The Application of Minimally Invasive Surgical Techniques. Part II: Total Knee Arthroplasty

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Abstract

Traditional surgical approaches often involve making large skin incisions and extensively dissecting healthy tissue to access diseased anatomy. Obviously more desirable is to make smaller incisions and more focused dissections and achieve the same postsurgical outcomes. Minimally invasive surgery (MIS) is gaining popularity in many orthopedic fields, but MIS techniques are not without risk. Continued use of these techniques is a topic of debate. If alignment is satisfactory with MIS, and if the complication rates of MIS are similar to those of traditional approaches, it seems sensible to consider the less invasive approaches to enable earlier patient recovery and improve cosmesis. Skeptics claim that there is no advantage in using MIS over time-tested approaches and are concerned that MIS approaches are being implemented before being properly subjected to peer review.

Traditional surgical approaches often involve making large skin incisions and extensively dissecting healthy tissue to access diseased anatomy. Such approaches are associated with a risk for nerve and blood vessel injury, wound infection, loss of function of surrounding muscles, and an unattractive scar. Obviously more desirable is to make smaller incisions and more focused dissections and achieve the same postsurgical outcomes. Minimally invasive surgery (MIS), which has been in development for many years and is still being refined, is based on 5 broad principles for decreasing surgical morbidity and recovery time[1,2]:

- Smaller incisions (<10 cm; actual dimension is debated).
- Development of mobile surgical window.
- Restricted dissection of soft-tissue structures.
- Modified and/or new instrumentation to enhance visualization.
- Accelerated recovery.

MIS is gaining popularity in many orthopedic fields, such as arthroplasty, fracture fixation, and spine surgery.[1,2] With improved instrumentation and surgical experience, these approaches can be further streamlined to limit deep soft-tissue dissection and shorten the incision.[3] However, these techniques are not without risk. During preoperative counseling, it is important to emphasize the risks of MIS to the patient and to explain that an MIS approach may be extended if deemed necessary during surgery. Continued use of these novel techniques is a topic of debate. Skeptics claim that there is no advantage in using MIS over time-tested approaches and are concerned that MIS approaches are being implemented before being properly subjected to peer review.

Background

Total knee arthroplasty (TKA) has been very successful for patients with degenerative knee arthritis. Although it is hard to imagine that results (2% rate of serious complications, 95% rate of 10-year implant survivorship) can be improved, patient surveys have indicated that patients are concerned about speed of recovery and return to function. Studies have been conducted to determine if MIS-TKA is the answer to these problems.[4]

MIS-TKA was developed after described MIS unicondylar knee arthroplasty (UKA).[5,6] UKA was first performed in the 1970s but was quickly abandoned by many surgeons because of early unfavorable results. In the 1990s however, improvements in surgical technique, implant design, and instrumentation led to a resurgence in use of the technique. Recent data showed that 10-year survivorship of a properly indicated UKA was higher than 95%, which approaches the rate for conventional TKA.[7,8] MIS-UKA had a revision rate of 7.9% (10 revisions in 126 patients) after a mean follow-up

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of 8 years. Several potential advantages of MIS-UKA were identified: low morbidity, same-day or short-stay hospitalization, shorter recovery than with TKA, less need for physical therapy, and lower cost than with primary TKA.[6] A prospective matched-pair comparison of MIS-UKA and conventional TKA in patients with isolated medial compartment arthritis concluded that MIS-UKA is more cost-effective and is associated with less blood loss, increased postoperative range of motion (ROM), shorter hospitalization, quicker rehabilitation, and earlier ambulation.[9] A proponent of MIS-UKA, however, noted that the procedure has narrow indications, is technically demanding, and that training in the United States is limited.[6]

There is much controversy surrounding the usefulness and application of MIS-TKA. Proponents claim that it decreases soft-tissue trauma, reduces blood loss, shortens recovery time, increases pain relief, improves knee function, and results in a better cosmetic appearance.[10-16] However, critics counter that these benefits have not been proved, operating time and risk for misaligned components are increased, and the prolonged learning curve is prohibitive and dangerous for patients.[15,17-19] There are conflicting data supporting both claims, and there is no definitive answer regarding whether MIS-TKA is an acceptable replacement for, or even an upgrade to, conventional TKA.

Surgical Approaches

The standard approach TKA consists of an extensive midline skin incision and a median parapatellar arthrotomy.[20] In MIS-TKA, the skin incision is approximately twice the length of the patella, or 6 to 14 cm. A curvilinear medial or lateral skin incision extending from the superior pole of the patella to the tibial joint line provides better exposure for varus and valgus knees, respectively.[19] A second lateral incision can be made from the lateral femoral epicondyle to just above Gerdy's tubercle.[21]

However, the cosmetic skin incision does not define MIS-TKA. Instead, the extent of soft-tissue and bony dissection determines the true invasiveness of the arthroplasty. Thus, during MIS-TKA, the median parapatellar arthrotomy, for example, should avoid extending into the quadriceps mechanism, and patellar eversion should be avoided. Quadriceps strength after conventional TKA was only 83% of the strength of the contralateral knee, possible secondary to tissue trauma and disruption.[22] The hope with MIS techniques is to avoid this complication.

A limited median parapatellar arthrotomy is favored by some authors, as the approach is familiar and facilitates a natural transition from conventional TKA to MIS-TKA.[23] It limits the proximal extension into the quadriceps tendon to only 2 to 4 cm and still allows for sufficient lateral subluxation of the patella. A randomized controlled trial compared the limited median parapatellar and mini-midvastus approaches and found similar ROM, pain, Harris Hip Score (HSS), and component alignment 6 months after surgery. However, these authors, like others before them, recommended the limited median parapatellar approach because of the ease of conversion to the standard approach.[24]

Other options include the midvastus, subvastus, quadriceps-sparing, and lateral approaches.[8,11,12,25] The midvastus approach involves cutting 1 to 3 cm of the vastus medialis obliquus. However, the vastus medialis obliquus is the only muscle that prevents lateral displacement of the patella when the knee is actively extended.[16] The subvastus arthrotomy avoids quadriceps mechanism disturbance but may result in difficulty in everting the patella. However, with satisfactory dissection and smaller instrumentation, patellar translation alone is sufficient. The quadriceps-sparing technique, essentially a subvastus approach with no patellar translation, necessitates modified instrumentation. The subvastus and quadriceps-sparing approaches often provide limited visibility of the lateral tibial condyle, and their learning curves are longer; these approaches are among those most unlikely to become the standard of care.[24]

The lateral arthrotomy, a newly described technique for MIS-TKA, involves an incision through the iliotibial band. This approach, which often requires navigation, obviates the need for an intramedullary guide for femoral component positioning, does not violate the quadriceps mechanism, permits eversion of the patella, and does not dislocate the knee joint. In a series of 166 patients who had TKA through a lateral arthrotomy, short-term results showed a 97% good or excellent objective Knee Society Scores (KSS).[21] A possible disadvantage of the lateral arthrotomy is reduced access to the tibia and the posteromedial soft-tissue attachments (ie, the incision is approximately 7 mm lateral to the tibial tubercle).[16]

Specialized Instrumentation and Techniques

The smaller incisions and arthrotomies in MIS-TKA are obtained using smaller instruments.[19] As exposure may be limited, many retractors are designed to protect the soft tissues while bone cuts are made. An example is a special 2-pronged retractor that protects the medial or lateral collateral ligaments while the distal femoral cuts are made. Special MIS-TKA instrumentation has been developed to facilitate either a medial or lateral approach; left medial instruments can be used as right lateral instruments and vice versa.[16] Manufacturers have also developed smaller cutting blocks to facilitate surgical access through a smaller window.

A mobile window concept is applied in MIS-TKA, and the surgeon must be vigilant to avoid placing undue stress on the soft tissue from aggressive retraction. Much of MIS-TKA is facilitated by 10° to 35° of flexion, compared with conventional TKA performed at 90° or more of flexion.[18] In addition, gravity can be

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used to assist in visualizing the knee joint and minimizing soft-tissue trauma, such as the suspended leg technique. By flexing the hip to 20° to 30° and allowing the knee 90° to 100° of flexion, the surgeon can manipulate the target portion of the knee into the surgical field. In a series of 20 patients who underwent this technique, decreased violation of the extensor mechanism and enhanced soft-tissue balancing were reported.[10]

Soft-tissue and bony manipulation techniques that are essential for successful MIS-TKA include superior and inferior patellar capsular releases, no patellar eversion, no tibiofemoral joint dislocation, specific order of bone cuts, and piecemeal removal of bone cuts. These techniques may vary with surgical approach.[17] Patellar capsular releases enhance the lateral mobility of the patella and expose the anterior joint. The surgeon minimizes postoperative quadriceps dysfunction by only subluxating or retracting the patella through the MIS approach, compared with complete patellar eversion used in conventional TKA.[26] Joint dislocation is preferentially avoided while making bone cuts to prevent capsular damage, which can affect postoperative pain and recovery. Conserving the soft-tissue envelope involves making specific bone cuts to maximize the joint exposure: first the tibia, then the femur, and finally the patella. Other authors have suggested that the best exposure is obtained by cutting the patella first (if it is to be resurfaced), then the distal femur, and then the tibia, and then making the remaining femoral cuts.[16] Progressive bone cuts increase the volume of available space through which surgery can be performed.[12] However, even when this tactic is used, the surgeon may need to adapt to completing bone cuts freehand and remove them piecemeal after the initial osteotomy is made with the miniaturized cutting guides.

Implant size is the limiting factor for the size of the skin incision and arthrotomy. Cemented and cementless components can be used, as with conventional TKA. Recently, tibial trays with a short and/or modular keel were designed. Use of a tibial tray decreases the need to subluxate the tibia and eases placement in the tray at cementing. With cemented components, meticulous effort must be made to remove the excess cement that may go unseen with the limited exposure. As the lateral femoral condyle and the lateral tibial plateau commonly have residual cement, these areas should be routinely explored.[17]

Outcome Studies

Developers of MIS-TKA continue to seek to decrease postoperative pain, speed recovery, shorten rehabilitation, and improve mobility. In early comparisons, successful outcomes were reported for MIS-TKA over conventional TKA. At 9-month follow-up, 70 patients who underwent MIS-TKA had less intraoperative blood loss, shorter length of stay, increased ROM, and implant accuracy similar to that of traditional TKA (conservative exclusion criteria were used to select appropriate patients; excluded were patients with serious medical comorbidities, >10° of varus deformity, >15° of valgus deformity, or >10° of flexion contracture).[12] Early observational results of MIS-TKA showed that 210 (97%) of 216 knees had good or excellent KSS.[21] According to a retrospective review of 48 knees, MIS patients were able to complete an active straight leg raise significantly earlier after surgery but had similar knee function at 2- and 4-year follow-up.[27]

A case control comparison of 32 knees after MIS-TKA (defined as 6- to 10-cm incision, no patellar eversion, no quadriceps splitting) and 26 knees after conventional TKA (>10-cm incision, patellar eversion, quadriceps splitting) showed mean KSS of 96 and 94 and mean functional scores of 99 and 90 for MIS-TKA and conventional TKA, respectively.[28] In another case–control study of 73 age- and sex-matched patients, the midvastus approach with no patellar eversion and preservation of the suprapatellar pouch was compared to a standard median parapatellar approach.[14] The mini-midvastus patients had more flexion 6 and 12 weeks after surgery. One year after surgery, mean flexion (125° in mini-midvastus patients, 116° in control patients) was statistically different. There were no differences in tibiofemoral angles, component alignment, or patellar alignment. Mean tourniquet time was 14 minutes longer for the mini-midvastus patients than for the median parapatellar patients.

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A randomized, double-blinded trial comparing extensor and flexor muscle function after mini-midvastus TKA versus conventional TKA, found that extensor peak torque was higher 3, 6, and 12 months after MIS-TKA, but flexor peak torque, Harris Hip Score, and Oxford Knee Score were all similar over the same periods.[29] The authors concluded that extensor function was preserved with MIS techniques versus standard TKA. Working with the same MIS approach, another prospective randomized trial used an accelerometer to analyze physical activity after surgery.[30] MIS patients were significantly more active on all measured postoperative days and achieved 80% of preoperative acceleration within a shorter period (mean, 3.0 days; standard deviation [SD], 3.3 days), compared with standard TKA patients (mean, 7.0 days; SD, 3.5 days).

A systematic review of 13 randomized controlled trials found that mean KSS was higher for MIS-TKA patients, compared with conventional TKA at 6 and 12 weeks after surgery.[31] However, this difference was lost at 6 months. In addition, 6 days after surgery, ROM was more improved for the MIS-TKA patients.

Complications and Limitations

MIS-TKA has been appropriately heavily scrutinized, and found to work best in carefully selected patient populations. Conventional TKA is probably better suited to patients with body mass index higher than 40, severe fixed valgus deformity, severe osteoporosis, previous knee arthrotomy, or rheumatoid arthritis.[23,32,33] Given the minimally invasive nature of the exposure, problems such as difficulty in visualizing cuts and leaving behind residual cement are not usually encountered in conventional TKA. In addition, because of the unique incisions made in specific MIS approaches, converting to the standard median parapatellar arthrotomy can be a problem and may require an entirely new incision.

A prolonged learning curve is another issue associated with these more difficult approaches. One study showed that a surgeon needed to perform 50 MIS cases to reduce operating time to that of conventional surgery.[34] Another study using operating time as an indicator found a learning curve of only 10 MIS cases.[35] In a comparison of 100 MIS-TKAs and 50 conventional TKAs, the authors estimated a learning curve of approximately 50 cases for a high-volume surgeon. Mean operating time was 102.5 minutes for the first 25 MIS-TKAs and 78.9 minutes for the first 25 conventional TKAs, which is a significant difference, but only for the first 25 knees. Compared with the last 25 MIS-TKAs, the first 25 MIS-TKAs had significantly less patellar resection accuracy and more patellar tilt. There was no significant difference regarding radiographic outliers in either group.[36]

A systematic review showed that MIS-TKA operating time was increased by 10 to 19 minutes.[37] In addition, the incidence of wound healing problems and infections was not significantly increased in the MIS group. However, there were no significant increases in overall complications or tibial and femoral radiographic alignment.

Overall, the major complaints about MIS-TKA are that it is unlikely to result in any improvement in component survivorship and that it may not actually be MIS as far as knee trauma is concerned. Literature reviews have identified reports that conflict regarding any functional knee improvement and long-term component longevity.[37] Serum levels of creatinine phosphokinase, myoglobin, aldolase, lactate dehydrogenase, glutamic oxaloacetic transaminase, and creatinine were measured on postoperative days 0, 1, 2, 4, 7, and 14 in an attempt to quantify soft-tissue damage.[38] When these values were compared to the preoperative values, the MIS and conventional techniques were found to be equally traumatic to the soft tissues. Likewise, a separate biochemical study found no difference between preoperative and postoperative C-reactive protein or interleukin-6 levels in a comparison of MIS and conventional techniques.[30] Studies such as these have led surgeons to question the definition of MIS, as incision length does not seem to define the invasiveness of a surgery. Given the expense of the new instruments, the potential for complications, and the learning curve requirements, MIS-TKA is recommended only for high-volume surgeons who receive specialized training.[19]

Perspectives on MIS Approaches to the Knee

The potential advantages of MIS techniques in knee arthroplasty include less operative blood loss, ease of surgical closure, decreased postoperative pain, shorter hospital stay, faster postoperative recovery, and improved cosmetic appeal.[32] However, possible problems with the surgical technique include its steep surgical learning curve, increased operative time, compromised surgical exposure, technical errors (eg, fracture, component malposition), and neurovascular injury.

Critics of MIS-TKA claim that its long-term outcomes would not be superior to those of the well-established approaches and that marketing schemes directed at patients paint a picture that is not supported by current literature. Some of the reported benefits of MIS approaches may be clouded by aggressive and innovative pain control protocols aimed at early rehabilitation of patients. Moreover, the benefits of MIS may be offset and overshadowed by the potential for wound complications and component misalignment. Patients are more likely to accept a larger incision if it minimizes chances of a second, revision operation.

Not unexpectedly, initial studies of MIS-TKA procedures have generated conflicting data. If alignment is satisfactory with MIS, and if the complication rates of MIS are similar to those of traditional approaches, it seems sensible to consider the less invasive approaches to enable earlier patient recovery and improve cosmesis. As many implants begin to show wear approximately 10 years after implantation, surgeons are waiting to see if the revision rate for MIS techniques is higher than what is currently seen for components inserted with conventional approaches. MIS is probably best suited to specifically trained high-volume surgeons.

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