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Total Joint Arthroplasty: Tips for Improving Efficiency

Mark Gittins, DO, FAOAO, and Diane Doucette, RN, ONC, MBA

Abstract

Total joint arthroplasty is a very successful procedure that alleviates pain in arthritic patients. However, our current healthcare delivery system may not be able to provide the value of arthroplasty to match the demand in our increasing arthritic population. Increasing hospital efficiency and value for patients needing total joint replacement will bring this pain-relieving procedure to more patients with benefits to surgeons and hospitals. This article reviews segments in the knee arthroplasty pathway that will provide efficiency and value when they are optimized.

Total knee replacement (TKR) has been regarded as a very successful procedure for arthritic knees both in the short- and long-term.[1-3] Annually, hundreds of thousands of Americans benefit from this surgery with substantial pain relief and increased activity. These results allow for a broader and more productive workforce for society and better quality-of-life for patients. Projections show that the demand for this technology-driven procedure will continue to grow with the baby boomer generation coming of age. It is estimated that 1 million knee arthroplasties will be performed by 2016 and 3.5 million by 2030, which will surely put stress on the system as we now know it.

The Centers for Medicare and Medicaid Services (CMS) instituted a professional fee reduction from 1991 to 2008. The total knee arthroplasty current procedural terminology (CPT) code 27447 decreased 36% and the revision total knee arthroplasty CPT code 27487 by 39%.[4] These reductions may be a contributing factor to why less orthopedic surgeons are specializing in adult reconstruction. The increasing demand for the procedure coupled with dwindling number of joint arthroplasty surgeons, may create a lack of healthcare access to the arthritic knee patient.[5]

To address this increasing concern, a new paradigm must be instituted. Historically, hospitals where joint arthroplasty was performed typically focused on decreasing the cost of the procedure while increasing quality outcomes. In today's arthroplasty world, the value of the joint replacement will be the result of quality and service compared to the cost needed. That is, Value (V) = [Quality (Q) X Service (S)]/ Cost (C).

Service is the combination of effectiveness, innovation, and efficiency. An orthopedic team working in conjunction with an ambitious hospital can make changes that impact the patient, surgeon, and hospital in a positive manner.[6] Key segments that influence hospital efficiency are as follows: workflow process, physician practices, staff effectiveness, patient/family engagement, service utilization, and information technology (IT) systems capability.

Each of the segments is briefly described. The individual segments are dependent on the total integration of the sum of segments to arrive at hospital efficiency. With focused energy on these parameters, even large academic institutions have been able to demonstrate improvements.[6]

Workflow Process

Time-stamped workflow is the practice of diagram mapping the steps required for a patient to obtain the full value from their joint replacement surgery. This diagram standardizes the process and establishes resource optimization and accountability. The patient benefits from multiple departments working interdependently to form a healthcare supply chain optimizing quality and minimizing cost and waste (**Table I**).

Physician Practices

Motivated physicians are foundational to accomplish the goal of efficiency in the arthroplasty hospital. The physician triad—surgeon, hospitalist, and anesthesiologist—is the brain trust that uses evidence-based knowledge to construct order sets and protocols for the patients. This interdisciplinary interaction starts before the patient arrives at the hospital. Proactive surgical clearance with the use of surgery-specific guidelines by the medical and anesthesia physicians, ensures quality patient care and is intended to minimize delays on surgery day. Collegial cooperation and co-management extends into the surgical procedure itself and continues with interdisciplinary floor rounds postoperatively. On-call coverage for the patient is constructed depending on the patient's needs.

Staff Effectiveness

Communication with and among staff members is imperative to cultivating efficiency. The staff should have the knowledge and skills to adequately provide value to knee patients. The

Authors' Disclosure Statement: Dr. Gittins wishes to report that he is a consultant for DePuy Synthes Joint Reconstruction. DePuy Synthes Joint Reconstruction is a division of DePuy Orthopaedics, Inc. Ms. Doucette reports no actual or potential conflict of interest in relation to this article.

Table I. **Patient Flow for Scheduled 7:30 AM in Operating Room**

	Registration				Preoperative		
	5:30 AM	5:40 AM	5:50 AM	6:00 AM	6:00 AM	6:45 AM	6:45 AM
Patient arrives at hospital							
Registration starts							
Registration stops							
Walks or escorted, arrives in preoperative area							
Pre-op starts*							
Patient transported to designated "Holding Area"							

*This is nursing's time to complete assessment, patient change clothes, day of surgery diagnostic testing, H&P, notify surgeon of any concerns, ensure consent signed etc.

	Holding Area						OR	
	6:50 AM	6:55 AM	7:15 AM	7:15 AM	7:20 AM	7:25 AM	7:30 AM	8:00 AM
Arrives in holding and RN checks in patient and prepares for block								
Anesthesia arrives, assessment and block insertion started								
Anesthesia block completed								
Surgeon arrives in holding								
Circulator reviews chart and assists anesthesia with transportaion								
Transportation to OR								
Arrives in OR; team position, preps and drapes								
Surgeon makes incision								

preadmission center composed of registered nurses (RNs) coordinates patient evaluations with the medical and anesthesia team to optimize a care plan prior to the patient's arrival to the hospital. A block team consisting of ultrasound technicians, nurses, and physicians, works with the goal of administering the anesthetic block to the patient prior to entering the operating theater. Orthopedic–service line leaders coordinate staffing and materials in the operating room (OR). The OR team consists of the RN, surgical technicians, orthopedic assistants, and physician assistants. Postanesthesia care unit (PACU) nurses and technicians work with dedicated floor nursing specialists, physical therapists, and nurse case managers to complete the in-house stay portion of care. This collaboration throughout the entire surgical process allows for a seamless procedure that offers the best value to the patient.

Patient/Family Engagement

Communication with patients, their support team, and family is crucial. The care plan must be constructed and delivered to the patient and family prior to the planned surgery date. A printed patient binder with the milestones of preoperative clearance, operative day, and six-week postoperative care is provided in our practice. Preoperative joint classes can also be attended. DVDs are also provided, which are often helpful when members of the family cannot be present for some of the preoperative instruction. The case manager serves as an excellent point person for the patient and family, and can assist in contacting financial services for questions. The RN also acts as a liaison from hospital to home, or extended care facility care after the joint replacement.

Service Utilization

The complete orthopedic service line is reviewed with each of the service line leaders. This focuses on all the aspects of care for total joint replacement patients, including the preoperative, operative, and postoperative stages. Reviewing metrics and discussing the data among the leaders of the hospital optimizes bed occupancy, scheduling of surgery cases, length-of-stay, staffing, and the hospital geographic layout. Even dietary items such as choice, quality, temperature,

Table II. **Workflow, First Case Starts**

First Case Starts							
	Schedule Start	OR Start	Cut Time	Schedule Start to Start	Schedule Cut to Cut[a]	Personnel Category	Personnel Name
09/24/2012 Reason: Delay - Other (Patient needed to use the restroom prior to surgery.)	6:30 AM	6:33 AM	6:54 AM	☒	★	Anesthesia staff Anesthesiologist coverage Certified physician assistant Circulator Orthopedic assistant Scrub Surgeon	Shafer, Derek Narcelles MD, Nestor Miller, Donnie Caputo, Amy Thompson, Benjamin Gray, Natalie Sybert DO, Daryl R
09/25/2012	6:30 AM	06:25 AM	6:50 AM	★	★	Anesthesia staff Anesthesiologist coverage Certified physician assistant Circulator Orthopedic assistant Scrub Scrub relief Spinal monitor technician Surgeon	Dyer, Chad Reno, Mark Valus, Brian Roche, Michael Sheahan, Gayle Hughes, Rob Hochdanner, Ken Chenetski, Renee Gale, Clare Mavain DO, Gregory Z Todd DO, Larry T
09/26/2012	6:30 AM	6:25 AM	6:57 AM	★	★	Administrator Anesthesia staff Anesthesiologist coverage Certified physician assistant Circulator Orthopedic assistant Scrub Surgeon	Feeney, Kathleen Susan Fry, Jack Narcelles MD, Nestor Miller, Donnie Barrow, Jennifer Thompson, Benjamin Chenetski, Renee Sybert DO, Daryl R
09/27/2012 Reason: Delay - Other (New monitoring equipment for anesthesis, respiratory therapist performed intubation)	06:30 AM	06:28 AM	7:08 AM	★	☒	Anesthesia staff Anesthesiologist coverage Certified physician assistant Circulator Contract services OR coordinator Orthopedic assistant Scrub Spinal monitor technician Surgeon	Karnes, John Narcelles MD, Nestor Roche, Michael Sheahan, Gayle Frazier, Timothy Chenetski, Renee Hughes, Rob Chenetski, Renee Gale, Matthew Swary, Christina Todd DO, Larry T

[a]Schedule Cut = Schedule Start + 30 minutes

and timeliness of dining are reviewed to provide the greatest possible value to the patient.

Information Technology Capability

The efficiency of the time stamp is a computer-generated flow schedule. To be successful, the IT system must have the capabilities to track patient flow and separate the tasks in the flow chart. These task stations can be entered manually or by bar code when they are initiated or completed, establishing efficiency and reducing waste. Reports of all the monitored components are posted for all of the team to review analytically (**Table II**).

With this network, the team knows that every person counts and every minute is essential. Wireless electronic real-time monitoring of the patients provides safety and alerts the staff of potential adverse effects. Utilization of end-user telecommunication keeps staff up- to- date with the workflow and integrates the entire hospital thus allowing for simultaneous parallel procedures (two ORs). Hospital systems are fiscally better served with parallel procedures by nearly doubling the patient throughput.

In addition to the six segments described, listed below are some key tips in crucial areas that make for a more efficient environment for the total joint patient.

Tips for Central Sterile Optimization

1. Decision making for instrument/power capital purchases is determined on "flash" utilization rates in the OR.
2. Vendor–loaner equipment sets are put together by the vendor near the central sterile department.
3. Use a central sterile product line leader to assist with coordination of cases and purchase of equipment.
4. Use picture books and count sheets for assembly of instrument sets by central sterile staff.

5. Set the expectation of communication between OR staff, central sterile staff and surgeon.
6. Pursue 100% certification of the central sterile staff; reward the staff if this metric is accomplished.

Postoperative Tips

1. Prior to surgery, create initial order sets that script out entire length of stay: pain medication, physical therapy, respiratory therapy, medical management, discharge planning, etc.
2. Provide the discharge goals to the patient prior to surgery. These goals should be reviewed with patient and family on the day of surgery. Educate the patient and family on the list of staff that will be assisting the patient: nurses, technicians, respiratory therapists, physical therapists, case manager, etc. Explain that with this team approach we anticipate discharge postoperative day one.
3. Permit a family member (caregiver) to stay in the room with patient.
4. Post a communication board in the room with discharge goals and pertinent information specific to the patient's case.
5. Patient ambulates on day of surgery with physical therapy. Post the distance walked and range of motion obtained on the patient's communication board.
6. The surgeon conducts daily rounds at a set time (6-7 AM) with physical therapy, nursing, and case manager to reinforce the team approach to valued care.
7. The surgeon reviews the team concept with patient and family.
8. Postoperative labs are drawn at 4 AM, case management arrives at 5 AM, physical therapy arrives at 5:45 AM in preparation for 6 AM physician rounds.
9. Rounding clipboard is prepared the night before morning rounds. It includes the patient list, progress notes, order sheets, continuity of care paperwork, and prescriptions for surgeon to sign.
10. The case management nurse meets with the hospitalist team to inform them of discharges to prioritize the "goals achieved" by patients for early discharge.

Tips for Efficient Bed Turnover

1. The discharge planning begins with the initial preadmission nurse call to the patient.
2. The RN case manager confirms the discharge plan with the family and patient on the day of surgery.
3. Establish afternoon "huddle" conference with RN case managers, physical therapists, charge nurse, and clinicians to anticipate the next day's discharges.
4. Pre-plan inpatient bed needs the day before surgery to reduce discharge bottleneck resulting from fresh postoperative cases needing an occupied bed.
5. Have the patient's floor bed to the OR to permit a single transfer upon completion of surgical procedure.

Conclusion

Total knee arthroplasty plays a valuable role in alleviating pain in arthritic knee patients. The demand for and popularity of the procedure continues to grow. The increased need for knee arthroplasty surgery in the future will put stress on the healthcare system as it currently functions. Providing value to the knee patient by increasing efficiency, maintaining quality, and containing cost is the primary goal. By optimizing key segments in the pathway for the knee arthroplasty patient, we can expect increased patient and family satisfaction by providing a clear understanding of expectations. Hospital employees will be more engaged due to standardization of care, and understanding the goals of value for the joint arthroplasty patient. Lastly, the new efficiency paradigm will provide increased physician satisfaction due to expanded patient volume, more predictability in their day, and decreased necessity to educate new employees as frequently.

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Acknowledgments: Clinical and efficiency findings are specific to the hospital operating room (OR) in which the procedure was performed and to the surgeon who performed the procedure. Results reported may therefore not be generalizable to other environments and/or other surgeons. Many factors influence OR efficiency and clinical outcome beyond use of Patient-Specific Instrumentation (PSI).

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Patient-Specific Instrumentation: Total Knee Arthroplasty in Sports Medicine

Scott A. Sigman, MD and Kristen Proverb, MSN, RN, NP-C

Arthritis is projected to affect 67 million Americans by 2030.[1] As the population and life expectancy increase, complicated by comorbidities like obesity, disability from arthritis will become even more significant. Orthopedic surgeons performed approximately 800,000 total knee arthroplasty (TKA) procedures in 2012. Primary interventions accounted for 650,000 of the procedures.

According to the Orthopaedic Practice in the United States (OPUS) report published by the American Academy of Orthopaedic Surgeons (AAOS) in 2010,[2] 59% of orthopedists completed a fellowship. Of the specialties, 48.6% completed sports medicine versus 14.0% total joint or 11.2% adult knee fellowships. Overall, 5.96 TKAs were performed per month on average.

Total joint fellowship-trained orthopedic surgeons will not be able to manage the care for knee arthritis alone. Generalists or sports medicine-trained surgeons will likely need to take on the task of performing TKAs for a large portion of the population.

A sports medicine orthopedic practice consists of patients with injuries often sustained through exercise, overuse, or trauma. When young people experience severe knee injuries as a result of childhood play or recreational sports, treatment is often reconstructive surgery to repair the knee, preserve function, and allow return to normal activities.

As patients age, treatment transitions from minimally-invasive arthroscopic surgical techniques to arthroplasty with the goal of return to or maintaining activity. Special attention is given to the treatment and/or prevention of further deterioration of joints, using techniques such as knee arthroscopy.

The baby boomer population accounted for over 26% of the US population in 2010.[3] This generation battles health issues like obesity, hypertension, and hypercholesterolemia, compared with previous generations.[3] Whether it is this awareness and/or combined general increased stress, the baby boomers are the first generation to incorporate exercise as a mainstay to promote health, subsequently suffering from the impact of these activities on their bodies. Sports-related injuries in baby boomers rose from an estimated 780,000 in 1991 to nearly 1 million in 1998.[4] It is almost inevitable for a member of this group to develop a close relationship with an orthopedic surgeon to help restore or maintain joint health. At some point, the options for treatment shift from knee arthroscopy, nonsteroidal anti-inflammatory drugs (NSAIDS), physical therapy, and periodic injections, to consideration of total joint arthroplasty. It is reasonable for a patient with a successful established orthopedic relationship to wish to continue their treatment through arthroplasty. A sports medicine-trained orthopedist skilled in TKA can continue the role of treating physician for patients in this continuum.

Advances in technology have enabled the development of patient-specific instrumentation (PSI) for TKA. These are patient-specific resection guides and pin guides that are created by means of obtaining preoperative computed tomography (CT) image sequences of the hip, knee, and ankle to obtain appropriate mechanical axis and best restore the diseased knee closest to its original anatomical structure and proper alignment.

The objective of achieving neutral mechanical axis through the use of PSI has been supported by Daniilidis and Tibesku.[5] The instrumentation has been shown to reduce operative time by reducing the equipment handling and intraoperative decision making.[6,7] Operating room turnover times have been reduced as well; because of the disposable patient-specific guides and preoperative sizing of implants, less equipment is necessary in the set-up for each case, thus improving efficiency of the surgeon.[7] The patient will also benefit from less time under anesthesia and lower blood loss by avoiding the placement of an intramedullary guide.[6] There has also been a study suggesting better overall clinical outcome and improved postoperative flexion with the use of PSI over conventional instrumentation.[8]

Advantages of PSI in Sports Medicine Practice

Sports medicine orthopedists treat patients with all types of knee injuries and pathologies. A comprehensive approach and ability to offer all possible treatments for sports-related injuries to the knee is an advantage both for the patient and the physician. Continuity of care and the option to provide a complete spectrum of surgical techniques to our patients is imperative in that continuity. Mastering technological advances such as PSI in TKA allows for the sports medicine orthopedist to continue caring for their patients rather than having to refer patients on to other providers. The majority of sports medicine orthopedists perform both open and arthroscopic procedures. According to the OPUS report, the average sports medicine-trained surgeon performs less than 100 TKAs per year.[2]

Authors' Disclosure Statement: The authors have no actual or potential conflict of interest in relation to this article.

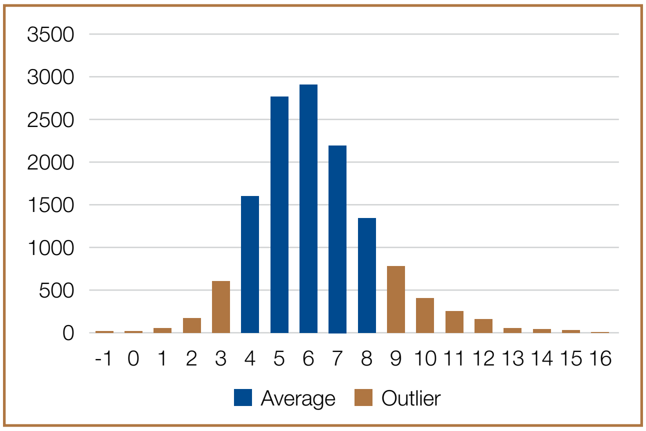

Figure 1. Graph of the frequency of each value of femoral valgus angle with outliers shown in gold.

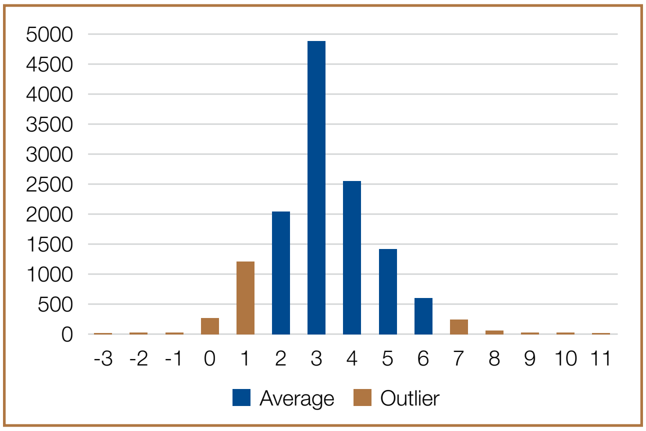

Figure 2. Frequency of each value of femoral rotation angle; outliers shown in gold.

Patient-specific instruments are designed to improve preoperative planning, reduce operative time, and improve patient outcomes and overall efficiency.

Preoperative Planning

Patients with radiographic osteoarthritis that do not respond to a conservative treatment program including physical therapy, bracing, cortisone injections, viscosupplementation, and NSAIDS are candidates for TKA. Once the patient has met the criteria for TKA, and has agreed to PSI, preoperative CT scans are obtained to determine the mechanical alignment of the knee.

As previously described by McGovern,[9] the scan is used to guide the production of individualized femoral and tibial resection guides based on the surgeon's preferences. Our preferences for the femoral design include a posterior referencing system, and femoral rotation is determined by the epicondylar line. An anterior shift and slight flexion of the femoral component is placed to avoid femoral notching. The tibial design reflects a resection perpendicular to the long axis of the tibia. The posterior slope is typically set at 3°.

Another advantage of PSI is the ability to identify preoperatively anatomic outliers, which may lead to potential negative outcomes after TKA. The CT analysis of the entire leg allows for precise evaluation of preoperative valgus angles (**Figure 1**) as well as appropriate epicondylar axis angles (**Figure 2**). If the anatomical outliers are not identified, malpositioning of components may take place producing reduced range of motion, painful range of motion or instability issues of the tibiofemoral and patellofemoral articulations. Once the valgus outliers are identified corrections can be made to ensure the appropriate mechanical axis cuts by adjusting the femoral resection guide.

The same holds true for the epicondylar axis. External rotation can be dialed into the femoral resection guide to ensure patient-specific patellofemoral tracking.

Once the individual design concept for each patient has been completed, the surgeon receives e-mail notification of the plan for review. The online review process then allows the surgeon to accept the plan as is, or request appropriate modifications. Once the plan is approved online, the patient-specific surgical guides are manufactured and ready for surgical use in 20 business days. Surgical preferences can be modified and stored as standard practice. For example, the posterior slope can be increased or decreased. Capacity for an 8-mm or 10-mm tibial insert can be integrated into a surgeon's preference for all plans going forward.

Intraoperative Technique

Our preference is to perform a midline incision with a medial parapatellar approach. We prefer to have our approved preoperative plan provided by DePuy Synthes Joint Reconstruction (Warsaw, Indiana) on a computer screen in the room for intraoperative verification of resection guide placement and subsequent distal femoral and proximal tibial cuts.

Femoral Component

Using PSI, appropriate soft-tissue removal is necessary for adequate visualization of anterior distal femur for the appropriate contact point of the customized femoral resection guide.[9] Our technique is to place the distal femoral resection guide onto the anterior femoral cortex first, and then flex into position for contact onto the femoral condyles. The femoral resection guide should lock into position with relative ease. There is a tactile feedback that will lock the guide into position. The surgeon will hold the guide in position while the assistant secures the guide with three-pin fixation, leaving the medial femoral condyle pin position open for the first distal femoral cut. Once the medial femoral condyle cut is made, a fourth pin is placed to secure the guide through the medial femoral condyle opening. Then the lateral femoral condyle pin is removed. The remaining distal femoral cut is made off the lateral femoral condyle. The remaining femoral cuts are made with a standard 4-in-1 cutting block.

Tibial Component

The position of the tibial resection guide can be challenging. There is less geography on the proximal tibial, compared with the distal femur. Thorough soft-tissue debridement is required in the area of the anterior and lateral fat pad. If possible, slight

Figure 3. Preoperative surgical plan (left) and postoperative radiographs (right).

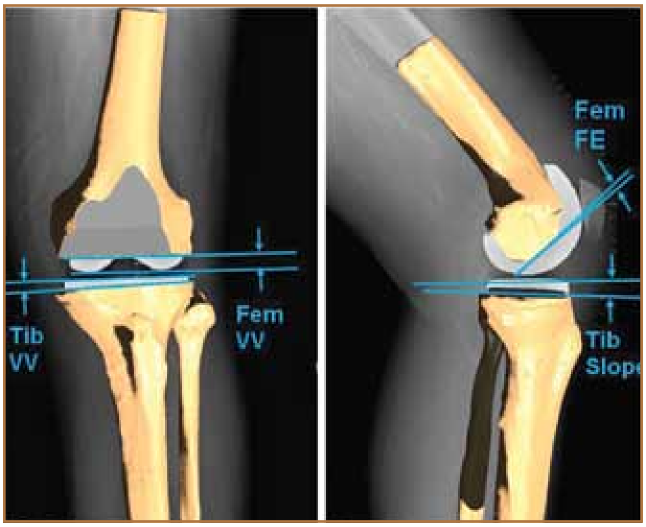

Figure 4. Comparison of the preoperative surgical plan and the postoperative radiograph.

anterior subluxation of the tibia with manual traction should be entertained. The resection guide should be applied to the anterior cortex first, and then flexed into position for contact of the medial and lateral phalanges. There are times the customized resection guide may slip into flexion, reducing your desired posterior slope and can be avoided by using a four-finger technique to minimize motion. This assures appropriate three-point contact of the customized tibial resection guide. Our preference is to have the surgeon maintain positioning of the resection guide while the assistant places the three fixation pins.

PSI should not be considered a replacement or substitution for traditional physician education in TKA surgical technique. PSI should supplement traditional arthroplasty experience. Sports medicine orthopedists that have minimal traditional arthroplasty experience may not be able to assess if the PSI cuts are appropriate and would also have limited ability to use standard instrumentation as a backup procedure.

Independent Postoperative Radiographic Review

The purpose of a postoperative radiographic review is to compare postoperative alignment of a series of radiographs to the preoperative TRUMATCH® Personalized Solutions plan.[10] These results can then be compared to what is found in the published literature.

Five radiograph sets were submitted for this review. Each radiograph was then matched to the preoperative plan using the case number (**Figure 3**). Using 3-dimensional (3D) computer-aided design software, the 3D model of the preoperative plan was best fit to the bony contours of the postoperative radiograph. Finally, the postoperative implant alignment was compared to the preoperative plan (**Figure 4**).

The results for each radiograph set are summarized in **Table I**. The results are then compared to what is reported in the literature in **Table II**. An example radiographic overlay is depicted in **Figure 5**.

Table I. **Summary of Radiograph Sets**

Case	Femoral Varus Valgus	Femoral Flexion/ Extension	Tibial Varus Valgus	Tibial Slope
Patient 1	0.8°	3.4°	0.7°	5.0°
Patient 2	0.6°	1.4°	1.2°	4.5°
Patient 3	0.7°	1.5°	-0.7°	-4.5°
Patient 4	0.0°	1.5°	-0.7°	6.5°
Patient 5	-2.0°	0.0°	0.6°	2.5°
Avg ± Stdev	0.0° ± 1.2°	1.6° ± 1.2°	0.2° ± 0.9°	2.8° ± 4.3°
Bias	None	Flexed	None	Undercut Slope

Table II. **Summary of the Literature**

Literature Reference	Femoral Varus Valgus	Femoral Flexion/Extension	Tibial Varus Valgus	Tibial Slope
Reference 12	2.0° ± 1.7°	3.8° ± 3.1°	2.2° ± 3.2°	3.4° ± 3.0°
Reference 14	7.0° ± 2.4°	4.6 ° ± 3.5°	2.7 ° ± 3.5°	2.9° ± 3.4°

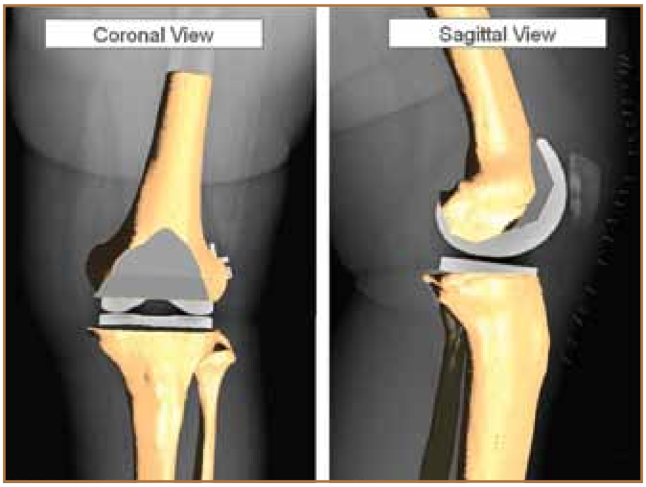

Figure 5. Radiograph overlay for Patient 4.

The results in **Table I** show there is no bias towards varus or valgus with an average of 0° for the femur and 0.2° for the tibia. However, there is a bias for femoral flexion with an average of 1.6° of flexion and an undercut of slope on the tibia by an average of 2.8°. Overall, the average degree of bias is lower in all cases, compared with the literature listed in **Table II**.

In addition, the standard deviation results shown in **Table I** are lower than the literature references with the exception of tibial slope, compared with the literature listed in **Table II**. The tibial slope showed the most deviation with 4.3°. Overall, the results showed the most bias and standard deviation for the tibial slope with all other averages and standard deviations lower than the literature references.

Conclusion

Regardless of an orthopedist's fellowship training, a skilled surgeon is the key to a successful surgical outcome. It is essential to have a base skill set in TKA, and not use PSI as a substitute for training. As a classically trained arthroplasty surgeon, I have performed over 5000 standard TKAs. I have subsequently started utilizing PSI and have now performed 100 PSI TKA procedures. The attention to detail of the preoperative planning provided by DePuy Synthes Joint Reconstruction based on CT analysis has greatly enhanced the precision of my intraoperative cuts as shown in the preceding postoperative radiographic review. The precise preoperative planning has increased my confidence level as a surgeon. PSI results in efficient intraoperative decision making. The ability to match an individual's anatomy preoperatively has translated into demonstrably improved clinical outcomes in the initial postoperative window as well. As we move forward to battle the foreseeable need for TKA, advances in technology like PSI will aid in meeting the demand. In combination with improved long-acting anesthetics and disposable instrumentation, TKA has the potential for the appropriate patient to evolve into an outpatient-based sports medicine-based practice while considerably lowering overall costs.

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Patient-Specific Instrumentation for the Obese Patient

Daniel P. Hoeffel, MD

The utilization of total knee arthroplasty (TKA) in the United States continues to increase. Hospital discharge data show that over 540,000 TKAs were performed in 2007 in the US.[1,2] By 2020, estimates suggest that 1 to 1.5 million TKAs will be performed annually in the US.[2] This is in combination with a more disturbing trend, obesity. The prevalence of obesity in the US population has appropriately been termed an *epidemic*.[3] It has been reported that 32% of men and 36% of women in the US are currently obese (body mass index [BMI] >30).[4] Analysis of the Nationwide Inpatient Sample (NIS) and Healthcare Cost and Utilization Project (HCUP) by Odum and colleagues[5] showed that the proportion of TKA patients with BMI greater than 30 rose from 11% in 2002 to 20% in 2009.

Several studies have indicated a greater risk for osteoarthritis in patients who are obese. Obese women have a five-fold increased risk, and obese men a four-fold increased risk for osteoarthritis.[6-9] In addition, obese patients undergo TKA at significantly younger ages than non-obese patients.[10] Obese TKA patients have significantly more medical comorbidities than their non-obese counterparts, with 60% of obese TKA patients having one or two comorbid conditions.[5] Obesity has been associated with lower quality of life outcomes and lower physical function outcomes.[11]

Obesity negatively affects postoperative limb alignment following TKA performed with mechanical instruments.[12] Although not absolutely correlated with outcome and satisfaction, coronal malalignment of greater than 3° outside of neutral has been shown to be associated with higher TKA failure rates.[13-18] Patients with TKA malalignment and BMI greater than 41 have a higher TKA failure rate, compared with non-obese patients with malaligned knees.[19]

With the rates of obesity and osteoarthritis inextricably linked, orthopedic surgeons will be performing TKAs in obese patients for the foreseeable future. Understanding the unique set of preoperative, intraoperative, and postoperative challenges posed by obese TKA patients is the first step in developing techniques and strategies to minimize complications.

The focus of this report will be on the intraoperative optimization of TKA in obese patients and the potential benefits of patient-specific instrumentation (PSI), compared with other currently available techniques.

Current Treatment Options

Current options for TKA instrumentation and alignment techniques include the use of standard mechanical instrumentation, computer-assisted mechanical instrumentation, and more recently, PSI.

Several reports have placed the accuracy of standard mechanical instrumentation in achieving neutral mechanical alignment +/- 3° at 75% to 85%.[20-22] The addition of computer-assisted guidance to mechanical instrumentation may increase accuracy to above 90%.[22,23] Early reports with PSI have reported 80% to over 90% accuracy in achieving a postoperative mechanical axis within 3° of neutral.[24,25] Most reports have not stratified results with regard to obesity and BMI.

Rationale for Using Patient-Specific Instrumentation

PSI first obtained FDA clearance in 2008. In its most general form, a preoperative computed tomography (CT) scan or magnetic resonance imaging (MRI) is performed to acquire lower-extremity alignment and morphologic data from an individual patient. This data is then used to design an operative plan, which can be adjusted or manipulated by the surgeon to optimize bony resections, implant size, and implant positioning for each individual patient. The goal is to achieve neutral mechanical alignment with regards to the coronal mechanical axis from hip center to ankle center. Pin guides or resection guides are then manufactured to match the patient's anatomy and produce desired resection levels, resection angles, and component rotation.

Preoperative Planning Challenges

Preoperative evaluation of a patient with significant limb obesity is difficult. On examination, flexion contracture is often underestimated as the soft tissue envelope obscures true bone position. Accurate standing x-rays are often difficult to obtain, because of the inability of the patient to adduct their legs adequately. The large medial soft-tissue envelope blocks adduction of the thighs. The lower extremities are held in an externally rotated position to allow clearance during gait; it also tends to be the stance position. This can be complicated if there is posterior tibial insufficiency or foot deformities, which can further influence the accuracy of long-leg radiographs. When standing, patients with large buttocks have difficulty position-

Author's Disclosure Statement: Dr. Hoeffel wishes to report that he is a paid consultant and speaker for DePuy Synthes Joint Reconstruction. DePuy Synthes Joint Reconstruction is a division of DePuy Orthopaedics, Inc.

Figure 1. Obese knee after total knee arthroplasty; note pannus overhanging distal thigh.

ing the knees within an acceptable distance from the x-ray plate. These positional factors, in combination with contrast and density variability, often result in suboptimal radiographs being used for preoperative planning.

When using PSI, data is acquired via CT scan or MRI. This data can be adjusted and manipulated to eliminate limb position error. This is especially helpful in light of the radiographic challenges with plain x-ray that are encountered in obese patients. In addition, PSI planning can accurately determine the distal femoral resection angle necessary to create a distal femoral resection parallel to the proposed tibial resection and parallel to the floor. This planning creates a neutral mechanical axis (0°). Many surgeons using mechanical instruments choose a single distal femoral resection angle (ie, 5°) for all patients. For patients with greater than 8° or less than 2° of femoral valgus, a distal femoral resection made in 5° valgus will introduce sufficient error resulting in a mechanical axis outside the desired +/- 3°. Using PSI, those patients are identified on the preoperative CT/MRI imaging, and the appropriate resection angle can be planned and performed.

Exposure Challenges

As noted previously, obese patients present challenges to the orthopedic surgeon both physiologically and technically. Intraoperatively, the technical challenges are in three areas: exposure, placement of instrumentation, and verification of bone cuts.

Exposure on obese patients can be quite challenging. Obese patients may be centrally obese or peripherally obese. Peripherally obese patients tend to carry their adipose tissue over the extremities and can develop even pannus-like folds when the knee is held in extension (**Figure 1**). This makes placement of the incision and exposure of the knee more difficult. Some patients have adipose tissue falling medially and laterally away from the knee, aiding exposure.

This is in contrast to the patient with "proud fat." Proud fat is firm, dense, and holds its form, only allowing a narrow window where the knee can be entered, even when using larger incisions and exposure aids, such as a quadriceps snip. The presence of proud fat can make exposure difficult during TKA in an obese patient. The depth of this fat makes placement of retractors difficult, especially retractors that are angled 90°. The depth of the wound may exceed the length of the 90°-retractor in some cases. Straight retractors or extra deep 90°-retractors must then be used.

Patellar mobilization and eversion in obese patients may require the creation of a subcutaneous pouch to aid in exposure. A small elevation performed below Scarpa's fascia with eversion of the patella aided by a towel clip or clamp, while moving from an extended to a flexed position, will often achieve eversion and create the necessary exposure for preparation of the femur and the tibia. Although the patellar resection can be done first, I do not recommend it in obese patients, as the extensor mechanism can be placed under significant strain during flexion intraoperatively, and patella fracture or patellar ligament disruption may occur. Firm adipose tissue in conjunction with a preoperative flexion limitation makes exposure especially difficult.

Femoral Challenges

Femoral difficulties presented by TKA in obese patients center on the inability to adequately visualize or palpate bony landmarks. The epicondyles can be difficult to visualize and may be difficult to palpate properly. Thus, computer-assisted registration of the epicondyles becomes more challenging and marking of the epicondylar axis on the distal femur is more difficult in mechanically instrumented TKA. The weight of the thigh itself can impact the accuracy of tensioning-type devices used in gap/ligament balancing techniques. These factors may result in inappropriate femoral rotation.

The preoperative planning for PSI allows for referencing via the posterior condylar axis, the epicondylar axis, and the patellar trochlear line. Intraoperatively, it does not require palpation or absolute identification of these landmarks, nor does it require registration of these points as in computer-assisted TKA. Femoral rotation is defined through appropriate placement of the PSI-pin guide or resection guide, and placing the distal pins. PSI-pin guides and resection guides do not have posterior condylar feet/paddles. They do not require direct contact with the posterior condyles to achieve appropriate rotation and sizing. Thus, placement of PSI femoral guides is not hindered due to limited flexion, which is frequently encountered in obese patients (**Figure 2**).

Adequate intraoperative flexion of the obese knee can be difficult to achieve. Frequently, flexion beyond 90° or 100° is blocked by soft tissue posteriorly. For surgeons who perform femoral cuts first, this creates difficulty in placement of the femoral sizing/rotational guide. The access to the posterior femoral condyles can be blocked because of inadequate flexion, even after the distal cut has been performed. Inadequate flexion also creates difficulty in registration of the posterior condyles when performing computer-assisted TKA.

Figure 2. TRUMATCH® Solutions femoral guide on distal femur. Note the ability to place the guide despite lack of knee flexion.

Tibial Challenges

Excess soft tissue in the lower limb creates difficulty in tibial exposure and preparation. Specifically, it can be difficult to palpate the tibial crest if there is a large amount of pretibial adipose.

Inability to accurately palpate the malleoli may introduce error in centering of the external tibial alignment guide and assessing posterior tibial slope when using mechanical instrumentation. Adipose over the malleoli hinders Computer-Assisted Surgery (CAS) registration of these landmarks. Computer-assisted techniques require accurate registration of the medial and lateral malleoli to appropriately extrapolate the center of the ankle. Registration error and subsequent error in tibial cut planning may result. One can perform a skin stab incision/percutaneous technique to more accurately register the malleoli. This is not advisable in obese extremities that have venous stasis conditions or lymphedema. PSI planning eliminates malleolar soft-tissue error by obtaining distal tibial data directly from the CT scan or MRI scan. Thus, intraoperative registration error is avoided.

Flexion is often limited by soft tissue in the obese patient. When flexion is inadequate, anterior subluxation of the tibia and access to the proximal tibia are hindered. This may lead the inexperienced surgeon to perform more soft-tissue releases, risking ligament imbalance, while trying to obtain adequate anterior translation of the tibia to complete tibial preparation and implantation.

Foot and ankle deformities are also common in morbidly obese patients. Posterior tibial insufficiency and subsequent midfoot collapse influences alignment of the external cutting jig for the tibia. Alignment landmarks, such as the second metatarsal, are more difficult to appreciate because of the inherent deformity in the foot.

With standard mechanical instrumentation, palpation of the tibial crest or identification of the second metatarsal is frequently used to guide the proximal tibial bone resection. The pretibial obesity, forefoot obesity, and frequent finding of posterior tibial insufficiency and midfoot collapse in obese patients make the use of these landmarks significantly more difficult than in non-obese patients.

Although not frequently considered, the use of PSI with the preoperative plan does allow for intraoperative verification of bony resections. Not only can the proposed resections be visually assessed prior to resection, post-resection measurements can be obtained via caliper and compared to the preoperative plan to assure agreement in the level of bony resection. This provides further evidence to the surgeon that appropriate resection has been performed.

When using mechanical instrumentation for TKA in an obese patient, there are several actions or options to optimize alignment results. The first and foremost is being methodical and diligent when creating adequate exposure to maximize the available flexion, and optimize the ability to palpate and visualize appropriate bony landmarks.

In addition, obtaining the center of rotation for the hip can be compromised in patients with a large buttock. When the hip is rotated during registration to find hip center, there is a floating-type effect of the pelvis making acquisition of the hip center difficult and possibly compromised.

Postoperative Difficulties

Obese patients frequently have inadequate upper body strength to mobilize from a seated position, because of their overall weight and general deconditioning due to the arthritic process. They have a large volume of distribution for pharmaceutical management of both pain and antibiotics. In addition, their airway is frequently compromised due to obstructive apnea and the large weight, which must be moved during respiration, especially in a supine position. This negatively impacts the ability to adequately manage their pain, as appropriate dosing of pain medications causing respiratory depression acts synergistically with the non-physiologic body habitus characteristics, which in turn negatively impacts their pulmonary system.

Reported Results

Bali and colleagues[26] reported their initial experience with 32 TKAs performed using customized cutting blocks. Twenty-nine of 32 knees were within 3° of neutral mechanical access. There was 100% femoral sizing accuracy and only two of the 32 TKAs required changes to the tibial tray size. There were no adverse intraoperative events. In another study, Barrett and colleagues[24] compared TKA alignment outcomes among PSI, CAS, and mechanical instruments. PSI was determined to be non-inferior to the other cohorts. Specifically, PSI achieved a long-leg mechanical axis with 3° of neutral in 81% of cases. CAS was 83% accurate, while standard instruments were 77% accurate. All PSI alignment error was noted to be varus. PSI accurately predicted femoral size in 95% of cases; tibial size was 84% accurate. Chareancholvanich and colleagues[27] reported a cohort of 80 TKA patients (40 PSI and 40 mechanical) using MRI–based patient-specific cutting guides. There were no cases of femoral notching and no PSI–related adverse events or complications detected. The authors concluded that both PSI and conventional instrumentation restore limb length and component alignment with a similar degree of accuracy. They also examined a subgroup of obese patients, and found no differences in alignment between the PSI and conventional cohorts. However, these results were not broken down by central or peripheral obesity. Daniilidis and Tibesku[28] examined 100 TKAs performed by a single surgeon using MRI-PSI technology. Eighty-nine percent were within 3° of neutral mechanical access in the coronal plane. Again, there were no intraoperative complications with the use of PSI. Ninety-three percent of these knees had a postoperative hip, knee, or ankle access that passed through the central third of the tibial base plate, termed the *zone of mechanical axis* (ZMA). In a retrospective analysis, Ng and colleagues[29] evaluated 724 TKAs (569 PSI, 155 mechanical) and used postoperative long-leg radiographs to assess alignment. Eighty-eight percent of the PSI TKAs passed through the central one-third ZMA, while only 78% of the mechanically instrumented knees passed through the central one-third ZMA. Analyzing a single-surgeon subset of that cohort, the authors looked at 105 PSI TKAs, compared with 55 manual TKAs. Overall, 91% of the PSI TKAs were within 3° of neutral mechanical axis and 78% of the mechanical TKAs were within 3° of a neutral mechanical axis.

A postoperative CT scans analysis has recently been reported on 78 TKA patients (51 PSI and 27 mechanical instrument).[30] Alignment was compared in the coronal, sagittal, and axial planes. PSI was more accurate than mechanical instruments in femoral rotational alignment, tibial rotational alignment, and tibial coronal alignment. Mechanical instruments also had more outliers greater than 2° from goal alignment in all three planes, compared with PSI.

Conclusion

While the technical challenges of TKA surgery in obese patients cannot be eliminated, they can be mitigated. The use of PSI with its robust preoperative planning, reduced dependence on intraoperative bony landmark palpation/identification, and sizing accuracy, can ease some of the difficulties encountered in obese TKA patients. The economic burden of obesity and arthritis is clearly linked. The impact on quality of life, mobility and the capacity to be gainfully employed in the obese patient with arthritis, cannot be overstated. Refinements and improvements in PSI will further enable orthopedic surgeons to better address the needs and complexities encountered in obese patients.

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Acknowledgments: Clinical and efficiency findings are specific to the hospital operating room (OR) in which the procedure was performed and to the surgeon who performed the procedure. Results reported may therefore not be generalizable to other environments and/or other surgeons. Many factors influence OR efficiency and clinical outcome beyond use of Patient-Specific Instrumentation (PSI).

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The Impact Patient-Specific Instrumention Has Had on My Practice in the Last 5 Years

Michael J. Collins, MD

I have performed total knee arthroplasty (TKA) using patient-specific instrumentation (PSI) (TRUMATCH® Personalized Solutions, DePuy Synthes Joint Reconstruction, Warsaw, Indiana) since July 2009. Since that time, I have performed over 600 of these procedures, all at the same hospital and all using the same personnel I worked with before I began using PSI. I do not have a physician assistant, but I do have a surgical assistant who scrubs with and assists me on all TKAs.

There are a number of reasons why a surgeon may decide to use PSI. This paper discusses the effect PSI has had on my practice in the last 5 years, including my experiences and conclusions.

Background

I completed my orthopedic residency at the Mayo Clinic in 1983. At the time, the surgical experience of Mayo residents included witnessing, assisting, and performing a great number of TKAs. Over the course of my professional career, I have witnessed first-hand the evolution in surgical techniques for TKAs.

In the late 1970s, most TKAs involved the surgeon eyeballing or free-handing the necessary bone cuts. The results of this technique, although often good, were unpredictable. Early on, the importance of anatomic alignment of the prosthetic components was recognized. Component malalignment was found to correlate with poor results and early failure.[1] Interestingly, not all malaligned components lead to catastrophic early failure. Most experienced reconstructive surgeons have encountered patients whose x-rays show less-than-optimal alignment, but who nevertheless seem to function quite well. However, it remains a universally accepted maxim that proper alignment of prosthetic components is of primary importance in TKA.

The introduction of the porous coated anatomic or Hungerford jigs in the late 1970s and early 1980s led to a significant improvement in the alignment of the prosthetic components.[2]

On a personal level, I, too, have constantly sought to improve surgical outcomes by achieving more accurate anatomic alignment. I experimented with navigation and computer-assisted systems, but found them disappointing. In addition to increasing operative time and increasing cost, it seemed these systems substitute one form of guessing (eg, determining the center of the medial epicondyle) with another.

Intrigued by the possibilities of PSI, I began using the TRUMATCH Solutions System (DePuy Synthes Joint Reconstruction) in July 2009. Although there were the usual learning curve challenges, I was quickly impressed with the accuracy of the bone cuts, especially in respect to rotation (**Figure 1**).

Physician-Perceived Advantages of Patient-Specific Instrumentation

Operative Time. My operative time has decreased with the use of PSI, and the more difficult the case, the more dramatic the decrease. Severe varus or valgus deformities are no longer as intimidating as they once were. Soft-tissue balancing remains a challenge, but getting the bone cuts right, especially in regard to rotation, greatly reduces the difficulty of these cases. See **Table I** for a list of all physician-perceived advantages of PSI.

Since my hospital did not keep accurate records of operative time during the course of my career, it is difficult to accurately quantify the improvement in operative time, but I would estimate that in the routine, uncomplicated arthroplasty, my operative time decreased 15-30 minutes per case. In addition, anesthesia time also decreased, which is another source of cost savings for the hospital.

A second, equally welcome time benefit of PSI, is the turnover of cases. Prior to using PSI, my nurses would have 8 or 9 trays of surgical instruments to clean, sterilize, and organize between each case. With PSI, they have only 1 or 2 trays. This significantly decreases the time needed to clean the room after one case, and to prepare it for the next. For busy surgeons who perform several knee replacements a day, the time savings associated with decreased operating room (OR) time and decreased turnover time can be significant.

Blood Loss. In my experience, PSI is associated with decreased blood loss. This, of course, may simply be related to the decreased OR time—or to other changes I have made in recent years, such as using tranexamic acid or the fact that I no longer routinely use a drain—but more accurate bone cuts tend to decrease the need for recutting. Soft-tissue balancing, while still an integral part of the procedure, is generally easier and more straightforward. Using prefabricated bone blocks means that another historically significant source of blood loss, the intramedullary alignment guide, can be eliminated.

Author's Disclosure: Dr. Collins wishes to report that he is a consultant for DePuy Synthes Joint Reconstruction. DePuy Synthes Joint Reconstruction is a division of DePuy Orthopaedics, Inc.

Because of other, concomitant changes I have made in my surgical technique (eg, tranexamic acid and no drain), it is difficult to state unequivocally that the use of PSI has led to a significant decrease in blood loss, but my impression is that it has. For all of the reasons mentioned above, I no longer routinely use preoperative autologous blood donations.

Improved Alignment. I routinely do full-length standing x-rays on all patients at the first postoperative visit, and have achieved significant improvement in alignment in both the anteroposterior and lateral projections, compared with cases performed without PSI.

Assessment of rotational alignment is much more difficult to evaluate. I do not routinely perform postoperative computed tomography (CT) scans to determine rotational alignment, but I can report anecdotally, a marked and humbling decrease in patellar subluxation with the use of PSI. Prior to using PSI, I would observe an occasional tendency toward patellar subluxation while ranging the knee in the OR immediately after fixation of the prosthesis. Of the 600 cases I have performed with TRUMATCH Solutions (DePuy Synthes Joint Reconstruction), patellar subluxation has happened only once; it was minor, with no clinical manifestation.

Difficulties in establishing proper rotational alignment have been observed since the dawn of the procedure, and numerous systems have been devised to help surgeons in this regard. Whitesides Line, measuring off the posterior condyles, and other techniques, have all attempted to achieve the correct amount of rotation of the femoral and tibial prostheses.

Prior to using PSI, I had assumed I was doing a good job of determining proper prosthetic rotation. However, after performing several hundred TRUMATCH Solution procedures, I came to the conclusion that, in the past, I must too often have underestimated the amount of external rotation required for anatomic alignment. This is almost never a problem now, even in the severe valgus knee.

Proper tibial alignment can always be verified with the external alignment guide that fits into the tibial bone block. When I first started doing PSI, I felt the resection guides tended to underestimate the amount of posterior tibial slope needed. This no longer seems to be a problem. Varus/valgus alignment has always been satisfactory, but I check it before cutting in every case, and even now, will occasionally feel the need to "tweak" the system in order to establish what I feel is a more accurate bone cut. The necessity for these tweaks is becoming less frequent, perhaps because of better design, perhaps because of increased surgical experience.

As is always the case, it is incumbent upon the surgeon to remain vigilant. There is no perfect system and the best results are obtained when the surgeon diligently checks and confirms decisions made preoperatively in the laboratory.

It is also important to note that prior to the manufacture of the resection guides, a plan is forwarded to the surgeon for review. It is at this time that the surgeon has the ability to modify the plan. I make changes to the preoperative plan approximately 20% of the time. The engineers in the laboratory work from a template we prepared when I first started using PSI, but there are times when I feel the template does not quite meet the needs of the individual patient. In my practice, the most frequent changes are decreasing the amount of tibial bone resection. My template calls for 10 mm of resection off the high side. While this template works well in many cases, if followed blindly, will occasionally result in the resection of too much bone. Similarly, increased posterior femoral bone resection in a patient with a flexion contracture is generally desired, but at the present time, my template calls for the same amount of bone resection in a man of 1.98 m with a 30° flexion contracture as a woman of 1.57 m with a 5° flexion contracture. These matters are, however, easily addressed at the time of the surgeon's preoperative review of the plan.

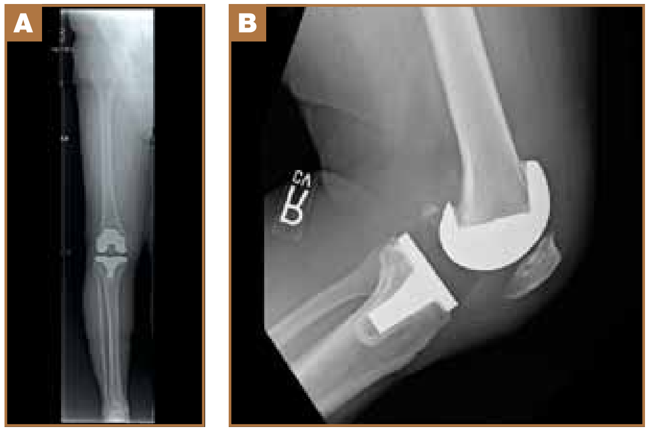

Figure 1. Full-length standing anterorposterior (A) x-ray and lateral view (B) of a TKA patient.

Component sizing is determined preoperatively and based on measurements made from the CT scan. Early on, I noticed that the tibial component would occasionally be oversized—an issue that has been recognized by the engineers and has been corrected in the last year or two.

Cost. With the advent of decreasing reimbursements and bundled payments, it behooves the surgeon to pay attention to cost. It is no longer enough to do the best job possible, using the best materials available. Not so long ago it would have been considered unethical for a physician to consider cost when

Table I. **Physician-Perceived Advantages of PSI**

1.	Decreased operative time
2.	Decreased blood loss
3.	Improved alignment
4.	Potential long-term cost benefits
5.	Increased referrals and personal stimulus

deciding on a course of treatment for a patient. This, sadly, is no longer the case.

The increased costs associated with PSI include the preoperative CT scan and the guides themselves, as described above. The short-term cost-benefits of PSI can now be examined and documented. While exact cost-savings figures are not available, one might infer that decreased OR time and anesthesia time along with decreased number of surgical trays have likely resulted in cost savings.

The long-term cost-benefits of PSI will be dependent upon two things. First, is alignment really better with PSI? It is my impression that it is, but further studies will be necessary to determine if this is actually the case. Second, even if alignment is improved, will that in turn result in an increase in longevity of the prostheses?

Increased Referrals. Our patients are becoming more knowledgeable about surgeons and surgical choices. But despite this, most patients come to me thinking they are going to get custom-made *implants* rather than custom-made *instrumentation*. Nevertheless, having something custom-made has great appeal to patients. A significant percentage of patients now come to me because of my reputation as a surgeon who uses PSI.

Our primary care colleagues are also becoming more knowledgeable about trends in orthopedics. I have had a number of referrals from primary care physicians who specifically sought out a surgeon who performed procedures using PSI.

Because I have a well-established practice and I am as busy as I wish to be, I have made no effort to market myself or this procedure. I do not advertise, give talks, or hold seminars at local nursing homes or hospital-sponsored venues. Were I to do so, I suspect my surgical volume would be significantly greater.

Personal Stimulus. The use of the PSI has forced me to re-examine many of my assumptions regarding what I do and why I do it. The engineers who design and make the resection guides are not surgeons. They work off a template provided by the surgeon. I helped construct my personal template, but have learned that it must frequently be modified in response to vagaries in anatomy as well individual factors such as contractures. I have, for example, had to redefine the optimum amount of tibial slope and have learned to modify it on certain occasions. The same is true for posterior femoral bone cuts.

Physician-Perceived Disadvantages of Patient-Specific Instrumentation

In my experience, the major difficulty yet to be solved in TKA is the patellofemoral joint. Total knee replacement has been a very successful operation in my hands, but looking at areas where I need improvement, they are almost all patellofemoral. As discussed previously, I am impressed with the exactitude of the system in terms of rotation of the femoral component. Maltracking is almost never a concern. However, I have seen no improvement in the percentage of my patients who develop patellar crepitation/clunk syndrome, usually 6 months to 1 year postoperatively. See **Table II** for other physician-perceived disadvantages of PSI.

Table II. **Physician-Perceived Disadvantages of PSI**

1.	Increased cost of preoperative magnetic resonance imaging (MRI)/CT.
2.	Increased radiation exposure, in the case of CT.
3.	Increased cost of resection guides.
4.	A tendency for the surgeon to rely too heavily on the engineer's preoperative assessments, rather than on the surgeon's intraoperative assessments.
5.	In training programs, the use of PSI may give residents and fellows less experience in personally determining proper bone cuts.

The fact that I do PSI knees obviously plays a role here, but I am dismayed at the lack of any well-accepted technique or device for making patellar cuts. The TRUMATCH Solutions System does not include anything to assist in cutting the patella. Even as an experienced surgeon, I find myself occasionally dissatisfied with my patellar bone cuts, an unhappiness assuaged somewhat by the fact that I have never been able to correlate lack of a perfectly symmetrical patellar cut with the likelihood of symptomatology, or the likelihood of developing patellar clunk. An informal survey of surgeons in my area reveals no consensus on the best way to perform this critical part of the procedure.

Conclusion

I have found PSI to be of significant benefit in my practice. It has improved my efficiency and accuracy in the OR. It is well received by my patients, who are satisfied not only with the results of their surgery, but also in feeling that they are part of a new, cutting-edge technique. Hospital response was somewhat guarded and cautious at first, but has become increasingly positive as they are now able to document significant cost savings. I look forward to the evolution of this technique, especially as it relates to patellofemoral kinematics.

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Acknowledgments: Clinical and efficiency findings are specific to the hospital operating room (OR) in which the procedure was performed and to the surgeon who performed the procedure. Results reported may therefore not be generalizable to other environments and/or other surgeons. Many factors influence OR efficiency and clinical outcomes beyond use of Patient-Specific Instrumentation (PSI).

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