

Original Article

Minimally invasive total knee arthroplasty using a cruciate-retaining knee system: A 3–5 year study with comparison to a standard approach

Che-Jen Shih^a, Kuo-Cheng Shih^{b,*}^a Department of Orthopedic Surgery, Taipei General Hospital, Department of Health, Taipei, Taiwan^b Department of Orthopedic Surgery, Miaoli General Hospital, Department of Health, Miaoli, Taiwan

ARTICLE INFO

Article history:

Received 15 September 2011

Received in revised form

31 October 2011

Accepted 17 November 2011

Available online 17 February 2012

Keywords:

midvastus cruciate-retaining knee

minimally invasive surgery

total knee arthroplasty

ABSTRACT

Background/Purpose: Minimally invasive surgery (MIS) for total knee arthroplasty (TKA) is a recent development. Most published studies of the procedure report on early experience, and have emphasized early recovery and good outcomes in the first 3 months to 1 year.

Methods: This retrospective study compared 121 TKA done through a minimally invasive midvastus approach with 50 TKA done using a standard medial parapatellar approach, and assessed the results at a minimum follow-up of 3–5 years. A cemented U2 cruciate-retaining knee (United, Taipei, Taiwan) was used in both patient groups.

Results: The postoperative mean knee score and function score were 95.3 (range, 69–110) and 82.3 (range, 20–100) respectively in the MIS TKA group, compared to 94 (range, 78–100) and 82 (range, 30–100) for the control group (standard approach). The postoperative Knee Society scores did not differ significantly between the two groups. The postoperative mean range of motion was 113.8° (range, 70–145°) in the MIS TKA group compared with 105.1° (range, 40–130°) for the control group, and the difference was significant ($p < 0.05$). There was no difference in postoperative coronal X-ray alignment between the two groups, neither were there any outliers in the component alignment and component size in the MIS TKA group. There were three knees (2%) with anterior femoral notching in the MIS TKA group compared to no knee notching for the control group.

Conclusion: Though the MIS TKA was technically demanding, the outcomes at 3–5 years' follow-up were at least as good as those obtained with the standard medial parapatellar TKA procedure.

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1. Introduction

Minimally invasive surgery (MIS) of the knee was first introduced for unicompartmental knee arthroplasty by Repicci¹ in early 1990s. Minimally invasive total knee arthroplasty (MIS TKA) was first reported by Tria² in 2003. Though there were many different approaches for MIS TKA (such as limited medial parapatellar,^{3–5} mini midvastus,^{6–15} mini subvastus^{13,16–18} and quadriceps sparing^{2,15,19–26}), the key benefits emphasized in all the reports were the small incision wound and reduced trauma to the soft tissues. Thereafter many studies^{2,5,9,10,13–15,17,19,20,23,24,28} showed that the MIS TKA had good early results including less wound pain, short length of stay, less blood loss, early recovery of knee quadriceps function, increased range of motion (ROM) and similar implant alignment accuracy to that achieved with traditional standard total

knee arthroplasty (STKA). However there were also many studies^{6–8,16,21,22,25–28} that reported more soft tissue complications, prolonged operative time and malalignment of implants in MIS TKR, with no benefit after 3 months as compared to STKA. Most of the published studies for MIS TKA reported only early clinical experience and their follow-up times were short (3 months to 1 year). Few reports^{19,21,22} have presented longer term clinical and radiological results allowing comparison with the STKA. The purpose of the present study was to assess the results of MIS TKA at 3–5 years' follow-up, and test our hypothesis that the results of MIS TKA are at least as good as those obtained with STKA at mid-term follow-up.

2. Materials and methods

A retrospective study of a consecutive series of one author's (K.-C.S.) first 121 primary MIS TKAs, in 106 patients, was undertaken between June 2005 and April 2007. This study was approved by the ethical committee of our institution. The inclusion criterion for MIS TKR was osteoarthritis or other end-stage arthritis of the

* Corresponding author. Department of Orthopedic Surgery, Miaoli General Hospital, Department of Health, 747 Wei-Gong Road, Miaoli City, Miaoli County 360, Taiwan. Tel.: +886 37 272745; fax: +886 37 264200.

E-mail address: shihkuocheng@yahoo.com.tw (K.-C. Shih).

knees with an indication for primary TKA. Individuals with severe varus deformity (femoro–tibial angle $>15^\circ$) or who had previously had knee surgery with open arthrotomy were excluded from the study. Patients with a high (greater than 30) body mass index (BMI) or with previous arthroscopy of the knees were not excluded. All the patients had an intact posterior cruciate ligament.

3. Surgical techniques for MIS TKA

In the MIS TKA group, the patient was under spinal or epidural anesthesia, and a tourniquet with 350 mmHg pressure was applied after exsanguinations. An anterior midline skin incision of 8–12 cm was followed by a mini midvastus arthrotomy. Splitting of the medial vastus muscle was limited to 2–4 cm proximally. A medial soft tissue release was done by dissection of the subperiosteal sleeve. After flexing the knee to 90° and lateral subluxation of the patella (not everted), resection of the distal femoral condyle was performed from anterior side. Distal femoral bone was removed, the thickness being equal to that of the femoral component to be inserted. The valgus angle of the distal femoral resection was made using an intramedullary guide, which was set to 7° for women and 5° for men. An appropriate thickness of the proximal tibial bone was resected using an extramedullary guide. The cut surface of the tibia was perpendicular to the anterior border of the tibial shaft in the coronal plane; a posterior slope was set with the tibial extramedullary guide parallel to the fibular shaft in the sagittal plane. The posterior cruciate ligament was preserved. The femoral cutting guide was placed in 3° of external rotation to the posterior condyle; this was ascertained with the help of the epicondylar axis and the Whiteside's line, and the cutting was performed using a posterior referencing system. Then the anterior, posterior and chamfer cuts were done in sequence. Hyperflexion and dislocation of the knee joint was avoided until for tibial preparation and implant insertion. Stability and alignment of the knee joint were assessed using trial implants, and the medial-lateral balancing of the soft tissue was checked in both flexion and extension positions. Patellar resurfacing was done using a patellar drilling jig with the knee in full extension and the patellar fat pad was not removed. A trial implant was used to check the patellar tracking. The tibial component was fully cemented using the cement in a doughy state, and was manually pressed into the bone surfaces. The polyethylene insert was assembled to the tibial tray. The femoral component was also fully cemented and pressed into the bone. The patellar component was fixed with cement, using a patellar clamp to apply pressure. All the above procedures were carried out making use of a 'mobile window' and with smaller modified instruments designed for MIS TKA (Fig. 1) to minimize soft-tissue tension.

A control group was selected, comprising 50 age- and sex-matched arthroplasties carried out between May 2004 and May 2005. All the control procedures were a standard total knee arthroplasty (STKA) carried out through an anterior midline skin incision (length 15–20 cm) and a medial parapatellar arthrotomy using conventional TKA instrumentation.

The same U2 cruciate-retaining prosthesis (United, Taipei, Taiwan) was used in all knees. The femoral component was made of cobalt-chromium alloy and the tibial component of titanium. The tibial insert, made of an ultrahigh molecular weight polyethylene, was a fixed bearing. The patellar component was an all-polyethylene in-set type prosthesis with a single central peg. All operations were performed by a single surgeon (K.-C.S).

After operation, all the patients in both groups received prophylactic antibiotics and a compression dressing for the wound. A drain was used for 24 h. Quadriceps-strengthening exercises were commenced immediately postoperatively and continuous passive movement was started on the first postoperative day. Weight-

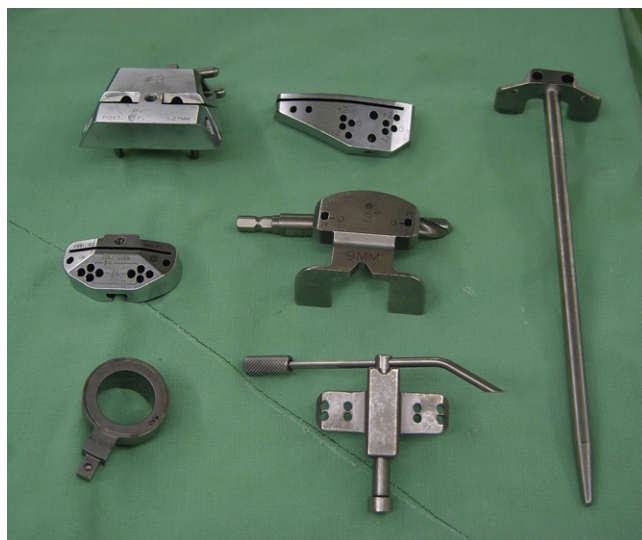


Fig. 1. The specialized and down-sized instruments for minimally invasive surgery total knee arthroplasty (MIS TKA).

bearing was allowed from the second postoperative day, and a walker was used for support in ambulation as needed.

The patients were followed up at 6 weeks, 3 months, 6 months, 1 year and annually thereafter. American Knee Society scores²⁹ (KSS), ROM, postoperative complications and radiological findings were recorded. Operative time and patient demographics including age, sex, diagnosis and BMI were recorded. The radiological films, including weight-bearing anteroposterior, lateral and patellar Merchant views, were reviewed. The anatomic femoro–tibial angle (F–T angle) in the coronal plane, femoral flexion, tibial posterior slope and femoral notching (>2 mm) in the sagittal plane were assessed. The outlier of the component alignment in the coronal plane was defined as 3° degrees or greater outside the ideal alignment (5° valgus for males and 7° valgus for females in the anatomic F–T angle). A component size that was 4 mm too large or too small and femoral notching >2 mm were also defined as outliers.²¹ The presence of radiolucent lines, used in the Knee Society Roentgenographic Evaluation and Scoring System (KSRESS),³⁰ was also recorded.

The two-sample Student *t*-test was used to compare the quantitative variables between the MIS TKA and STKA groups. Categorical data were analyzed using the chi-square test. The prevalence of radiological outliers was analyzed using Fisher's exact test. All analyses were conducted using SPSS 12.0 for Windows (SPSS, Chicago, IL, USA). A *p* value ≤ 0.05 or less was considered statistically significant.

4. Results

4.1. Clinical results

One hundred and seventy-one knees (156 patients) were included in this study. The MIS TKA was performed in 121 knees, and the STKA in 50 knees. In the MIS TKA group, there were 106 unilateral and 15 bilateral procedures, which were performed at least 1 week apart. Two male and 13 female patients received bilateral procedures. In the STKA group, all the knee surgeries were unilateral. There were no significant differences in patients' demographics, preoperative knee ROM, preoperative knee score or function score between the MIS TKA and STKA groups (Table 1).

All the knees were followed for a mean of 3.7 years (range, 3–5 years). The operative time, the postoperative knee score and the postoperative function score were not significantly different

Table 1

Demographic data for 156 patients who underwent minimally invasive surgery total knee arthroplasty (MIS TKA) or standard total knee arthroplasty (STKA).

	MIS TKA	STKA
Parameters		
Knees	121	50
Age	69.9 (55–88)	67.6 (36–80)
Body mass index	27.6 (20–39)	27.7 (21–41)
Sex		
Female	95	45
Male	26	18
Diagnosis		
Osteoarthritis	115	45
Rheumatoid arthritis	5	1
Other	1	1
Preoperative		
Knee score*	19.9 (0–45)	20.9 (0–41)
Function score*	24.4 (0–35)	25.2 (0–50)
Range of motion	106.7° (38–135)	104.5° (32–125)

Data are presented as *n* or mean (range). *p* > 0.05 for all parameters when MIS TKA is compared with STKA. *American Knee Society rating scores.

between the two groups (*p* > 0.05). The postoperative ROM in the MIS TKA group was greater than that in the STKA group, and the difference was significant (*p* < 0.05) (Table 2). In the MIS TKA group, 80 knees (62%) achieved a postoperative range of motion >110°; 25 (50%) did so in the STKA group. There were 29 (24%) knees with a postoperative range of motion greater than 125° in the MIS TKA group, and only four (8%) in the STKA group.

4.2. Radiological results

The preoperative F–T angle and the postoperative F–T angle were not significantly different between the two groups (Table 3). There was no outlier of the component alignment in F–T angle in the MIS TKA group (Fig. 2), and one outlier (2%) in the STKA group. The mean final femoral flexion angle was 2.4° in the STKA group and 1.5° in the MIS TKA group; the difference was clinically negligible. The mean tibial posterior slope was 1.6° in the MIS group and 2.3° in the STKA group; again, the difference was negligible. In the MIS TKA group, radiolucent lines (<2 mm) were noted in seven knees: in the medial tibia (zone 1 and 2) in four (3.3%), in the lateral tibia (zone 3 and 4) in two (1.7%), and in the anterior femur (zone 1) in one (0.8%). In the STKA group, two knees had a radiolucent line in the medial tibia (zone 1 and 2). No change in implant alignment was noted and at follow-up the radiolucent lines had not progressed in either group. Three knees with anterior femoral notching (>2 mm) were observed in the MIS TKA group, but no related femoral supracondylar fracture was noted. There was no knee with a component size outlier in either group.

4.3. Complications

No intraoperative complications (such as fractures or ligament injuries) were noted in either group. In the MIS TKA group, there was one (0.8%) tibial fracture, sustained in a fall, which healed

Table 2

Operative times, knee scores and range of motion at final follow-up.

	MIS TKA	STKA	<i>p</i>
Operative time (min)	74.8	71.5 (48–72)	0.128
Knee score	95.3 (69–100)	94 (78–100)	0.125
Functional score	82.3 (20–100)	82 (30–100)	0.915
Range of motion (°)	113.8 (70–145)	105.1 (40–130)	0.001*

Data are presented as mean (range). **p* < 0.05 for range of motion when MIS TKA compared with STKA. MIS TKA = minimally invasive surgery total knee arthroplasty; STKA = standard total knee arthroplasty.

Table 3

Radiological results.

	MIS TKA	STKA	<i>p</i>
Preoperative			
F–T angle (°)*	3.3 varus (12.3 varus–23.8 valgus)	5.0 varus (16 varus–23 valgus)	0.076
Postoperative			
F–T angle (°)*	6.3 (3–9.3)	6.6 (3.2–11)	0.243
Femoral flexion angle (°)	1.5 (–5.8–5.9)	2.4 (0–6.1)	0.001
Tibial posterior slope (°)	2.3 (0–7.4)	1.6 (0–4.6)	0.010
Femoral notching	3 (2.5%)	0	0.001

Data are presented as mean (range) or *n* (%). *F–T angle = femoro-tibial valgus angle in antero-posterior view; MIS TKA = minimally invasive surgery total knee arthroplasty; STKA = standard total knee arthroplasty.

uneventfully with conservative treatment. One (0.8%) superficial wound infection healed after debridement and antibiotic treatment without sequel. In the STKA group, there was no skin complication. Neither group had cardiopulmonary complications or clinically evident deep vein thrombosis. There was no revision TKA in either group at the final follow-up.

5. Discussion

The MIS TKA was associated with less soft tissue disruption during operation, in which there was a shorter skin incision, no patellar lateral eversion, minimal incision of the quadriceps mechanism and avoidance of tibial dislocation. These factors may explain the rapid functional recovery and improved range of motion in the early recovery period.^{7,9,10,14–16} However many studies have reported that the MIS TKA, as compared to the standard TKA, had no benefit after 3 months,^{5,7,10,22,28} and only in a few studies has there been longer term follow-up.^{19,21} As a result, surgeons have had some concerns about routinely using a MIS technique for TKA. Our study showed good outcomes in the MIS TKA group at 3–5 years' follow-up; it was not our primary aim to focus on the early recovery period after MIS TKA. After an average 3.7 years of follow-up of the knees in our study, neither the knee score and function score nor the percentage of good or excellent results differed significantly between the two groups.

The MIS TKA group had a greater postoperative ROM as compared to the STKA group in this study. The same finding was also reported by Haas⁹ in their 1-year follow-up (125° in MIS TKA vs. 116° in STKA group). And there were more knees with a flexion >125° in MIS TKA group as compared to the STKA (24% vs. 8%). Devers' study³¹ revealed that a high degree of flexion of the knee was associated with fulfillment of expectation, functional ability and improved outcome for the patient after TKA. The increased ROM may be attributable to less tissue disruption and no patellar eversion in MIS TKA.

More local complications, such as skin necrosis and delayed wound healing, have been reported after MIS TKA in some studies,^{27,28} but in the present study we did not find a higher incidence of skin complications. We performed the MIS TKA with careful attention to skin and soft tissue retraction, and through the whole procedure we used the 'mobile window' concept and extended the wound length as necessary to lessen soft tissue stretching. Our operative time was similar in both groups; shorter operative time reduces the wound complication and infection rate.

The main criticisms of MIS TKA have concerned component malalignment on X-ray, especially the femoro-tibial angle in coronal view^{6,21,22} and the medial placement of the tibial component.^{23,26} Ritter³² reported that the postoperative varus alignment of the TKA had inferior long term survival as compared to normal or valgus alignment of the TKA. The medial position of the tibial

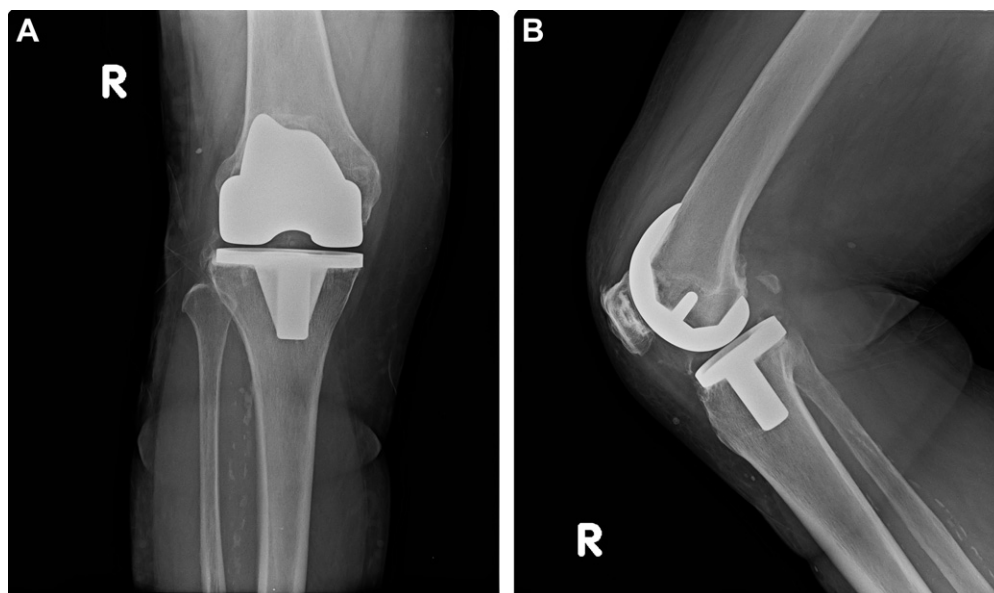


Fig. 2. A 68-year-old woman with osteoarthritis of the knee received minimally invasive surgery total knee arthroplasty (MIS TKA). The joint showed good X-ray alignment in (A) the antero-posterior view and (B) the lateral view 4 years after operation.

component in relation to the anatomic axis affects the measurement of the postoperative mechanical axis in TKA.³³ Dalury⁶ reported that MIS TKA may compromise the component alignment, with four of 30 patients having tibial varus malalignment. Niki²⁶ reported that MIS techniques decreased radiographic accuracy in patients with severe genu varum. Others^{2,8,21,22} reported that use of the side cut led to more outliers in the coronal plane. In our study there was no outlier in component alignment, but exclusion of severely deformed knees may have biased our results. Another reason for our low outliers in the coronal femoro–tibial alignment was that we did not use the side cut for the femoral bone resection,^{8,21,22} as this can decrease the accuracy of alignment. But because of the surgeon's experience and substantial learning curve he was able to maintain a clear operative field, so that component alignment was not impeded. King²⁴ reported that a high-volume surgeon may need to perform 50 procedures to complete the learning curve. This learning curve seems to be too long to be achieved by a low-volume surgeon. Malrotation of the component could be assessed in the present study, as we had only two-dimensional X-ray facilities. The effect of this factor was not clear at follow-up.

More femoral notching was noted in MIS TKA as compared to STKA, but there was no particular analysis. Poor operative visualization may be one of the factors. In this study the three cases of femoral notching all occurred in the first 30 MIS TKAs and they seem to be related to the surgeon's inexperience in the early stage of this study.

In the MIS TKA group 5.8% of knees had a radiolucent line, compared to 4% in the STKA group. These radiolucent lines had not progressed at follow-up. Barrack²⁵ reported a high prevalence of MIS early failure occurring within 24 months; the difference in time to revision was 14.8 months in MIS TKA compared to and 80 months in STKA. In our study we used the same type of knee prosthesis, and we found no difference in the femoro–tibial angle at an average 3.7 years' follow-up in both groups; and we had no revision at follow-up. Therefore we do not think that this MIS TKA technique will alter the long term durability of the prostheses.

Although this study was not of prospective, randomized design, we had a control group matched for sex, age, and BMI. The follow-

up period was not short, and the case number was not small. The operations were performed by a single surgeon at same hospital, so the results can be considered to be reliable. We concluded that though the MIS TKA was technically demanding, the results were at least as good as those achieved with STKA at 3–5-year follow-up. However a prospective, randomized, double blind and long term study is required to warrant the wide use of the MIS technique for TKA.

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