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Minimally Invasive Total Knee Arthroplasty: surgical implication for recovery

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Abstract

Background—Despite growing interest in minimally invasive surgery (MIS) technique for total knee arthroplasty (TKA), few randomized controlled trials have compared MIS and conventional TKA using a combination of functional performance, knee pain, knee range of motion (ROM), surgical and radiographic outcomes.

Methods—A prospective, randomized investigation comparing early outcomes of TKA using conventional or MIS approaches (n = 44). Patients were assessed pre-operatively, 48 hrs, 4 and 12 wks post-operatively by blinded evaluators. Outcome measures included timed-up-and-go, 100 foot walk, knee pain, passive knee ROM, knee society score, blood loss, tourniquet time, hospital length of stay, surgical complications, and radiographic outcomes.

Results—No significant differences in functional performance, knee pain, knee ROM, surgical or radiographic outcomes were observed between groups at 48hrs, 4 or 12 wks postoperatively.

Conclusion—While surgical and radiographic outcomes were not compromised with MIS surgery, there were also no improvements in pain, ROM, or functional performance with MIS TKA.

Keywords

Total Knee Arthroplasty; Minimally Invasive Surgery; Function

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LEVEL OF EVIDENCE: Prospective randomized controlled trial, Level I

INTRODUCTION

The role of total knee arthroplasty for treatment of degenerative knee disease has been well documented. More than 2 million total knee arthroplasty (TKA) procedures will be performed annually in the United States by the year 2030.¹ A significant interest in less invasive TKA techniques has evolved in recent years.²⁻⁴ Despite growing popularity for minimally invasive TKA surgery, there is no precise definition for this procedure, although methods generally describe shorter skin incisions, less extensive surgical dissection, and avoidance of extensor mechanism eversion.^{5,6} As such, minimally invasive surgery (MIS) for TKA has been touted to achieve rapid recovery and accelerate return to activity.^{4,7-14} In particular, the potential for shorter hospital stay, lower blood loss, and improved pain control are elements that appeal to patients and providers alike.^{4,7-14} Advances in MIS TKA have also been paralleled by a variety of accompanying developments, which also facilitate rapid recovery. These include local peri-operative anesthesia, innovative surgical instrumentation, smaller low profile implants, computer surgical navigation, and progressive mobilization techniques.⁶ Surgeon experience is a key element for success with TKA, as is patient education, hospital pain management strategies, and rehabilitation support.⁶

As many variations in surgical technique and approach have been described for TKA, there have also been a variety of approaches to MIS knee arthroplasty.⁶ Traditional exposures include medial parapatellar, mid-vastus, as well as subvastus techniques. A lateral approach has also been described.¹⁵ Derivations of such approaches have been commonly utilized in multiple MIS techniques described in recent years.⁶ Differences in the order of tissue dissection and bone preparation account for the various methodologies currently employed in MIS techniques. Although the ultimate goal for MIS remains a safer, faster, and more efficient recovery, less attention has been given to the consequences of aggressive local tissue handling as a result of the new technique.^{7,9} Furthermore, in the evaluation of 7 MIS TKA series from 2001 – 2008, outcome measures included flexion, blood loss, pain, alignment, hospital stay, and complication rates.⁶ The lack of functional performance measures in this early body of literature is apparent. Yet, functional performance is an important outcome because a year after TKA, patients still experience a 27% deficit in walking speed and take twice as long with stair climbing as healthy age-matched groups without knee pathology.¹⁶ These functional deficits are largely attributed to quadriceps muscle weakness.⁶

Extensor mechanism weakness is most prominent in the early weeks following TKA¹⁶⁻¹⁸ and is partly attributed to intra-operative hyperflexion of the knee, patellar eversion, and retraction of the tissues.² Variations in cutting length of the arthrotomy have also been observed, and likely play a role in weakness.¹⁹ Such weakness may contribute significantly to postoperative function,^{17,18,20} thus limiting the capacity for rapid recovery. The lack of such reported functional recovery, combined with surgical outcomes in the MIS data in a prospective randomized study, fueled interest for the current investigation. Given the inherent difficulties with assessing implant survivorship on a short term basis, the investigators of the current study examined early surgical, radiographic, and functional performance findings with MIS TKA.

We have previously reported results from a prospective randomized controlled trial comparing MIS and conventional TKA procedures before, 4 and 12 weeks after TKA. The current manuscript expands upon this by including the following important findings: 1) acute (48hrs) surgical and functional performance outcomes, 2) details on post-operative complications, 3) details on radiographic outcomes, and 4) inclusion of additional outcome measures not described in the parent manuscript. Therefore, the aim of the current investigation was to evaluate functional performance, knee pain, knee range of motion (ROM), surgical and radiographic outcomes, along with occurrence of post-operative complications from a randomized, controlled trial comparing MIS and conventional TKA. In particular, both acute, post-operative outcomes (within 48hrs after TKA) and outpatient outcomes (4 and 12wks after TKA) were examined to better evaluate the potential benefits of MIS TKA. The authors hypothesized that better outcomes for functional performance in the MIS TKA group would accompany similarly improved outcomes in post-operative self-report of function, knee pain, passive knee range of motion (PROM), hospital length of stay (LOS), tourniquet time and blood loss. Further, such findings would occur without more complications or implant mal-alignment in the MIS group.

MATERIALS AND METHODS

Design

A randomized, prospective controlled trial was designed to assess the benefits of MIS total knee arthroplasty. Patients were randomized to an MIS or conventional (CONTROL) TKA surgical group. Randomization with concealed allocation included stratification for sex and decade of age. Patients were assessed 1–2 wks before surgery and at 4 and 12 weeks after TKA at the Clinical Translational Research Center at the University of Colorado by blinded evaluators. The study was approved by the Colorado Multiple Institutional Review Board and informed consent was obtained from all participants. Randomization was performed at the time of surgery and employed the use of a randomization table accessed only by the surgeon.

Patients diagnosed in an adult arthroplasty clinic with indications for primary total knee arthroplasty were approached by the surgeon (MRD) after surgery was scheduled between December 2006 and June 2010. Eligible candidates planned to receive a unilateral knee replacement for osteoarthritis (OA), were between 50 and 85 years of age, and met the following inclusion criteria: 1) no significant neurologic impairments, 2) no uncontrolled hypertension, 3) minimal contra-lateral knee OA (as defined by pain less than 5/10 with activity), and 4) no additional symptomatic lower-extremity orthopedic conditions. In addition, all patients met additional criteria for MIS eligibility: 1) minimum of 80° degrees of active knee flexion, 2) no greater than 15° clinical knee varus or valgus, and 3) body mass index $\leq 40 \text{ kg/m}^2$. At the time of recruitment, patients were counseled that skin incisions would not differ between groups, and that post-operative physical therapy would be identical regardless of surgical technique.

Surgical Technique

Both conventional (CONTROL) and MIS TKA approaches were performed through an anterior midline incision using a medial parapatellar approach.¹⁵ Identical skin incision lengths were used for both groups. In the CONTROL group, the arthrotomy incision extended proximally from the level of the distal tibial tubercle to 4–6 cm cephalad to the superior border of the patella. In the MIS group, the arthrotomy extended proximally from the level of the superior tibial tubercle to no more than 1 cm proximal to the superior border of the patella. For both study groups, the surgical technique was conducted in the following order: 1) patellar resurfacing; 2) proximal tibial resection; 3) femoral resection and preparation. Sizing and implant orientation were determined according to gap balancing techniques.²¹ Patella eversion was not used for the MIS group. A suture was used at the proximal end of the quadriceps arthrotomy incision in MIS candidates to prevent unintended propagation of tendon dissection and tissue damage. All TKA procedures performed utilized a posterior stabilized design, allowing resection of the posterior cruciate ligament (PCL). Furthermore, all TKA procedures utilized mobile-bearing, cemented implants using the P.F.C. Sigma Rotating Platform Knee System (DePuy Johnson & Johnson, Warsaw, IN, USA) according to manufacturer's specification. Closure was performed using absorbable suture for capsule, subcutaneous tissue, and skin. Intra-articular drains were placed for 24 hours in all knees, regardless of study group. Importantly, identical skin incision lengths for both groups allowed for patient blinding to surgical group because cosmetically, neither patients nor investigators could discern any differences between groups. Regardless of group, a tourniquet was employed for all TKA procedures. Pre-tourniquet exsanguination was performed with the assistance of gravity.

Rehabilitation

All patients were provided with a standard rehabilitation program following TKA, consisting of a standard set of core exercises as previously described.^{22,23} Inpatient rehabilitation began on postoperative day 1 and continued twice daily for the remainder of the hospital stay. Following hospital discharge, patients were treated at home for 6 visits over 2 weeks and then began outpatient physical therapy (10–12 visits over 6 weeks). Physical therapists reported treatment session details via a flow sheet that was reviewed by the study team to monitor treatment consistency.

Outcomes and Follow-up

Functional Performance Measures—The timed-up-and-go (TUG) and 100 foot walk (100FWT) tests were used to measure functional performance. The TUG test measures the time it takes a patient to rise from an arm chair (seat height of 46 cm), walk 3 m, turn and return to sitting in the same chair without physical assistance.²⁴ The 100FWT measures the time it takes a patient to walk 100ft starting from a standing position. A timed 100ft walk test was chosen because criteria for inpatient hospital discharge following TKA in the United States often includes ambulating at least 100ft.^{25,26} Pain during the 100ft walk test was measured utilizing an 11-point verbal numeric pain rating scale (NPRS). Patients were asked to rate their pain towards the end of the 100ft walk on a scale of 0 to 10 with 0 representing no pain and 10 representing the worst pain imaginable.

Health Status Questionnaire—The Knee Society Score (KSS) was used to evaluate self-assessed knee function.²⁷ The KSS consists of a knee score (pain, stability, range of motion) and a functional score (walking distance, stair climbing). With a maximum of 100 points allotted in each area, the functional score is considered more valid in early to intermediate follow up period, with noted age-related decline. Hence, the knee score component may be more relevant in long term survivorship studies. Values are correlated with success in the following manner: 80–100, Excellent; 70–79, Good; 60–69, Fair; below 60, poor.

Range of Motion—Passive PROM of the knee was measured in supine position using a long-arm goniometer as previously described.²⁸ For passive knee extension, the heel was placed on a 4-inch block while the therapist applied firm pressure to extend the knee. For passive knee flexion, the evaluator flexed the knee as far as possible keeping the heel on the supporting surface.

Additional Peri-operative Data—Intra-operative blood loss was recorded for both groups. While blood loss is well controlled in TKA with the use of tourniquets, variations in these values may reflect the procedure time, extent of dissection and visualization of tissues. Tourniquet time was measured and considered to begin prior to procedure start during elevation and end at tourniquet release preceding wound closure. Additional data recorded in the peri-operative period included resting pain levels (NPRS) at 48hrs after surgery and length of inpatient hospital stay for both study groups.

Radiographs—Routine preoperative and postoperative radiographs consisted of weight-bearing antero-posterior, lateral and patellar views. Post-operative radiographs were obtained at 6 weeks, 3 months, 6 months, 1 year, and yearly thereafter. Pre-operative and 6-week post-operative radiographs included a full length hip to ankle weight bearing anterior-posterior view. Radiographs were analyzed using the Knee Society Roentgenographic Evaluation and Scoring System to evaluate for differences in alignment and well as retained cement, and development of periprosthetic radiolucent lines.²⁹ Investigators performing these measurements were blinded to subject surgical group assignment.

Data Analysis

The primary outcome and endpoint for the randomized controlled trial was difference in quadriceps torque between intervention (MIS) and CONTROL TKA at 4 weeks, which was previously reported. This manuscript focused on additional surgical, radiographic, and functional performance measures. These confirmatory measures were evaluated at 48hrs, 4 weeks, and 12 weeks after surgery with change from baseline regressed on sex and age. Baseline characteristics of the treatment groups were previously compared using two-sample t tests for continuous measures or a chi-square test for independent proportions for categorical measures.²² A two-sided alpha level of 0.05 was designated for statistical significance. SAS version 9.2 (SAS Institute Inc., Cary, NC) was used for all statistical analyses.

RESULTS

One hundred seventy five patients scheduled for TKA at University of Colorado Hospital were assessed for eligibility when they were scheduled for TKA surgery as previously described.²² Forty four patients (22 males, 22 females) ages 50–85 years (64.3 ± 8.4 years) were enrolled. Pre-operatively, there were no differences between groups in sex, age, height, weight, or body mass index (BMI), as previously described.²² Furthermore, there were no significant group differences in any outcome measure at baseline.

There were no significant differences between groups in TUG or 100FWT at 48 h, 4 or 12 wks after TKA (Table 1). There were also no significant differences in KSS Pain or Function scores at 4 or 12 wks after TKA. There were also no differences in knee PROM extension or flexion 48 h, 4 or 12 wks after TKA. Furthermore, knee pain at rest or during the 100FWT was not different between groups at any time point.

Blood loss was 22% greater in the CONTROL group; however, this difference was not significant (Table 2). Neither tourniquet time nor hospital length of stay were significantly different between groups. Although the two patients with only a 2 day length of stay were in the CONTROL group, the vast majority were discharged on post-operative day 3 and differences between groups were not statistically significant.

Surgical Complications

Surgical complications were identified during the intra- or post-operative periods. Complications included a medial condyle avulsion fracture in the CONTROL group treated successfully with activity modification; two superficial suture abscesses in the CONTROL group successfully treated with antibiotics; four wound hematomas (3 CONTROL, 1 MIS), and two cases of deep venous thrombosis, both in the MIS group, treated with oral anticoagulation.

Radiographs

The average post-operative mechanical axis was not different between MIS and CONTROL groups ($p=0.47$) (mean $\pm$ SEM); (MIS: 2.7 ± 0.6 varus; CONTROL: 3.3 ± 0.5 varus). There were 4 patients with greater than 4 degrees of varus alignment in both the CONTROL and MIS groups. Two patients in the CONTROL group had retained cement compared to one in the MIS group. There was one case of femoral notching in each group. Finally, a retained drill bit tip was noted in the femoral condyle of one patient in the CONTROL group.

DISCUSSION

Few previous prospective investigations of MIS TKA have included functional performance outcomes in a comprehensive battery, other than those self-reported through health status questionnaires.^{4,22,30} Yet, performance-based assessments, such as speed on a TUG, have preferred responsiveness compared to changes in self-report questionnaires which are often more closely related to patients' pain relief.^{31,32} Further, previous studies have not blinded both patients and evaluators fully to group assignment by standardizing superficial incision

lengths. Finally, few studies include a standardized post-operative rehabilitation program to further decrease variability in post-operative assessments.

The current study results suggest no convincing advantage for MIS technique in TKA. Our previous report of outcomes from this investigation showed quadriceps and hamstrings strength loss were decreased at 4 wks with the MIS technique.²² Yet, the present findings suggest that attenuation of quadriceps and hamstring strength losses do not translate into better functional performance in the TUG and 100FWT and were not paralleled by improvements in PROM or knee pain. We previously reported that at 12 weeks after TKA, strength gains with MIS surgery were no longer present. Therefore, although the use of MIS surgical techniques for TKA led to faster early recovery of strength in patients undergoing TKA, there was no apparent benefit of MIS on other outcomes, suggesting that the benefits of MIS TKA may not outweigh the risks associated with limited surgical visualization.

Previous advocates have purported MIS would allow for lower blood loss and shorten hospital stay.³³ While there were not differences in length of hospital stay in the present study, there was a pattern for decreased blood loss with MIS surgery (22% less loss), although not significant. Importantly, measurement of intra-operative blood loss with TKA is not considered to be comprehensive because of exsanguination upon tourniquet release and subsequent closure. However, tourniquet is released prior to closure, so this blood loss is usually noted. Hence, the estimated blood loss reported in the current study may have been influenced by this factor. Furthermore, it was somewhat unexpected that tourniquet times would be comparable between groups,³⁴ although a number of variables can influence tourniquet time measures: body mass index, effectiveness of the tourniquet, and external implant factors can all impact tourniquet time and do not reflect anatomic exposure.³⁵ Technical performance of TKA is also a factor in a study of this design. While only one surgeon was involved, this allowed consistency in surgical execution. The surgeon who performed all procedures was trained in minimally invasive TKA techniques and had more than 5 years of experience with MIS total knee arthroplasty prior to initiation of this investigation.

Previous investigations have reported more complications resulting from limited visualization with MIS TKA. The lack of extensive wound and articular joint exposure may result in unintended soft tissue damage, retained methacrylate cement, component or limb mal-alignment, and enhanced unwitnessed blood loss. In the current investigation, complications were confined to the CONTROL group, with the exception of one deep vein thrombosis and one wound hematoma. These results do not strongly implicate the MIS technique as a greater risk for adverse events, yet these findings may be attributed to the experience of the surgeon performing the TKAs.

Component mal-alignment has been shown to significantly affect longevity in total knee arthroplasty, regardless of the technique utilized for implantation.³⁶ Previous studies on MIS TKA have shown an increased incidence of component mal-alignment compared with a conventional TKA approaches.^{37,38} Importantly, the data from the present study suggests that there is not an increased risk for component mal-alignment with a MIS technique. This finding supports the results of the most recent meta-analysis on MIS technique by Smith et

al.³⁰ which indicated that MIS technique did not lead to a greater incidence of component mal-alignment compared to a standard technique. Importantly, surgeon experience with MIS techniques may also contribute to the incidence of mal-alignment.

Supporters of MIS TKA indicate that the technique allows for faster recovery time, greater early post-operative quadriceps strength, shorter hospital stays, less pain, less narcotic usage, less need for assistive devices, better knee flexion during the early post-operative period, and improvements in function.^{4,30} In contrast, others have raised concerns over more complications with limited visualization during the surgery that could impact long-term outcomes (e.g. increased operative time, component mal-alignment, etc.) and the learning curve necessary for successful execution of MIS techniques.

The measures reported herein were not the primary outcomes for the trial, which somewhat limits the interpretation of these findings. Yet, the results of this carefully controlled investigation with blinding, standardized rehabilitation, and objective evaluation of functional performance provide important information that leads to questioning of the benefits of MIS TKA. Future clinical trials with a comprehensive battery of outcome measures should include not only more subjects, but also more than one surgeon to increase generalizability of findings.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Abbreviations

MIS	minimally invasive surgery
TKA	total knee arthroplasty
ROM	knee range of motion
PROM	passive knee range of motion
LOS	length of stay
CONTROL	conventional surgical group
MRD	surgeon
OA	osteoarthritis
PCL	posterior cruciate ligament
TUG	the timed-up-and-go
100FWT	100 foot walk
NPRS	verbal numeric pain rating scale
KSS	Knee Society Score
RCT	randomized controlled trial
BMI	body mass index

DVT

deep venous thrombosis

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Table 1

95% Confidence Intervals for the Primary and Secondary Outcome Measures at 48 hours, 4 and 12wks^a

Variable	Difference in the Change from Baseline (48 hours): MIS - Control (95% CI) ^a		Difference in the Change from Baseline (4 weeks): MIS - Control (95% CI)		Difference in the Change from Baseline (12 weeks): MIS - Control (95% CI)	
		p value		p value		p value
Timed Up and Go (sec)	4.42 (-26.98, 35.81)	0.78	0.10 (-2.83, 3.04)	0.94	-1.03 (-1.92, -0.13)	0.03
100 ft Walk (sec)	9.65 (-58.51, 77.81)	0.77	-1.09 (-10.7, 8.49)	0.82	-1.30 (-4.22, 1.63)	0.37
100 ft Walk Pain (points)	0.04 (-1.55, 1.62)	0.96	-1.41 (-2.74, -0.08)	0.04	-0.31 (-1.30, 0.68)	0.53
Flexion Passive ROM (deg)	5.69 (-2.90, 14.27)	0.19	1.84 (-5.67, 9.34)	0.62	1.18 (-4.67, 7.03)	0.68
Extension Passive ROM (deg)	-1.28 (-4.19, 1.64)	0.38	-0.37 (-3.44, 2.69)	0.81	-1.91 (-5.07, 1.25)	0.23
KSS Pain (points)	NT	NT	-2.19 (-9.50, 5.12)	0.53	-0.49 (-9.12, 8.15)	0.90
KSS Function (points)	NT	NT	4.36 (-8.05, 16.76)	0.47	4.52 (-5.49, 14.52)	0.34
Resting Pain (points)	0.32 (-1.26, 1.90)	0.68	-0.19 (-1.55, 1.16)	0.77	0.15 (-0.81, 1.12)	0.75

NT=not tested; CI=confidence interval, ROM=range of motion, KSS=Knee Society Score

^aValues are +/- standard error of the estimate. Negative values reflect a deficit from baseline; positive values reflect an improvement from baseline. P values are from the estimated between-group difference in change from baseline, conditioned on baseline and controlling for age and sex. The model is change from baseline regressed on baseline and treatment assignment.

Table 2

Tourniquet time, blood loss, and length of stay

Variable	CONTROL Mean $\pm$ SD	MIS Mean $\pm$ SD	Difference -	<i>p</i> value
Tourniquet Time (min)	72.6 $\pm$ 12.2	71.4 $\pm$ 16.3	1.2 $\pm$ 14.5	0.7894
Blood Loss (mL)	126.8 $\pm$ 97.4	98.4 $\pm$ 102.2	28.3 $\pm$ 99.9	0.3631
Inpatient length of stay	2 Days (2)* 3 Days (16) 4 Days (1)	2 Days (0) 3 Days (19) 4 Days (1)		0.4733

*
Parentheses refer to number of patients