation coefficient (ICC) between the 2 blind measurements and the ICC between the blind and load-observing measurement were poor in 2 of the 12 (17%), especially measurements in 10° of flexion.³⁰⁾ Although the advocates of sensor-assisted TKA claim that real-time feedback is possible, it does not give feedback in every steps of the procedure as navigation does and can obtain load data only in the trial reduction stage after bone resection is finished. It may be too late in practice, and efficient surgical options may not remain for accurate gap balancing.

Load data displayed by the sensor may be overly sensitive, compared to the gap data displayed by the tensiometer.⁹⁾ Song et al.⁹⁾ reported that load imbalances still remained on the sensor, even after an appropriate gap balance was achieved using the tensiometer in cruciate-retaining TKA. Additional rebalancing procedures with the sensor were required to achieve a balanced load in 37 of 50 knees (74%), following conventional gap balancing using the tensiometer. Thus, the sensor can detect load imbalances precisely in a large portion of cases, but may

pose risks of unnecessary additional balancing procedures and iatrogenic ligament injury; slightly asymmetric extension and flexion gaps with a tighter medial than lateral compartment reproduce the medial pivot kinematics of the normal knee.³¹⁾

Some clinicians have concerns with respect to the increased operative time and learning curve. Lakra et al.³²⁾ quantified the learning curve for electronic sensor use, based on operative time. They reported that approximately 41 sensor-assisted TKA cases were needed to achieve operative times identical to conventional TKA cases (first 41 sensor-assisted TKA cases vs. last 41 sensor-assisted TKA cases vs. manually balanced TKA cases: 120.4 vs. 108.9 vs. 109 minutes). Woon et al.³³⁾ demonstrated that while balancing technique can be trained by the sensor, the benefits of training are transient, and they are lost when the sensor is removed. They suggest that consistent balancing is more predictable with constant use of sensor. Therefore, we assume that the sensor technique is easily adopted, but that its educational effect is transient.

Finally, there is a lack of evidence for the clinical benefits of the sensor. Gustke et al.²⁰⁾ reported promising short-term clinical outcomes of sensor-assisted TKA, and their study has been cited as representative evidence by proponents of intraoperative load sensors. However, they did not compare sensor-assisted and manually balanced TKAs; instead, they compared balanced and unbalanced groups after sensor-assisted TKA, as in the study by Meneghini et al.⁸⁾ Several studies have compared the outcomes of sensor-assisted and manually balanced TKAs. Chow and Breslauer¹⁰⁾ reported that the clinical score and range of motion were significantly higher after sensor-assisted TKA in demographically matched patients who did not undergo radiographic evaluation. Geller et al.¹¹⁾ reported that use of the sensor significantly reduced the rate of arthrofibrosis. However, both of these studies involved patient matching only in terms of general demographics, not in terms of knee parameters that affect clinical outcomes (e.g., range of motion and severity of deformity). In a prospective randomized trial, Song et al.¹²⁾ reported that early clinical and radiographic outcomes did not differ between patients undergoing sensor-assisted TKA and those undergoing manually balanced TKA. More sophisticated studies regarding the clinical benefits and long-term survival rates associated with sensor-assisted TKA are required.

SURGICAL TECHNIQUE

There are 2 sensors available, VERASENSE and eLIBRA.

This portion of the review will focus on the application of VERASENSE because of its relatively widespread use. The conventional surgical approach and traditional TKA procedures are performed prior to use of the sensor. After all osteophytes are removed, a meticulously planned soft-tissue release is performed at the medial or lateral contracted side of the soft tissue. The equal flexion and extension gaps are achieved with tibial slope modification and additional distal femoral resection.³⁴ After initial balancing, trial implants are placed. The stability and knee kinematics are evaluated. A keeled, plastic tibial trial device is preferred to match the femorotibial contact points between the trial and real implants.^{9,26,27} The intraoperative load sensor is then inserted. Patellofemoral articulation is carefully evaluated using the “no thumb” technique.³⁵

The VERASENSE device is a wireless and disposable tibial trial insert embedded with a micro-force sensor to objectively quantify the medial and lateral compartmental loads (Fig. 1A). The device has identical geometry to the trial inserts. Shims can be attached under the device to replicate the thickness of the trial insert (Fig. 1B). The sensor relays real-time loading values and location of the femorotibial contact point to a display screen (Fig. 2A). The patella is located in the trochlear groove and fixed with towel clips; tibiofemoral contact point and rotational congruency are then evaluated (Fig. 2B).³⁶ With the sensor device in place, the loading data are displayed graphically and superimposed on a virtual sensor image (Fig. 3). Intercompartmental loads are evaluated at 10°, 45°, and 90° of knee flexion. For precise evaluation, the load can be checked twice at each flexion angle and patella position. The device is re-zeroed because minor plastic deformation of the sensor can occur at the time of initial implantation and it may alter the load measurement accuracy at the

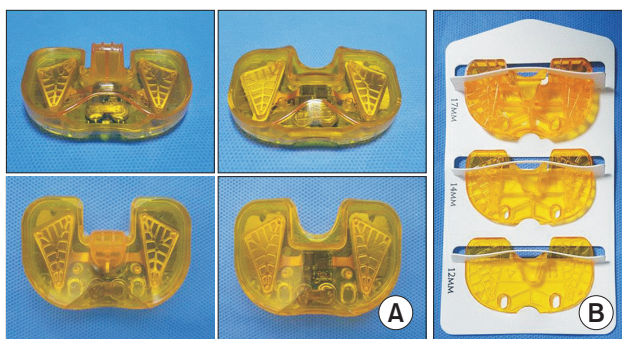


Fig. 1. A wireless load sensor. (A) The trial VERASENSE tibial insert is embedded with a micro-force sensor to measure the contact force and location. It is specifically designed to conform to cruciate-retaining and posterior-stabilized polyethylene inserts. (B) Shims can be placed under the device to adjust the thickness.

time of second implantation. The measurement of loads in the fully extended position with an excessive axial load is not allowed because this can overload the sensor and create a load outside the measurable range.

Additional procedures are performed for appropriate balancing until medial and lateral compartmental load is below 55 and 40 lb, respectively, and its difference is < 15 lb (Fig 3).^{8,20} Real-time changes in the loading values can be observed during these additional procedures.¹²

PROPER APPLICATION AND POTENTIAL PITFALLS

Ideal Target Loads

The ideal target loads of medial and lateral compartments have been arbitrarily proposed by numerous clinicians in

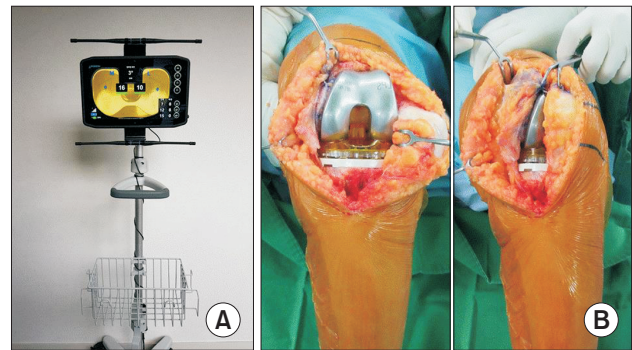


Fig. 2. Wireless connection of the sensor. (A) Wireless connection between the load-detecting computer system and the sensor. (B) Intraoperative placement of the tibial trial sensor device. A keeled, plastic tibial trial device is used to avoid mismatching of the tibiofemoral contact point between the trial and real implants. The patella is located in the trochlear groove; the compartmental loads can be evaluated while avoiding the tethering effect of the extensor mechanism by patellar eversion or lateralization.

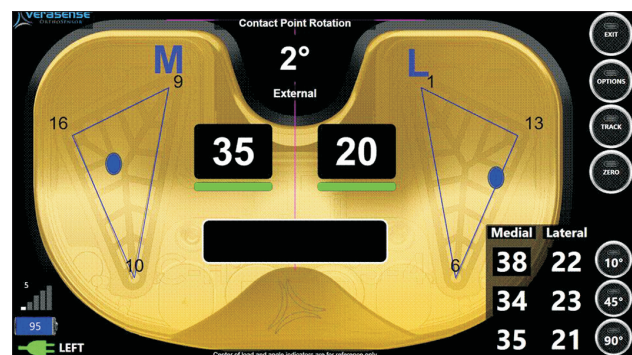


Fig. 3. Display screen of the computer system. The monitor shows loading values and femoral contact point positions real time. The VERASENSE is able to display the compartmental loads as the sum of loads at triangular points, instead of the average.

a non-evidence-based manner (Table 1).^{12,20,22)} In addition, there are many important factors to consider when interpreting sensor data. Gustke et al.²⁰⁾ defined a sagittally stable implanted knee as a knee with a contact point in the middle third of the tibial base plate, minimal excursion, and a stable endpoint during the posterior drawer test. Risitano et al.²²⁾ emphasized the importance of restoring the medial pivoting motion of the knee and obtaining a stable endpoint in the medial compartment and a physiologic posterolateral rollback of the lateral femoral condyle. Although a mediolateral intercompartmental difference of 15 ± 5 lb. has been considered acceptable in most studies,^{20,21,33)} Song et al.⁹⁾ found that a high load in the medial compartment was present despite tensiometer-assisted gap balancing. A mediolateral intercompartmental difference of 15 ± 5 lb. with a high load in the medial compartment and lower load under knee flexion than knee extension provides ideal physiologic posterolateral rollback of the lateral femoral condyle (Fig. 4). VERASENSE displays compartmental loads as the sum of loads at triangular points, instead of the average (Fig. 3). It has been suggested that acceptable loads are higher than previously reported values.²⁰⁾

Consistent Position of the Patella

It is known that the position of the patella and extensor mechanism affect intraoperative compartmental loads during TKA.^{12,23)} A dislocated (everted or not) and lateralized extensor mechanism artificially increases the lateral compartment loads in 90° of knee flexion during TKA.^{12,23)} The intercompartmental loads must be measured and compared with a consistent patella position during all soft-tissue balancing procedures. Indeed, instruments such as the sensor, which allow intraoperative soft-tissue balance with the patella in a physiologic position during all TKA procedures, are more likely to replicate the postoperative soft-tissue status.²³⁾

Consideration of Femorotibial Contact Points and Kinematics

As the specific femorotibial contact point is identified based on peak loads, plastic tibial trials with keels appear to be necessary to avoid the mismatch of femorotibial contact points between floating trials and real implants. The sensor displays the femoral contact point position real time on a monitor screen (Fig. 4). Tibiofemoral contact points and rotational congruence are considered before the compartmental loads are evaluated. The medial and lateral femorotibial contact points should be located on the middle third at 10° and 45° of knee flexion; the lateral femorotibial contact points can be rolled back during further knee flexion (Fig. 4).

If the femorotibial contact points are excessively anterior, excessively posterior, or rotationally incongruent (Fig. 5A-C), they must be corrected before load data acquisition.¹⁹⁾ If one compartment has 0 lb. of undetectable load according to the sensor, a 2-mm shim is attached to the original sensor; the loads are then re-evaluated, such that both compartments exhibit detectable loads (Fig. 5D).

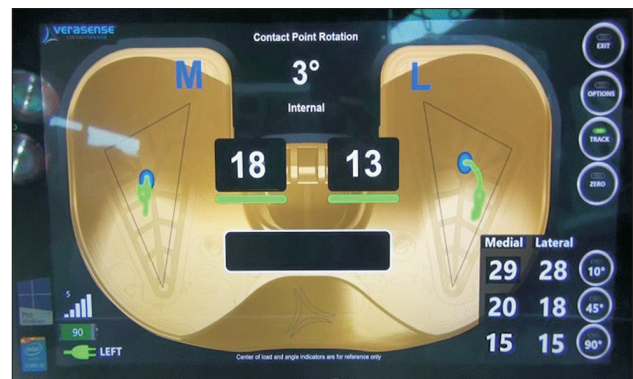


Fig. 4. Evaluation of knee kinematics, such as femoral rollback and medial pivot motion, by tracking femorotibial contact points after proper soft-tissue balancing using the sensor.

Table 1. Ideal Target Loads in Sensor-Assisted Total Knee Arthroplasty

Variable	Gustke et al. ²⁰⁾	Risitano et al. ²²⁾	Song et al. ¹²⁾
Maximum load (lb)	40	70	55
Maximum mediolateral difference (lb)	15	15 ± 5	15
Medial (lb)	0–40	50 ± 20 (30–70)	10–755
Lateral (lb)	0–40	35 ± 20 (15–755)	10–740
Other factor	< 10 mm excursion	Medial pivoting	Extension > flexion Medial > lateral

Values are presented as mean \pm standard deviation, range, or mean \pm standard deviation (range).

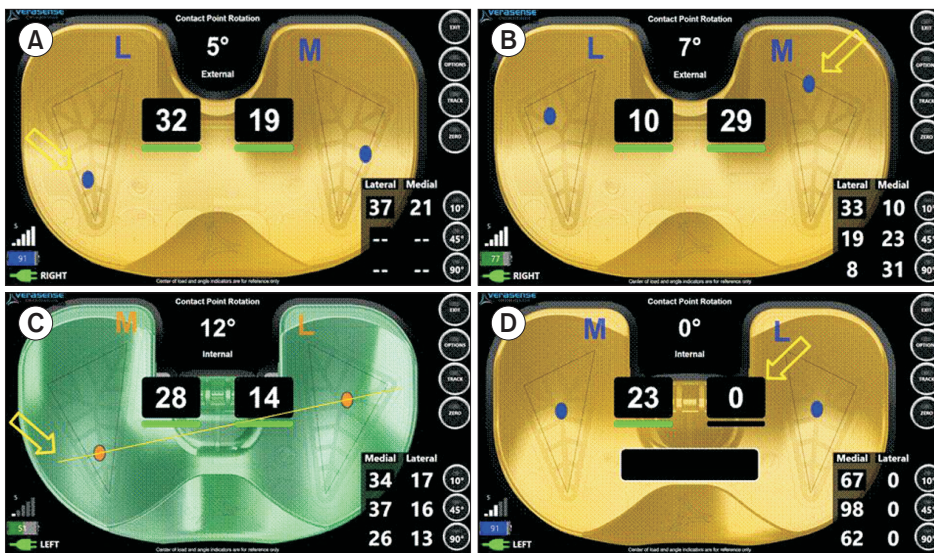


Fig. 5. Various types of pitfalls in the interpretation of the load data from the sensor. If the femorotibial contact points are excessively anterior (A), excessively posterior (B), or rotationally incongruent (C), these errors must be corrected before load data acquisition. If the compartment has 0 lb of undetectable load (D), the load is re-evaluated with a 2-mm shim attached to the original sensor, such that both compartments exhibit detectable loads.

Stepwise Releasing Strategies in Specific Compartments with High Loads

The target structure and amount of soft-tissue releasing depend on wireless load assessment during flexion and extension of the knee.²²⁾ Knees with preoperative varus deformity nearly always have high loads in the medial compartment during the initial balancing stage. Because the deep medial collateral ligament (MCL) is released during the surgical approach and resection of medial meniscus, other stepwise releasing strategies are required in the posteromedial capsule, semimembranosus, and anterior or posterior bundle of the superficial MCL. Authors sometimes modify the tibial surface with a narrow electronic saw.^{9,12)} Slight intentional varus resection or elevation of the posterior slope angle of the tibial surface can reduce loads efficiently and quantitatively in the medial compartment or posterior portion of compartments with high loads. When all other procedures are inadequate in knees with severe varus deformity, pie-needling or crusting of the superficial MCL is performed while maintaining caution with respect to medial over-release in the end stage of balancing procedures. Based on the high-load position in flexion or extension, the specific bundle of superficial MCL can be selectively released.

REVIEW OF CLINICAL RESULTS IN THE LITERATURE

Although many studies suggest superior results of sensor-assisted TKA compared to manually balanced TKA,^{11,26)} they are mainly of cadaveric studies and small-scale clinical studies. Gustke et al.²⁰⁾ first proposed the use of the VERASENSE for TKA soft-tissue balancing.¹⁹⁾ They dem-

onstrated that balanced knees (153 of 176 knees) showed greater improvements in Western Ontario and McMaster Universities Osteoarthritis Index scores, compared to unbalanced knees (23 of 176 knees). However, their study had several limitations: the lack of a control group of manually balanced TKA, a significantly smaller unbalanced group, the participation of 8 different surgeons with non-homogeneous surgical techniques, and the use of different levels of polyethylene constraint.

Meneghini et al.⁸⁾ reviewed 189 consecutive TKAs that were intraoperatively balanced using the VERASENSE. They confirmed that the average compartment loads were higher in medial compartments than in lateral compartments (70.7 vs. 44.0 lb). Notably, they demonstrated that the patient-reported measurement outcomes were unrelated to mediolateral load balances of the knees.

A blinded cadaveric study³⁷⁾ investigated differences in medial and lateral compartmental gaps and loads through range of motion during cruciate-retaining TKAs performed by multiple surgeons. Sensor-assisted TKA was associated with significantly reduced medial, lateral, and total mediolateral gaps; TKA performed without the sensor resulted in a greater lateral compartmental load. The authors demonstrated that the use of wireless load-sensors allowed the surgeon to reproduce the normal medial-to-lateral load ratio in cruciate-retaining TKAs via progressive and stepwise procedures.

A retrospective case-control study by Geller et al.¹¹⁾ compared the incidences of arthrofibrosis between 252 sensor-assisted TKAs and 690 manually balanced TKAs. The sensor-assisted group had a statistically significant reduction in the incidence of manipulation under anes-

thetia, with improved ligamentous balancing (5% vs. 1.6%, $p = 0.004$). A prospective comparative study by Song et al.¹²⁾ demonstrated no difference in early clinical results in terms of Knee Society Knee and Function score and Western Ontario and McMaster Universities Osteoarthritis Index scores when sensor-assisted TKA and conventional TKA were compared in patients with similar demographics and preoperative deformity.

A recent prospective multi-center study³⁸⁾ compared the early clinical results of Forgotten Joint Score and 2011 Knee Society Satisfaction questionnaires between sensor-guided TKA and surgeon-guided TKA, and between balanced TKA and unbalanced TKA. Significantly more balanced knees were observed in sensor-guided TKA than in surgeon-guided TKA (84.0% vs. 50.6%). The balanced group of sensor-guided or surgeon-guided TKA exhibited significantly better outcome scores. Experienced users achieved a quantitatively balanced knee in 93% and 60% of cases during sensor-guided and surgeon-guided TKA, respectively; for inexperienced users, both levels were lower (72% and 46%, respectively). Notably, the proportion of balanced knees after TKA was higher in sensor-guided TKA by inexperienced users than in surgeon-guided TKA by experienced users (72% vs. 60%). However, more sophisticated studies are needed to clearly establish the clinical benefits of the sensor.

FUTURE OUTLOOK

To produce academic evidence for the advantages and disadvantages of the sensor in computer-assisted TKA, it is necessary to ascertain the load and kinematic patterns of natural knees and balanced knees after TKA. The main criticism in the use of the sensor to mimic physiologic knee kinematics in TKA is that the ideal target load has been arbitrarily suggested and lacks support from both kinetic and kinematic research. Another criticism is that sensor data from intraoperative procedures do not reflect the weight-bearing load.^{39,40)} The interrelationship of the passive kinematics during surgery and the active kinematics in daily living activities should be defined in future studies. It is still debatable whether the cost savings realized from reducing the patient dissatisfaction rate and revision rate will outweigh the initial cost of the sensor in TKA. It can also be argued that the sensor may not be a worthwhile investment for high-volume surgeons. Future studies should adopt high methodological standards for the study design and randomization.

The application of the sensor may solve the major challenges of the revision TKA, especially with respect to

instability as a failure mode. Specifically, the sensor can be used to avoid unnecessary ligament release and/or bone adjustment by finding femorotibial incongruence to correct for previously undetected femoral or tibial malrotation. Therefore, avoiding the unnecessary procedures and performing essential procedures without omission using the sensor may enhance patient recovery and function after revision TKA.

The software for the sensor is expected to improve, offering greater convenience and accuracy. Similarly, the wireless load sensor is expected to become simpler, easier to use, and less expensive. Future integration of sensors, which quantify soft-tissue tension and knee stability through a full range of motion, will allow robotic implant and bone readjustment to actually customize a patient's soft-tissue balance and alignment. Peter F. Drucker, the inventor of business management, stated that "you cannot manage what you cannot measure." The quality of soft-tissue balancing can be improved by detecting the load imbalance. Sensors may be a valuable tool for achievement of accurate soft-tissue balancing without the need for a change in the surgical workflow, apart from the use of other computer-assisted methods for TKA (e.g., navigation and robotic surgery).

CONCLUSION

The wireless load sensor is an intraoperative tool that provides objective data for soft-tissue balancing. However, there is no apparent consensus regarding the definition of a truly load-balanced knee in sensor-assisted TKA and whether such knees will result in improved functional results. Ideal target loads must be determined through well-designed kinematic studies. In addition, there is a need to determine whether delicate improvements in soft-tissue balancing influence long-term results and survival rates, thereby offsetting the cost of sensor-assisted TKA and potential risk of soft-tissue over-release.

An orthopedic surgeon's experience, adaptability, and technical knowledge of the sensor are crucial to the success of sensor-assisted TKA. If orthopedic surgeons clearly understand the technology and advantages and disadvantages, they will be able to determine whether the sensor is appropriate for use in specific cases.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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