CLINICAL ARTICLE

The Comparison between Mini-Subvastus Approach and Medial Parapatellar Approach in TKA: A Prospective Double-Blinded Randomized Controlled Trial

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Abstract

Objective: Minimal invasive approach has been increasingly used in total knee arthroplasty (TKA) and more is expected of early rehabilitation in terms of pain release and recovery of knee function. The approach type is one of the major factors that determines the early rehabilitation after TKA. The purpose of this study is to determine whether mini-subvastus approach (MSVA) is superior to the traditional medial parapatellar approach (MPA) in TKA.

Methods: From 2018 to 2019, a randomized double-blinded prospective study was conducted on 58 patients who underwent simultaneous bilateral TKA. The subjects included eight men and 50 women, with an average age of 65 years. One side was randomized using MSVA and the other side using MPA. Visual analog scale (VAS), operative duration, recovery time to straight leg raising (SLR), range of motion (ROM), HSS score, release rate of lateral retinaculum, satisfaction rate were recorded and compared. Paired-samples T test were used for quantitative data and chi-square test for qualitative data.

Results: There was no statistical difference in the ratio of left and right sides, preoperative ROM, VAS, HSS score, muscular strength of lower limbs, KL grade, operative order, and operative duration between the two groups. The average ROM (118.91 ± 8.21 vs. 107.60 ± 7.99, $t = 14.320$, $p = 0.0000$) and HSS score (72.03 ± 4.55 vs. 61.22 ± 4.36, $t = 13.095$, $p = 0.0000$) on POD 3, VAS in rest and motion on POD 1 and 3, the recovery time to SLR (1.17 ± 0.38 vs. 3.09 ± 0.76, $t = 19.902$, $p = 0.0000$), and the satisfaction rate on POD 1 (96.55% vs. 74.14%, $\chi^2 = 9.9251$, $p = 0.0016$) were superior in the MSVA group over MPA group. ROM in rest and motion and HSS score on POD 30 had no difference. The release rate of lateral retinaculum was less in the MSVA group than in the MPA group. The mean value of HKA, FFC, and FTC and the proportion of outliers did not differ significantly between the two groups.

Conclusions: Compared with MPA, MSVA can make ROM of knee and SLR recover earlier, reduce postoperative pain after TKA, improve the early postoperative satisfaction and reduce the lateral release rate. MSVA can be used as a favorable measure in the concept of enhanced recovery after surgery (ERAS).

Key words: enhanced recovery after surgery; medial parapatellar approach; mini-subvastus approach; total knee arthroplasty; visual analog scale

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Introduction

Total knee arthroplasty (TKA) has been one of the most effective procedures for treating end stage of knee diseases in terms of osteoarthritis, rheumatoid arthritis, traumatic arthritis, and other problems of the knee[1]. The procedure of TKA has been refined continuously and therefore most patients receive excellent functional improvement, durable relief from pain, and good long-term survival.

With the popularization of the concept of enhanced recovery after surgery (ERAS), rapid rehabilitation after TKA has become one of the focuses that people pay more and more attention to. ERAS can shorten hospitalization duration, shorten rehabilitation time, improve economic benefits and so on[2]. Surgical approach is also one of the factors affecting ERAS after TKA.

Most of the surgeons use medial parapatellar approach (MPA) to perform TKA, and this approach provides satisfactory exposure for us. However, some documents have reported complication associated with this approach. The MPA have been reported to compromise the blood supply of the patella by dividing the peripatellar vascular plexus[3]. This destruction of blood supply might contribute to patellar prosthesis loosening, patellar fracture, and anterior knee pain[4]. There are also other complications associated with this approach such as vastus medialis dehiscence and maltracking of patellar[5]. It has been reported that the medial parapatellar approach destroys the integrity of the knee extension mechanism, which may lead to maltracking of the patellar, and even need surgery again[6].

The mini-subvastus approach (MSVA) is a development of the subvastus technique pioneered by Hoffman *et al.*[7,8]. Currently, the relevant literature reports that this approach is beneficial to protect the knee extension mechanism. Proponents of this approach have reported less postoperative pain, quicker recovery of quadriceps function, and better early ROM[9–11].

The long-term performance of TKA is evaluated using several outcomes including global and disease specific validated tools such as Knee Society Score (KSS), VAS score, implant alignment on radiographs, and ROM. However, short-term outcomes have only been evaluated in a few studies and the difficulty of rehabilitation associated with TKA has been largely overlooked. We usually use VAS score, ROM, recovery time to SLR, HSS score, short-term complication to evaluate the short-term performance of TKA. But short-term patient satisfaction has been barely investigated, especially when use MSVA comparing with MPA. I have found no studies investigating short-term patient satisfaction in the area of TKA using MSVA. Whether the MSVA has advantages over the traditional MPA in the short term after operation is still controversial and the problem whether component alignment has been compromised or not when using the MSVA still needs to be ascertained.

Our hypothesis is that in a properly prospective, comparative study, MSVA can improve early flexion function, reduce postoperative pain, get a high satisfaction rate, and does not increase the risk of complications after TKA when compared with MPA. We believe that MSVA should be a beneficial measure for achieving ERAS. Our aims of this study are to investigate the following questions: (i) Does MSVA have advantages over the traditional MPA in terms of postoperative short-term outcome? (ii) Which specific aspects such as postoperative ROM, VAS, satisfaction rate or clinical score support the advantage if it exists? (iii) Is the component alignment compromised when using the MSVA compared with the traditional MPA?

Materials and Methods

Study Design

This is a prospective double-blinded randomized controlled trial of patients who underwent simultaneous bilateral TKA conducted at the authors' institute (ChiCTR1900021942). One side of knees was subjected to MSVA, and the other side was subjected to MPA. On the basis of our previous experience, a power analysis was conducted to estimate the minimum sample size needed to assess the significant difference between the two groups. The type I error was set at 0.05 ($\alpha < 0.05$) and type II error at 0.2 (80% power). The minimum sample size of 58 subjects (116 knees) would be required. Numbers 1–58 were sorted randomly into groups A and B by computer. Patients in group A underwent MSVA on the left knee and MPA on the right knee. Patients in group B underwent MSVA on the right knee and MPA on the left knee. Each patient was assigned an envelope which contained the group information. The surgeon is blinded to the randomization assignment until operation and the patient, clinical observer, and data analyst are blinded to the randomization assignment.

Clinical Data and Techniques

According to the chronological order of the patient's operation, 58 patients with end-stage osteoarthritis who were to undergo bilateral TKA from May 1, 2018, to May 1, 2019, according to the screening criteria were included into this study. The MSVA was used on one side knee joint of the patient and the MPA was used on the other side.

Inclusion criteria were defined as: (i) patients aged 50–80 years old with no limitation of gender; (ii) the patients were skeletally mature; (iii) end-stage osteoarthritis of bilateral knees in patients who were undergoing bilateral TKA; (iv) the patients were undergoing primary total knee arthroplasty; (v) subjects or guardians were willing and able to sign informed consent before surgery. Exclusion criteria were defined as: (i) patients with neuromuscular insufficiency (e.g. paralysis, myolysis, or myasthenia); (ii) patients were mentally incapacitated or unable to understand the requirements of participating in the study; (ii) patients who have substance abuse problems; (iv) poor compliance was expected; (v) BMI >25; (vi) the patient was known to have a history of allergies to one or more of the implanted materials; (vii) the presence of active infectious lesions in the knee

or other parts of the body; (viii) there was severe osteoporosis, metabolic bone disease, radiation-induced bone disease or tumor around the knee joint; (ix) a pregnant or lactating woman; (x) severe varus deformity of more than 15° or valgus deformity; (xi) previous surgery on knee (e.g. high tibial osteotomy) or severe comorbidity (ASA≥GRADE III). Drop out criteria were defined as: (i) subject withdraws informed consent; (ii) serious violation of clinical trial protocol; (iii) women who became pregnant during clinical trial; (iv) death of Subject; (v) subjects are lost to follow-up.

A total of 58 patients were enrolled, including 50 females and eight males, aged 65 ± 5.11 years, height 160.22 ± 6.61cm, weight 60.66 ± 6.07 kg, and BMI 23.60 ± 1.36. Details are shown in Table 1.

Operative Techniques

Surgical Technique of MSVA

Anterior midline skin incision started from the medial aspect of the superior pole of patella, which is about 10 cm in length. The deep fascia was exposed, and the vastus medialis and quadriceps tendon was strictly preserved without any dissection. We then incised the capsule medial and below to the patella. The inverted L-shaped arthrotomy was performed along the medial border of the patella tendon, then extending proximally along the medial border of the patella up to the inferior vastus medialis obliquus (VMO) border. The proximal arthrotomy was made at about 50° angle relative to the long axis of the lower limb and paralleling to the inferior edge of the VMO muscle (Figure 1). The patellar cut was made at the start of the bone resections to provide improved exposure. To gain adequate exposure, we did a blunt dissection of the VMO off the vastoadductor membrane and divided the medial patellofemoral ligament. We then pulled the patella and extensor mechanism laterally without everting the patella, using the moving window technique to get adequate surgical exposure. Specialized tools for MSVA were used to conduce the osteotomy of femur and tibia and the fixation of the prosthetic components. The osteotomy of proximal tibia was first conducted with 3° of posterior slope. The osteotomy of distal femoral resection was conducted through a medially mounted cutting block specialized for MIS in 5° to 7° valgus referenced to previously measured valgus on long-leg radiograph. Femoral rotation was referenced to trans-epicondylar axis. Posterior reference method was used for femoral sizing and the anterior, posterior, and chamfer cuts. Ligament and soft tissue releases were conducted if required. No-thumb test was conducted to confirm the patellofemoral tracking. Then cement the tibia and femoral component keeping the knee flexed and retracting the patella tendon laterally. Attention was not paid to injuring the patella tendon and lateral femoral condyle because the surgical exposure was constrained (Figure 1).

TABLE 1 Baseline demographics of MSVA group and MPA group

Characteristics	Patients
Age (years)	65 ± 5.11 (50–72)
Weight (kg)	60.66 ± 6.07 (45–75)
Height (cm)	160.22 ± 6.61 (145–178)
BMI (kg/m^2)	23.60 ± 1.36 (18.03–24.98)
Gender female/male	50/8
MSVA group right/left side	31/27
MPA group right/left side	27/31

Abbreviations: MPA, medial parapatellar approach; MSVA, mini-subvastus approach.

Surgical Technique of MPA

In the MPA group, the anterior median skin incision of the knee was taken, which was about 12–15 cm long, extending from the tubercle of the tibia to the 4–7 cm proximal to the superior end of patella. Then, arthrotomy was conducted proximally from the quadriceps tendon incision along the junction between the VMO and the quadriceps tendon. Then, the capsule was incised downward along the medial patella and the medial patellar tendon. The patella eversion was performed to obtain sufficient surgical exposure and TKA was performed with traditional surgical instruments.

Perioperative Protocol

The concept of ERAS was adopted in all patients. In addition to preoperative guidance and education, emphasis was placed on preoperative physiotherapy, preoperative analgesia, and updated fasting guidelines. Importance of preoperative functional exercise was emphasized to enhance muscle strength and increase the ROM of the joint. During the outpatient duration, the patients began 4 weeks of functional training under the guidance of physiotherapists and nurses. In addition, balloon blowing and cough exercises are encouraged to improve lung function. Preemptive analgesia was performed with etoricoxib (30 mg/day) before operation. If patients do not have gastrointestinal motility disorders, they can eat food up to 8 h and eat solid diet of starchy foods up to 6 h before operation and oral transparency liquid up to 2 h before operation. On the night before the operation, diazepam 5 mg was given to ensure the patient's preoperative sleep quality. Preoperative education for patients were conducted by nurses before operation (Table 2).

All operations were performed by a high-volume attending surgeon. General anesthesia is the first choice. All posterior cruciate ligament were resected (Vanguard-Biomet, UK, Ltd), and femoral and tibial prostheses were fixed with cement. Tourniquet were used in all operations before cutting the skin and were released before closure of the incision without drainage. Patients in both groups received patellar replacement, and no thumb test was performed during the operation. If the patellar trajectory was not satisfactory, the lateral retinaculum of the patella was released. Five milligrams of Tropisetron is injected intravenously before anesthesia induction to prevent

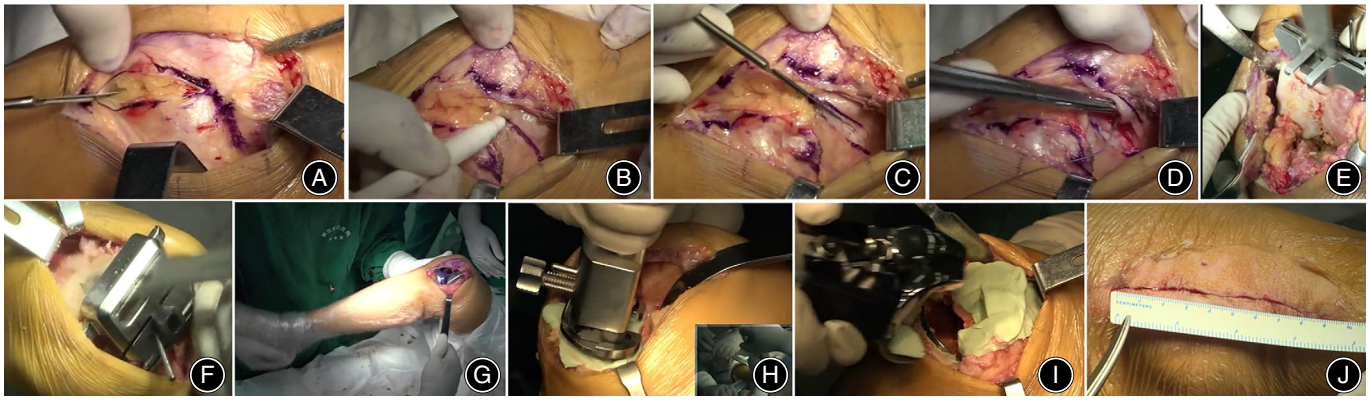

Fig. 1 Surgical technique of MSVA. Photographs showed the MSVA in which the vastus medialis and quadriceps tendon was strictly preserved without any dissection (A), and then the capsule medial and below the patella was incised (B, C). The capsule was marked with suture for later closure of the capsule (D); then, osteotomy of the femur and tibia were performed using moving window technique and component trial were used to test the stability and ROM (E, F, G), and after implantation of component, the length of skin incision was about 9 cm in MSVA group (H, I, J).

postoperative nausea and vomiting. The mean arterial pressure was maintained between 60 and 70 mmHg. Tranexamic acid was used intravenously and intraarticularly. "Cocktail" therapy was used for bilateral knees to relieve the pain around the knee joint. Actively warm up during operation and avoid excessive intravenous infusion during operation (Table 2).

Postoperative multimode analgesia was used. All patients received patient-controlled analgesia (PCA, piperidinamide) for similar pain control during the 2 days after operation. Tramadol sustained-release tablets (100 mg/tablet) were given twice a day with one tablet for each time, and pareoxib sodium were given twice a day for 4 postoperative days. Two hours after returning to the ward, patients were encouraged to start oral intake and conduct early functional exercise as soon as possible. Patients were permitted to start ordinary food on POD 1. After the patient woke up from anesthesia, ankle pump training was performed immediately (200 times a day). Cold compressive dressing was conducted on both knee joints on all patients four times per day for20 min each time for 6 weeks after operation. The isometric contraction of quadriceps femoris and straight leg raising exercises were performed on POD 1. The patients began to walk with the help of assistive tools, to enter the toilet independently, and the knee joints began to bend and straighten. Functional exercises were performed regularly every day in the 3 months after operation. Nadroparin calcium (2050 iu/time, 1 time/night) was used for postoperative prophylaxis of DVT (Table 2).

Postoperative Data Collection

VAS, ROM, Recovery Time to SLR and HSS Score

The outcomes were measured by another experienced orthopaedic surgeon. The statistics was conducted by a data analyst. The level of postoperative pain was measured by VAS scores (0–10). The VAS scores in rest and in motion were evaluated on POD 1, POD 3, and POD 30. Every day after operation, the patient was instructed to raise the straight leg. The recovery to SLR is defined as that patient was able to raise the straight leg by 30° and maintain the lift for 10 s. The recovery time to SLR was recorded and were compared between the two groups. A standardized postoperative ROM measurement was performed on POD 3 and POD 30. HSS score were evaluated preoperatively and on POD 3 and POD 30.

Operative Duration, Postoperative Satisfaction Rate, and the Release Rate of Lateral Retinaculum

The operative duration of the two groups was recorded and the mean value was compared and analyzed. On POD 1, the patients were asked whether they were satisfied with the operation for each side, and the satisfaction rates of the two groups were recorded and statistically analyzed. If the trajectory of the patella is not good after the implantation of the prosthesis during the operation, the lateral retinaculum of the patella will be released, and the release rate of the two groups will be recorded and compared.

Radiographic Outcomes

The alignment of the femoral and tibial component was evaluated using hip–knee–ankle angle (HKA), frontal femoral component angle (FFC) and frontal tibial component angle (FTC) measured on full-length standing radiograph of the lower extremity. The HKA was the angle between the mechanical axis of the femur and the mechanical axis of the tibia measured on full-length standing radiograph of the lower extremity. The FFC was the angle between the mechanical axis of the femur and a line parallel to the distal surface of the femoral component. The FTC was the angle between the mechanical axis of the tibia and a line parallel to the surface of the tibial component. The ideal values of the HKA, FFC, and FTC were 180°, 90°, and 90°. Outliers are defined as measurements that

TABLE 2 The details of the protocol of ERAS

	Protocol	Details
Preoperative	Preoperative exercise protocol	quadriceps exercise (15–20 min/time, 4–5 times per day), knee joint ROM exercise (20 min/time, 4–5 times per day) and ankle pump exercise (300–500 times per day)
	Lung function exercise	balloon blowing and cough exercises are encouraged to improve lung function
	Preoperative fasting protocol	patients can eat solid diet up to 6 h before operation and oral transparency liquid up to 2 h before operation.
	Preemptive analgesia	etoricoxib (30 mg, PO)/within 1 h before operation
	Sleep improvement	On the night before operation, diazepam 5 mg was given PO to ensure the patient's preoperative sleep quality.
Intra-operative	Prevent nausea and vomiting	5 mg Tropisetron is injected intravenously before anesthesia induction to prevent postoperative nausea and vomiting
	anesthesia	General anesthesia is the first choice
	Blood pressure	The mean arterial pressure was maintained between 60 and 70 mmHg
	Tranexamic acid	10 min before skin incision, 1 g tranexamic acid (100ml)/IV, and 1 g/intraarticular before incision closure
	"Cocktail" therapy	tranexamic acid 2 g [200 ml] + ropivacaine [75 mg × 3], compound betamethasone injection [1 ml × 2], pareoxib sodium [40 mg × 2] epinephrine [10 drops]
	Others	Avoid excessive intravenous infusion and actively warm up
Postoperative	Multimodal analgesia	PCA (piperidinamide), for 2 days. Tramadol/PO, 100 mg, twice/day, pareoxib sodium/IV, twice/day for 4 days.
	Early initiation of oral intake	Patients were permitted to drink liquid after returning to the ward and start ordinary food on POD 1
	Cold compressive dressing	4 times per day and 20 min for every time, The temperature were maintained at about 10° centigrade
	Sleep improvement	Diazepam 5 mg/PO, once/night
	Mobilization	Early functional exercise as soon as possible

Abbreviations: ERAS, enhanced recovery after surgery; IV, intravenously; PCA, patient-controlled analgesia; POD, postoperative day.

exceed ideal values by ±3°. The proportion of outliers in the MSVA group and MPA group was calculated respectively. (Figure 2).

Statistical Analysis

The data were analyzed by a data analyst. In order to compare the postoperative VAS, recovery time to SLR, ROM, operative duration, HKA, FFC, and FTC between the two groups, paired *t*-test was used for statistical analysis. The bilateral test value of $p < 0.05$ was considered to be statistically significant. χ^2 test was used in bivariate analysis. The continuous variables in accordance with the normal distribution are expressed as mean ± standard deviation. SPSS statistical software (version 17.0) was used to analyze the data.

Results

Demographic Characteristics

There were 27 cases on the left side of the MSVA group (46.55%) and 31 cases on the left side of the MPA group (53.45%). There was no statistical difference between the two groups ($p = 0.5775$) (Table 1). There were 47 (81.0%) KL (Kellgren-Lawrence) Grade 4 patients in the MSVA group and 48 (82.8%) KL Grade 4 patients in the MPA group, and the rest of the patients were all KL Grade 3. Chi-square test ($p = 1.0000$) showed that there was no statistically significant difference in KL grading between the two groups, and small differences in KL grading had little influence on the results. There were no bone defects in both groups. All patients were firstly operated on the left knee and then the right knee. Since patients were randomly enrolled on the left and right sides, the surgical sequence of the MSVA group and the MPA group was also theoretically random. In fact, there were 27 cases on the left side and 31 cases on the right side in the MSVA group, that is, the proportion of patients who were first to receive operation in the MSVA group was 27/58 (46.6%) while in the MPA group it was 31/58 (53.4%). Chi-square test was performed (p value = 0.5775); consequently, there was no statistical difference between the two groups. Lumbar disease was excluded in all enrolled patients, and muscle strength was measured before surgery. The lower limb muscle strength of all patients was grade 5.

Follow-Up

The VAS scores in rest and in motion were evaluated on POD 1, POD 3, and POD 30. A standardized postoperative ROM measurement was performed on POD 3 and POD 30. HSS score were evaluated preoperatively and on POD 3 and POD 30. On POD 1. The satisfaction rates of the two groups on POD 1 were recorded. The operative duration,

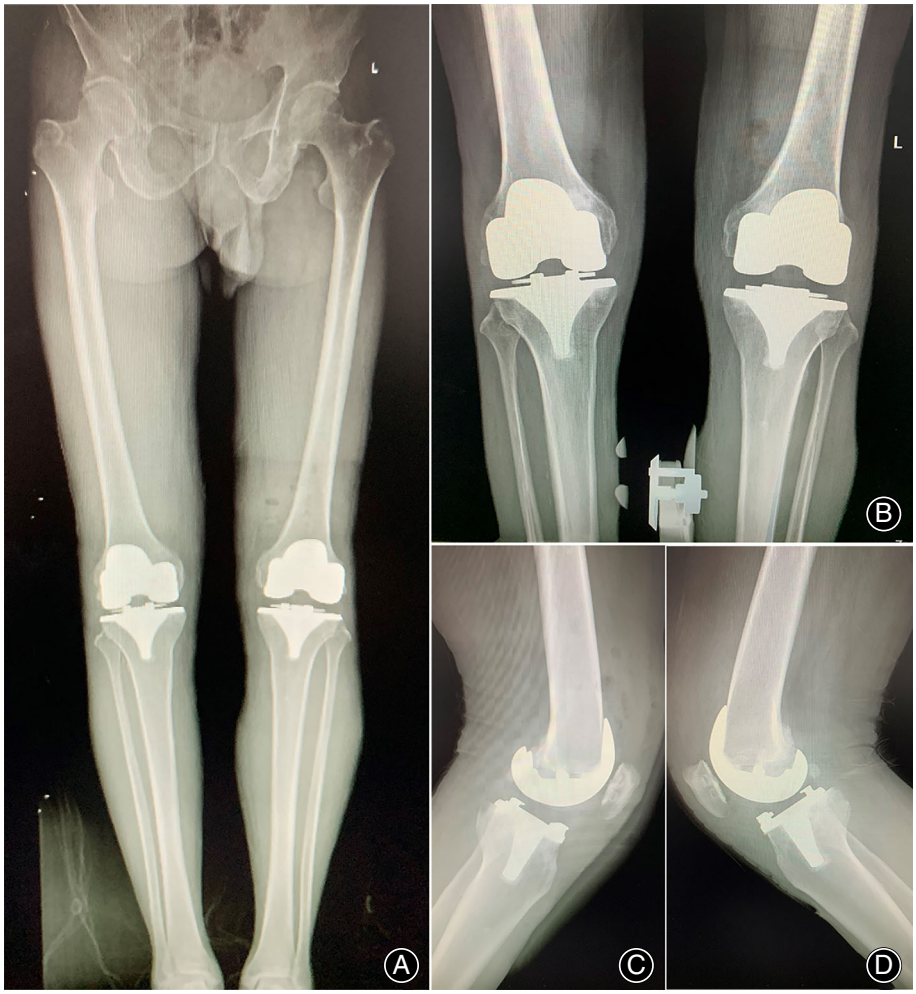

Fig. 2 Postoperative X-ray of the patient. This figure shows postoperative X-ray of the patient with the right knee as the experimental group and the left knee as the control group, including standing full-length lower limb radiographs (A), AP radiographs (B), left knee lateral radiographs (C), and right knee lateral radiographs (D).

the release rate of the lateral retinaculum, recovery time to SLR, HKA, FFC, and FTC were recorded within 1 week after operation. All the detailed data of results can be found in Table 3.

General Results

The operative duration in the MSVA group was 65.55 ± 7.09 min, and that in the MPA group was 63.83 ± 6.09 min. There was no significant difference between the two groups ($p = 0.1221$).

Clinical Improvement

The postoperative recovery time to SLR in the MSVA group was 1.17 ± 0.38 days, and that in the MPA group was 3.09 ± 0.76 days. There was significant difference between the two groups (p = 0.0000) (Table 3). Release rate of lateral retinaculum of patellar in the MSVA group was 10.34% (6/58), and that in the MPA group was 27.59% (16/58). There was significant difference between the two groups ($p = 0.0330$).

Radiographic Improvement

With regard to the radiographic outcomes after operation, the mean HKA, FFC, and FTC did not differ significantly between the two groups ($p > 0.05$), and the proportion of outliers between the two groups was not different either ($p > 0.05$).

Functional Evaluation

The VAS (0 = no pain, 10 = maximum pain) was conducted on the specified preoperative and postoperative day. There was no significant difference in VAS score in motion between the two groups before operation ($p = 0.6159$). On POD 1 and POD 3, the VAS score both in rest and motion in the MSVA group and MPA group had significant difference between the two groups ($p = 0.0000$). On POD 30, the VAS score both in rest ($p = 1$) and motion ($p = 0.4843$) in the MSVA group and MPA group had no significant difference between the two groups.

The average preoperative ROM was similar between the two groups. The preoperative ROM of the MSVA group was 113.10 ± 9.45° and that of the MPA group was 111.98 ± 9.32°. There was no significant difference between

TABLE 3 Comparison of the main outcomes between MSVA group and MPA group

	MSVA group	MPA group	Statistic value	*p* value
Preoperative ROM (degree)	113.10 ± 9.45	111.98 ± 9.32	$t = 1.038$	0.3036
ROM on POD 3 (degree)	118.91 ± 8.21	107.60 ± 7.99	$t = 14.320$	0.0000
ROM on POD 30 (°)	122.76 ± 6.01	122.93 ± 5.12	$t = 0.353$	0.7253
Preoperative VAS in motion	6.62 ± 0.83	6.53 ± 0.90	$t = 0.504$	0.6159
VAS on POD 1 in rest	1.47 ± 0.73	2.38 ± 0.49	$t = 7.247$	0.0000
VAS on POD 1 in motion	3.29 ± 0.88	5.28 ± 0.89	$t = 15.103$	0.0000
VAS on POD 3 in rest	1.19 ± 0.51	1.74 ± 0.44	$t = 5.958$	0.0000
VAS on POD 3 in motion	2.67 ± 0.47	3.83 ± 0.82	$t = 9.836$	0.0000
VAS on POD 30 in rest	0 ± 0	0 ± 0	$t = 0.000$	1
VAS on POD 30 in motion	0.21 ± 0.41	0.24 ± 0.43	$t = 0.704$	0.4843
Recovery time to SLR (days)	1.17 ± 0.38	3.09 ± 0.76	$t = 19.902$	0.0000
Preoperative HSS score	46.91 ± 5.85	48.66 ± 4.89	$t = 1.811$	0.0753
HSS score on POD 3	72.03 ± 4.55	61.22 ± 4.36	$t = 13.095$	0.0000
HSS score on POD 30	82.98 ± 3.45	82.79 ± 3.72	$t = 0.329$	0.7436
Operative duration (min)	65.55 ± 7.09	63.83 ± 6.09	$t = 1.569$	0.1221
Satisfaction rate on POD 1	96.55% (56/58)	74.14% (43/58)	$\chi^2 = 9.9251$	0.0016
Lateral release rate	10.34% (6/58)	27.59% (16/58)	$\chi^2 = 4.5435$	0.0330
HKA	179.047 ± 1.540	179.275 ± 1.594	$t = 0.859$	0.3938
FFC	89.259 ± 1.526	89.479 ± 1.646	$t = 0.989$	0.3268
FTC	89.836 ± 1.537	89.740 ± 1.585	$t = 0.319$	0.7508
HKA outlier	2/58 (3.45%)	2/58 (3.45%)	$\chi^2 = 0.0000$	1
FFC outlier	1/58 (1.72%)	2/58 (3.45%)	$\chi^2 = 0.0000$	1
FTC outlier	1/58 (1.72%)	1/58 (1.72%)	$\chi^2 = 0.0000$	1
Complication rate	1/58 (1.72%)	2/58 (3.45%)	$\chi^2 = 0.0000$	1

Abbreviations: FFC, frontal femoral component angle; FTC, frontal tibial component angle; HKA, hip-knee-ankle angle; HSS, hospital of special surgery; MPA, medial parapatellar approach; MSVA, mini-subvastus approach; POD, postoperative day; ROM, range of motion; SLR, straight leg raising; VAS, visual analog scale.

the two groups ($p = 0.3036$). The ROM on POD 3 was 118.91 ± 8.21° in the MSVA group and 107.60 ± 7.99° in the MPA group. There was significant difference between the two groups ($p = 0.0000$). The ROM on POD 30 was 122.76 ± 6.01° in the MSVA group and 122.93 ± 5.12° in the MPA group. There was no significant difference between the two groups ($p = 0.7253$).

The number of patients who were satisfied in the MSVA group on POD 1 was 56, and the number of patients who were not satisfied in the MSVA group was two. The satisfaction rate in the MSVA group was 96.55%. The number of patients who were satisfied in the MPA group on POD 1 was 43, and the number of patients who were not satisfied in the MPA group was 15. The satisfaction rate in the MPA group was 74.14%. There was significant difference between the two groups ($p = 0.0016$).

There was no significant difference in HSS score between the two groups before operation ($p = 0.0753$). On POD 3, the HSS in the MSVA group and MPA group had significant difference ($p = 0.0000$). On POD 30, the HSS in the MSVA group and MPA group had no significant difference ($p = 0.7436$).

Complications

In the MSVA group, there was a superficial wound exudation, which stopped after 3 days of local compression dressing and the complication rate was 1.72%. In the MPA group, there were two cases with superficial wound exudation, and the wound exudation stopped in 3 and 4 days after local compression dressing, respectively, and the complication rate was 3.45%. There was no significant difference between the two groups ($p = 1$).

Discussion

In this study, we have found the MSVA group has an advantage over conventional MPA group in terms of ROM, HSS score, VAS, satisfaction rate, and the recovery time to SLR within 7 days after operation. However, the above outcomes showed no statistical difference on POD 30 between the two groups. The alignment of the component did not differ significantly between the two groups.

Disadvantages of MPA

TKA is a widely performed, mature, and effective orthopaedic surgery, which is often used to correct knee joint deformity, remove knee joint pain, and restore knee joint function[12–14]. The standard approach for TKA is the MPA. Standard MPA separates the medial vastus muscle from the patella through the quadriceps tendon. Because it is simple and can provide excellent joint exposure, it is widely used[9,15]. However, this approach will cause the quadriceps tendon to break at its medial 1/3 and may lead to reduced blood supply of the patella, loss of extensor strength and imbalance[16,17] of the medial extensor mechanism and the rupture of the

articular branches of the descending genicular artery, the medial superior genicular artery, and the medial inferior genicular artery[18]. Scuderi *et al.* reported that 56% of patients showed "cold patella" on tritium scans when the MPA and the lateral retinaculum release were simultaneously used. The ratio was 15% when MPA was performed without lateral release[3].

Advantages of MSVA

In addition to the MPA, the other common approach for minimal invasive TKA is MSVA. Many investigations showed that the function of quadriceps femoris recovered faster and had less pain after TKA[9]. MSVA is an alternative approach to MPA developed in the early 1990s[8]. It is reported that the advantages of MSVA include better control of quadriceps femoris[19–21], earlier functional recovery[21], less anterior knee pain[19,21], less blood loss[19], and better clinical score for knee joint[21,22].

Better Control of Quadriceps Femoris

A number of studies have shown that the MSVA can make the function of the quadriceps femoris recover faster in the early stage after operation. Many surgeons use MSVA to achieve faster recovery of quadriceps function after TKA[19–21]. Postoperative knee function is the most concerning issue for surgeons and patients when the efficacy of TKA is evaluated. The difference in functional results between MSVA and MPA is due to the rupture of quadriceps tendon in MPA. Therefore, we think that postoperative knee extension function, including recovery time to SLR, is a better and more comprehensive index to reflect the functional difference between MSVA and MPA. Therefore, on this basis, we regard it as the main outcome of this analysis. The results show that compared with MPA, MSVA shortens the days of recovery to SLR. In a blind prospective study, Boerger *et al.*[19] performed primary TKA *via* either MSVA or MPA and they found that it was better to use the MSVA for the recovery time to SLR early after operation. In two other randomized controlled studies, the MSVA also had advantage over the MPA during early rehabilitation with regard to the recovery time to SLR[20,21]. The above studies are consistent with our investigation. The knee extensor mechanism has no compromise in MSVA group, so that the function of the quadriceps femoris can recover more quickly.

Less Anterior Knee Pain

A number of studies have shown that MSVA can reduce early *postoperative pain*. Postoperative pain plays an important role in functional recovery, and it is also a concern of surgeons. In previous studies, MSVA was associated with less postoperative pain[19,21]. Many surgeons use the MSVA described by Hoffman *et al.*[7,8] to achieve less pain after TKA. A meta-analysis[9] about approaches for TKA included 52 articles involving 4533 patients. The results showed that the MSV approach demonstrated the lowest VAS pain score compared with mini-medial parapatellar, mini-midvastus, and quadriceps sparing approaches in short-term follow-up. The study reported by Varela-Egocheaga[23] showed that fewer patients of the MSVA group needed opioids for pain control in the first 24 h and the first 48 h after operation. The above studies are consistent with our investigation. And in our investigation, 1 month after the operation, the participants recovered almost completely, so the difference of VAS pain score between MSVA and MPA had disappeared.

Earlier Functional Recovery

Several previous investigations[19–23] showed that in short-term after TKA, MSVA had a better ROM than MPA. In order to further analyze the postoperative knee joint function, the meta-analysis reported by Filippo[9] was conducted to analyze the knee flexion data after operation. The results showed that MSVA could significantly improve the knee flexion function in the short-term after operation. Proper patellar trajectory is very important for rehabilitation after TKA. In theory, MSVA may produce a better patellar trajectory because this method does not destroy the quadriceps tendon that maintains the patella in its original position.

Complications

There are few reports about complications related to MSVA. Boerger *et al.*[19] reported a patellar ligament rupture and a lateral femoral condylar fracture. In his study, all patients including those with complications had good clinical results. No differences were found in surgical time between MSVA and MPA groups in the study conducted by Varela-Egocheaga *et al.*[23]. In our study, no differences were found in operative duration between the two groups. In contrast to the above studies, in the study reported by Boerger *et al.*[19], reduced access and visibility led by MSVA prolonged the tourniquet time by an average of 15 min which prolonged the operative duration of patients in the MSVA group. Julien *et al.*[24] compared the MSVA to the MPA in 40 patients who underwent TKA. They found no difference in the KSS, SF-12, patient milestone diary of activities such as "discontinue walker, Walk a six-block distance, take care for normal daily activity" and so on 2 months after operation. Isometric quadriceps strength and 3-D gait parameters showed no difference between the two groups. Except for the fracture and the prolonged operative duration caused by MSVA, this approach was also reported to have another disadvantage. Some of the documents reported that the exposure of the SVA is not satisfactory, which might compromise the alignment of the component[25,26].

Matters That Need Attention

MSVA has no compromise to the medial vastus muscle and has the advantage to protect vessels and nerves of medial vastus muscle from injury. In contrast, we need to pay attention not to compromise the vessels and nerves of the medial vastus muscle when we are using midvastus approach. Cooper *et al.*[27] reported that the average distance between patella and popliteal artery was 8.3 ± 1.4 cm in female and 9.5 ± 1.2 cm in male patients. They describe the anatomical variables (vessels/nerves) of the medial femoral

neurovascular bundle and recommend that the midvastus should be done in a safe range to protect neurovascular. The authors suggest that sharp separation be performed within 4 cm from the edge of the patella and blunt separation of muscle if more exposure is required. The MSVA is much safer than midvastus approach with regard to this point.

Contribution of the MSVA to ERAS

The concept of ERAS is widely accepted in the field of TKA. The goal of this concept is to pursue faster, better, and painless recovery of knee joint function after operation. Some perioperative measures in line with this concept have been widely used, including multi-mode analgesia, minimally invasive surgery, application of tranexamic acid, advanced intestinal management and perioperative diet management, early knee joint functional exercise, advanced blood management concepts and measures, patient education, etc.[28–31]. The MSVA can restore the function of the knee joint earlier after operation, and the pain is less with few complications, which is greatly in line with the concept of ERAS. Therefore, we believe that this approach could become a favorable measure of the concept of ERAS.

Limitations

There are some limitations to this study. Due to the limited samples, it is difficult to avoid some bias, such as the order of surgery, KL grading, etc. Although the order of operation on the left and right sides was random and there was no statistical difference between the MSVA group and the MPA group, physical strength of the surgeon would affect the second side operation, which would lead to a small bias. Although the KL grading difference between the MSVA group and the MPA group is small, there are still differences of KL grade between the two groups and a small bias in the results was inevitable. However, the limitations have been controlled to an acceptable degree because this study was a RCT comparative study, and the results of this experiment can reflect the real clinical situation to a great extent.

Conclusion

Patients in MSVA group had faster recovery than those in conventional MPA group in terms of functional improvement, pain relief, and satisfaction rate in the short term after operation. However, the above outcomes showed no difference in long-term follow-up between the two groups. The alignment of the component had not been compromised. MSVA can be used as a favorable measure in the concept of ERAS. More centers and larger amounts of patients need to be investigated to confirm both short-term and long-term effects of MSVA on patients received TKA.

Author Contributions

Ming Ni and Peng Ren designed research; Lei Geng, Guo-qiang Zhang, and Yiming Wang performed research; Jun Fu, Quan-bo Ji, and Peng Xin analyzed data; Lei Geng, Guo-qiang Zhang, and Qing-yuan Zheng wrote the paper. No potential conflict of interest was reported by the authors. I would particularly like to acknowledge all of the authors for their wonderful collaboration. There is no funding for this study.

Ethics statement

The clinical investigation was approved by the Ethics Committee of this hospital (S2015-034-01).

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