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Research Article

MAKO Robot-Assisted Total Knee Arthroplasty: The Impact of Adjusting Femoral Component Rotation to Reconstruct the Trochlear Groove on Patients' Functional Activities: A Prospective Randomized Controlled Study

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ABSTRACT

Purpose: This study aimed to assess the impact of MAKO robot-assisted total knee arthroplasty on restoring patients' physiological trochlear groove and evaluating its influence on joint function.

Method: This study included patients who underwent primary unilateral total knee arthroplasty using MAKO robot. Patients were randomly assigned to the trochlear groove reconstruction group (TG reconstruction group) (n=95) and the control group (n=96). In the TG reconstruction group, the rotational angle of the femoral component was adjusted to restore the patient's original trochlear groove morphology, while the control group received conventional preoperative planning (TEA=0°). Outcome measures included patellofemoral index, patellar tilt angle, advanced activities, knee range of motion (ROM), knee society score (KSS), Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), the medical outcomes study 36-item short-form health survey (SF-36), five times sit-to-stand test (5xSST), and occurrence of adverse events. Follow-up assessments were conducted at 2 weeks, 6 weeks, 3 months, 6 months, and 1 year postoperatively.

Result: There were significant statistical differences in preoperative TEA planning between the two groups (1.42±1.89 vs 0° p=0.00). Postoperatively, the TG reconstruction group showed better patellofemoral index (1.28±0.58 vs 1.72±0.78, p=0.040) and patellar tilt angle (2.82±2.32 vs 9.40±7.30, p=0.040) compared to the control group. At 1 year postoperatively, the TG reconstruction group exhibited superior KSS (86.03±10.35 vs 81.09±10.74, p=0.006) and WOMAC (6.50±6.64 vs 10.52±10.23, p=0.014) compared to the control group. Additionally, at 1 year postoperatively, the TG reconstruction group performed better than the control group in terms of knee ROM (126.43±9.94 vs 120.75±11.63 p=0.006), 5xSST (14.24±4.78 vs 16.88±5.88 p=0.026), carrying a shopping bag for a block (75% vs 57% p=0.032), and squatting (42% vs 22% p=0.002). There was no significant difference between the two groups in terms of SF-36 scores. There were no significant differences in the occurrence of adverse events between the two groups.

Conclusion: MAKO robot-assisted total knee arthroplasty, which adjusts the rotational alignment of the femoral component to restore the patient's physiological trochlear groove morphology, can enhance joint function in patients. This underscores the importance of personalized preoperative planning in MAKO robot-assisted total knee arthroplasty.

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1. Introduction

Research indicates that the complication rate of total knee arthroplasty (TKA) can be as high as 12% [1-4]. This includes chronic pain, prosthesis wear, malalignment, and patellar tracking abnormalities [1, 4-8]. Among these, patellofemoral complications are a major reason for revision surgery. Most patellofemoral complications are reported to be related to abnormal patellar tracking [9]. Changes in patellar tracking may lead to increased polyethylene wear, aseptic loosening, and patellar instability. Literature suggests that femoral component malposition is a significant cause of abnormal patellar tracking [10-12]. This is because improper rotation of the femoral component can result in patellar maltracking, leading to abnormal stress on the patella [13-16]. This can significantly impact the functionality of the patient's knee joint function and even lead to revision surgery.

Currently, the typical placement of the femoral component in total knee arthroplasty (TKA) uses the transepicondylar axis as the rotational axis of the knee joint. However, determining the knee joint rotational axis during surgery remains challenging [17]. Auxiliary methods such as whiteside's line and posterior condylar axis also have inherent errors in determining the knee joint rotational axis [18, 19]. Additionally, there are also some controversies in the placement of the femoral component: Fuchs [20] and Woiczinski *et al.* [16] suggested placing the femoral component in the medial or externally rotated position. Steinbrück *et al.* [10], suggested placing the femoral component 3°-6° externally rotated relative to the transepicondylar axis (TEA) while maintaining soft tissue balance. Due to individual anatomical variations, personalized surgical planning may offer a better solution [21, 22].

In recent years, the introduction of robotic-assisted surgery has provided new prospects for total knee arthroplasty. Particularly in surgical planning and precision, robotic-assisted TKA has shown significant advantages [23, 24]. Through robotic assistance, precise preoperative planning can be implemented, and adjustments to the rotational angle of the prosthesis can be made accurately.

Therefore, this study aims to adjust the rotation angle of the femoral component, determine the rotational axis of the knee joint, restore the patient's physiological trochlear groove morphology, and adapt to the patellar morphology. Additionally, it aims to evaluate the impact of these adjustments on knee joint function, aiming to provide more precise guidance and references for total knee arthroplasty.

2. Methods

2.1. Data Collection

This study was approved by the Ethics Review Committee of the Chinese People's Liberation Army Medical College, with the approval number of S2021-094-01. Patients undergoing MAKO robot-assisted total knee arthroplasty at the First Medical Center of the Chinese PLA General Hospital from January 2022 to March 2023 were consecutively enrolled. Inclusion criteria were as follows: patients aged 18 years or older undergoing primary unilateral total knee arthroplasty due to osteoarthritis. Exclusion criteria included: i) history of knee surgery or traumatic osteoarthritis within the past 3 months. ii) Patients unwilling to participate in the study. iii) Patients planning or having undergone contralateral knee surgery within 90 days. iv) Patients with severe patellofemoral arthritis (Grades III-IV). v) Patients with trochlea dysplasia.

Baseline data collected included: age, gender, BMI, comorbidities, surgery time, knee range of motion (ROM), knee society score (KSS), Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), The medical outcomes study 36-item short-form health survey (SF-36) and five times sit-to-stand test (5xSST). Postoperatively, patellofemoral index and patellar tilt angles were measured. Follow up with patients at 2 weeks, 6 weeks, 3 months, 6 months, and 1 year postoperatively. Follow-up assessments included: WOMAC, KSS, SF-36, knee joint ROM, and 5xSST. Functional outcomes related to squatting and advanced activities at 1 year postoperatively were evaluated using specific questions from the KSS score. Patients scoring 4 or 5 points were defined as capable of squatting, while those scoring below 4 points were defined as unable to squat. Similar analytical methods were applied to other questions. Postoperative complications and adverse events were recorded during follow-up.

2.2. Surgical Technique

Patients were randomly assigned to either the control or trochlear groove reconstruction group (TG reconstruction group). All patients underwent a medial parapatellar approach. The Mako TKA system (Stryker, Mahwah, NJ) was used in this study. This is a CT-based tactile platform that assists surgeons in precise bone resection and provides real-time feedback during ligament balancing [25]. Preoperatively, CT scans were performed to create a 3D model of the knee joint based on which surgical planning was conducted by surgeons.

2.3. Trochlear Groove Reconstruction Group (TG Reconstruction Group)

Patients in the TG reconstruction group underwent preoperative planning using the Mako surgical system. Preoperative planning was standardized and performed by one physician (ZGQ). During preoperative planning, adjustments were made to the rotation angle of the femoral component to ensure as close a restoration of the native trochlear morphology as possible on axial plane sections: specifically, to align the femoral component's trochlear groove “parallel” to the patient's native groove, aiming for optimal patellofemoral alignment. “parallel” was defined as an angle difference of less than 3 degrees between the trochlear groove of the knee prosthesis and the native knee, with equal medial and lateral spacing wherever feasible (Figure 1).

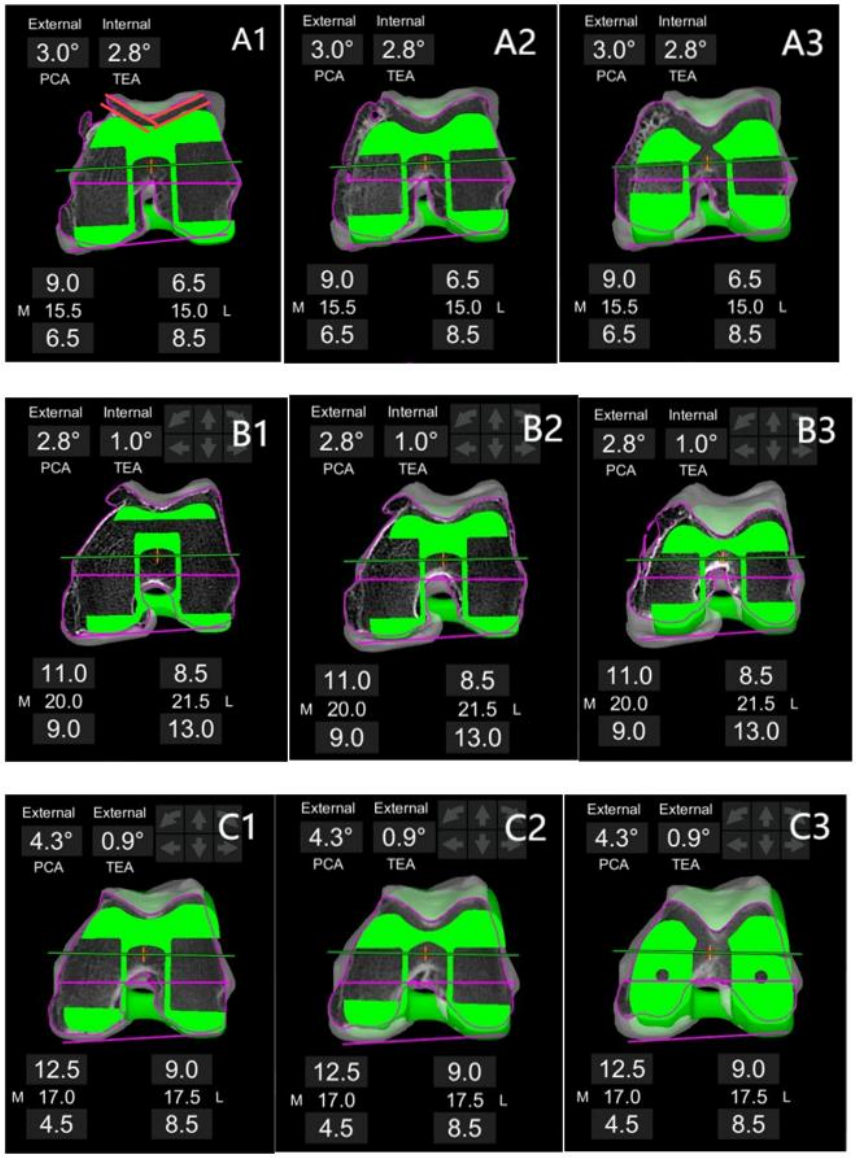

Fig. 1. A1-A3) Preoperative planning of Patient 1, as shown in A1, where the upper edge of the prosthesis is parallel to and equidistant from the patient's native trochlear groove. **B1-B3)** Preoperative planning of Patient 2. **C1-C3)** Preoperative planning of Patient 3.

2.4. Control Group

The control group followed an initial plan with a femoral component TEA angle of 0° and employed a standardized bone resection method during preoperative planning. All patients were assessed during follow-up evaluations by the same physician who was blinded to the group assignments. Both groups of patients underwent postoperative rehabilitation using a home-based recovery manual. Outpatient follow-up and guidance were conducted at 2 weeks, 6 weeks, 3 months, 6 months, and 1 year postoperatively. Based on our preliminary results, the squatting rate was 35% in the experimental group compared to 17% in the control group [26]. Therefore, each group requires 90 patients to meet statistical requirements.

2.5. Statistical Methods

Data normality was assessed using the Shapiro-Wilk test. Variables that met the criteria for normal distribution (e.g., KSS, WOMAC, SF-36 scores) are presented as mean ± standard deviation (SD) and were compared using independent t-tests. Non-normally distributed variables are presented as median with interquartile range, and group comparisons were made using the chi-square test. A significant level of $P \leq 0.05$ was considered statistically significant. Patients with missing data at two or more follow-up visits were considered invalid and were excluded from the study. All data were analyzed using SPSS version 26.0 (IBM, Armonk, NY, USA).

3. Results

A total of 244 patients who underwent MAKO total knee arthroplasty at the First Medical Center of the PLA General Hospital from January 2022 to March 2023 were included in the study. 24 patients were excluded due to severe patellofemoral arthritis, 5 patients were excluded due to traumatic osteoarthritis, and 20 patients were excluded due to patellar dysplasia. There were 97 patients in the TG reconstruction group and 98 patients in the control group. One patient in the TG reconstruction group withdrew from the study due to early postoperative periprosthetic joint infection. One patient from the TG reconstruction group and two patients from the control group were lost to follow-up. A total of 95 patients in the TG reconstruction group and 96 patients in the control group were included in the analysis (Figure 2). There were no significant differences between the two groups in terms of age, gender, surgical time, preoperative KSS, WOMAC, SF-36, and time for 5xSST. There were no statistically significant differences between the two groups in terms of femoral component flexion and tibial component slope (Table 1).

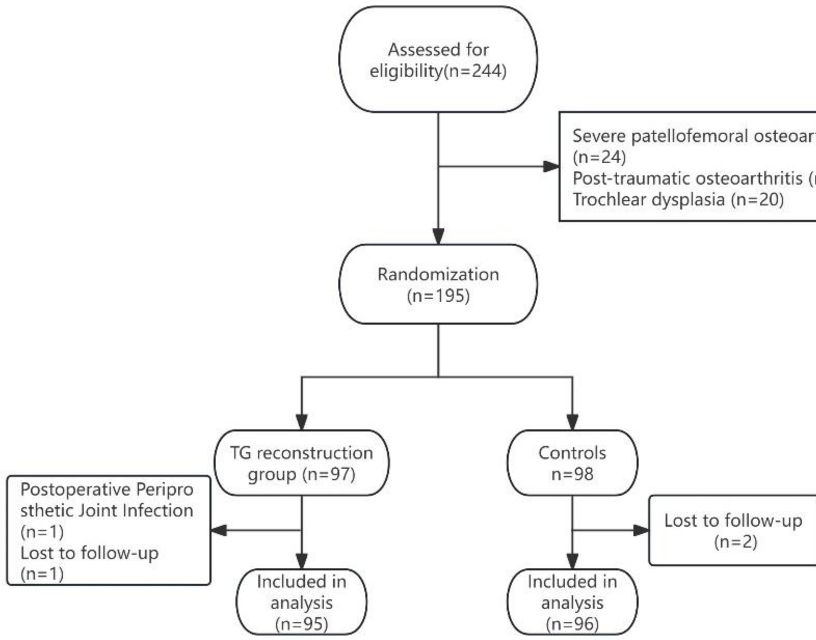

Fig. 2. Enrollment, randomization, and follow-up of the study patients. TG reconstruction group: Trochlear groove reconstruction group.

Table 1. Comparison of preoperative baseline characteristics between the TG reconstruction group and the control group.

	TG reconstruction group	Control group	*P* Value
Mean age	65.30±6.37	66.02±8.76	0.572
BMI	26.94±2.72	26.83±3.10	0.821
Surgical duration	68.37±19.36	66.51±19.00	0.665
Proportion of women	77%	82%	0.166
Comorbidities			
COPD	5%	6%	0.770
Coronary heart disease	32%	35%	0.688
Diabetes	25%	27%	0.813
Hypertension	37%	44%	0.368
Other	12%	14%	0.632
TEA	1.42±1.89	0±0	0.000
PCA	3.95±1.76	2.32±2.03	0.000
Femoral prosthesis(flexion)	3.26±1.74	3.22±1.82	0.895
Tibial prosthesis (slope)	2.61±1.34	2.52±1.59	0.650
Range of motion (flexion)	108.59±18.20	105.12±13.97	0.226
KSS	41.78±15.11	39.73±13.58	0.244
5xSST	20.28±10.36	18.38±15.46	0.569
WOMAC			
Total score	42.39±11.87	45.87±11.83	0.243
Pain	9.94±3.07	10.89±2.72	0.248
Stiffness	2.89±2.47	3.29±1.69	0.480

Physical function	29.54±8.74	30.89±10.02	0.530
SF-36			
Physical functioning	35.33±13.94	28.97±15.52	0.172
Role-physical	18.33±20.84	24.36±42.33	0.341
Bodily pain	30.67±10.56	36.59±14.77	0.163
General health	56.00±18.57	61.95±22.15	0.319
Vitality	61.00±17.94	60.00±26.38	0.893
Social functioning	45.00±20.48	54.48±18.69	0.110
Role-emotional	27.76±37.76	29.88±40.99	0.297
Mental health	77.6±22.81	73.85±27.60	0.628
Health transition	63.33±20.91	63.46±24.89	0.985

TG reconstruction group: Trochlear groove reconstruction group; BMI: Body Mass Index; COPD: Chronic Obstructive Pulmonary Disease; WOMAC: The Western Ontario and Mcmaster Universities Osteoarthritis Index; KSS: Keen Society Score; SF-36: The Short Form-36 Questionnaire; 5xSST: Five Times Sit-to-Stand Test.

In the TG reconstruction group, the mean external rotation of the femoral component relative to the TEA was 1.42°±1.89°, compared to 0° in the control group. The mean external rotation of the PCA in the TG reconstruction group was 3.95° ± 1.76°, while in the control group it was 2.32° ± 2.03°. There were statistically significant differences between the two groups (p=0.000 for both comparisons) (Figures 3 & 4). The TG reconstruction group had a better patellofemoral index (1.28±0.58 vs 1.72±0.78, p=0.040) and patellar inclination angle (2.82°±2.32° vs 9.40°±7.30°) compared to the control group (Figure 5). At 1 year postoperatively, the squatting rate was 43% in the TG reconstruction group and 22% in the control group, with a statistically significant difference (p=0.002); The TG reconstruction group also performed better in "Carrying a shopping bag for a block" (75% vs 57%, p=0.032). "Climbing a ladder or step stool" showed nearly statistically significant differences between the TG reconstruction and control groups (41% vs 32%, p=0.067). At 1 year postoperatively, the TG reconstruction group showed better knee ROM (126.43° ± 9.94° vs 120.75° ± 11.63°, p=0.006) and time to 5xSST (14.24 ± 4.78 vs 16.88 ± 5.88 seconds, p=0.026) compared to the control group (Table 2) (Figures 6 & 7).

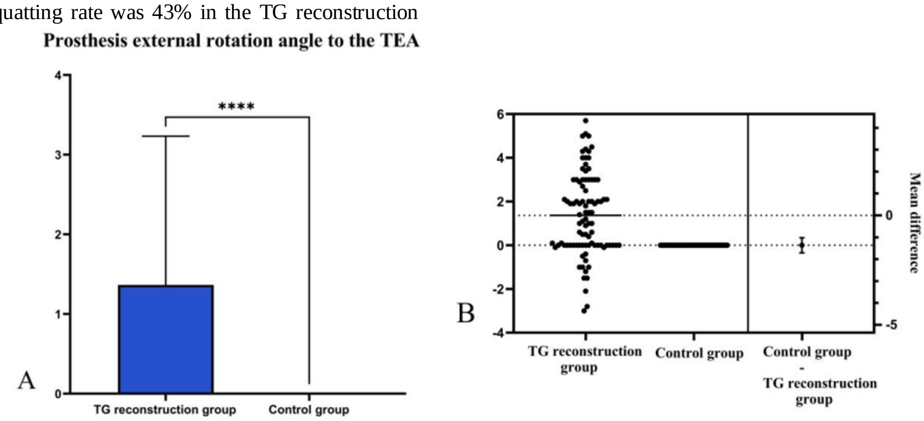

Fig. 3. A) Comparison of prosthesis external rotation angle relative to the TEA between the two groups. **B)** Distribution of TEA external rotation angles in the two groups.

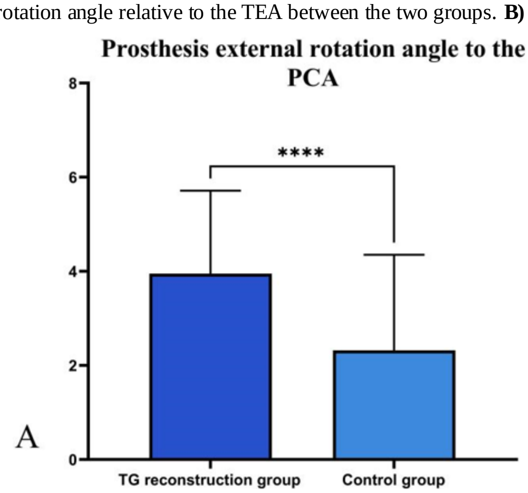

Fig. 4. Comparison of prosthesis external rotation angle relative to the PCA between the two groups.

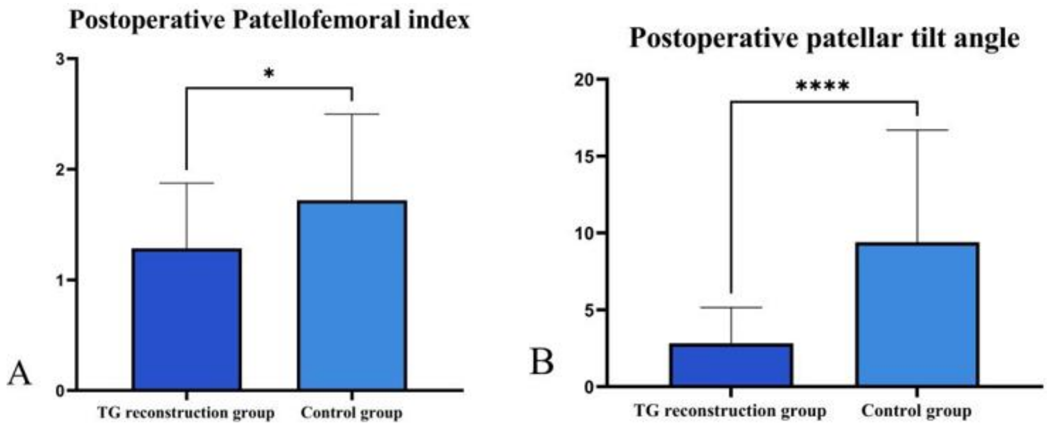

Fig. 5. A) Comparison of postoperative patellofemoral index between the experimental and control groups. **B)** Comparison of postoperative patellar tilt angle between the experimental and control groups.

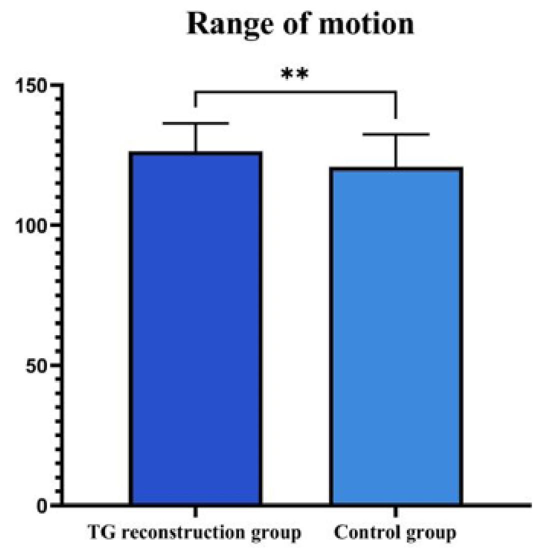

Fig. 6. Comparison of knee joint range of motion between two groups at 1 year postoperatively.

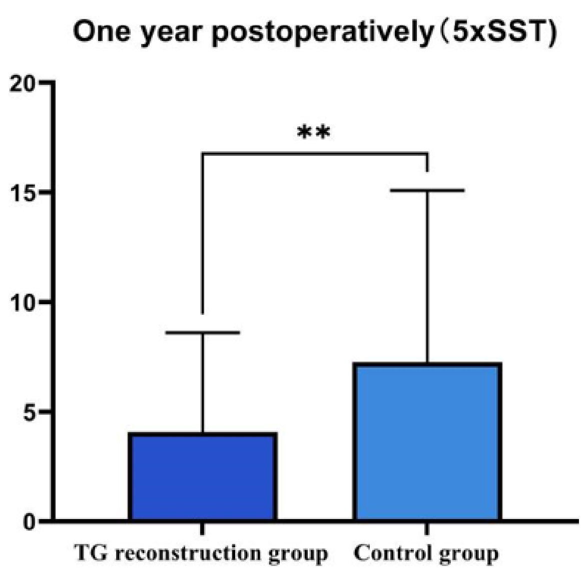

Fig. 7. Comparison of time taken to complete 5xSST between the two groups at 1 year postoperatively. 5xSST: Five Times Sit-to-Stand Test.

Table 2. Comparison of preoperative and postoperative HKA (hip-knee-ankle) angle, patellofemoral index, and patellar tilt angle between the Trochlear groove reconstruction group and the control group. Comparison of knee joint range of motion, 5xSST, and advanced activities between the two groups at 1 year postoperatively. 5xSST: Five Times Sit-to-Stand Test.

	TG reconstruction group	Control group	*P* Value
Preoperative			
HKA	171.4±6.17	170.40±6.38	0.762
Patellofemoral index	1.54±0.86	1.60±0.82	0.762
Patellar tilt angle	9.28±6.34	10.53±6.72	0.38
Postoperative			
HKA	177.92±1.72	177.38±2.25	0.895
Patellofemoral index	1.28±0.58	1.72±0.78	0.040
Patellar tilt angle	2.82±2.32	9.40±7.30	0.000
Range of motion	126.43±9.94	120.75±11.63	0.006
5xSST	14.24±4.78	16.88±5.88	0.026
Climbing a ladder or step stool	41%	32%	0.067
Carrying a shopping bag for a block	75%	57%	0.032
Squatting	43%	22%	0.002
Kneeling	32%	28%	0.732
Running	30%	25%	0.499

The TG reconstruction group had higher KSS scores compared to the control group at 6 weeks postoperatively (58.64±12.63 vs 53.18±11.40, p=0.039) and at 1 year postoperatively (86.03±10.35 vs 81.09±10.74, p=0.006). By 6 months postoperatively, there was a near statistically significant difference in KSS scores between the two groups (77.68 ± 11.63 vs 74.48 ± 15.01, p = 0.086) (Table 3) (Figure 8).

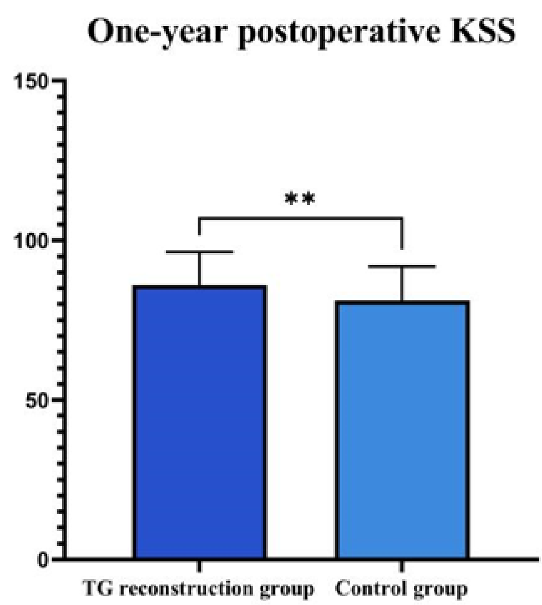

Fig. 8. Comparison of KSS (Knee Society Score) between two groups at 1 year postoperatively.

Table 3. Comparison of KSS scores between the two groups.

Time	TG reconstruction group	Control group	*P* Value
2 weeks postoperative	44.62±13.87	44.66±13.85	0.989
6 weeks postoperative	58.64±12.63	53.18±11.40	0.039
3 months postoperative	72.30±12.50	70.22±9.35	0.364
6 months postoperative	77.68±11.63	74.48±15.01	0.086
1 year postoperative	86.03±10.35	81.09±10.74	0.006

In terms of WOMAC scores, at 3 months postoperatively, the TG reconstruction group showed significant improvement over the control group in total WOMAC score (13.28 ± 10.38 vs 17.84 ± 7.48, p = 0.019), pain sub score (2.91 ± 1.99 vs 4.38 ± 2.49, p = 0.005), and physical function sub score (8.34 ± 8.78 vs 11.51 ± 5.72, p = 0.045). At 6 months postoperatively, the TG reconstruction group continued to show superiority in total WOMAC score (8.63 ± 7.24 vs 12.46 ± 11.13, p = 0.014) and physical function sub score (5.10 ± 5.42 vs 8.31 ± 8.38, p = 0.006). This advantage persisted at 1 year postoperatively in total WOMAC score (6.50 ± 6.64 vs 10.52 ± 10.23, p = 0.014) and physical function sub score (4.07 ± 4.53 vs 7.26 ± 7.82, p = 0.008). Even at 6 weeks postoperatively, the TG reconstruction group showed a trend towards better scores in the physical function sub score (12.95 ± 8.82 vs 16.45 ± 8.54, p = 0.059) (Table 4) (Figure 9).

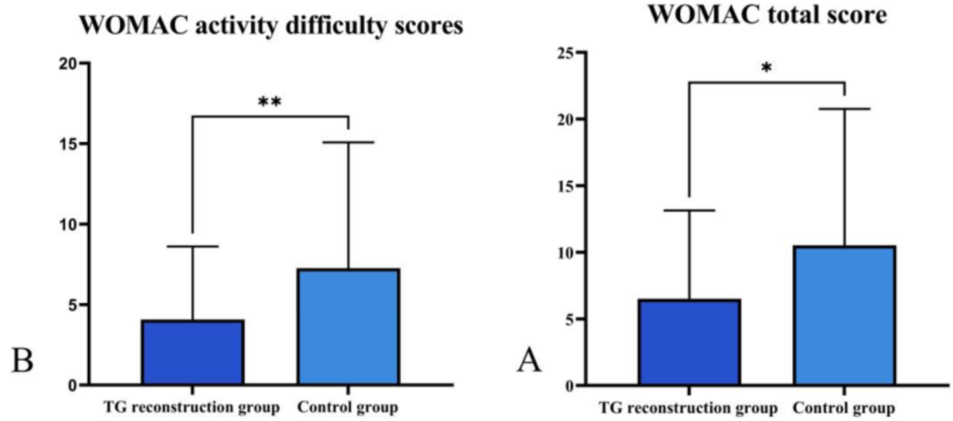

Fig. 9. A) Comparison of postoperative 1-year WOMAC total scores between the two groups. **B)** Comparison of postoperative 1-year WOMAC activity difficulty scores between the two groups.

Table 4. Comparison of WOMAC scores between the two groups.

	TG reconstruction group	Control group	*P* Value
2 weeks postoperative			
Total score	37.05±14.46	36.98±17.12	0.98
Pain	7.67±3.58	8.29±3.69	0.286
Stiffness	3.23±1.35	3.2±1.54	0.901
Physical function	26.15±11.76	25.46±13.31	0.733
6 weeks postoperative			
Total score	20.27±11.64	23.11±10.56	0.223
Pain	4.85±2.65	4.16±2.78	0.232
Stiffness	2.48±0.90	2.69±0.88	0.266
Physical function	12.95±8.82	16.45±8.54	0.059
3 months postoperative			
Total score	13.28±10.38	17.84±7.48	0.019
Pain	2.91±1.99	4.38±2.49	0.005
Stiffness	2.03±0.86	2.00±0.96	0.880
Physical function	8.34±8.78	11.51±5.72	0.045
6 months postoperative			
Total score	8.63±7.24	12.46±11.13	0.014
Pain	1.96±1.90	2.31±2.49	0.347
Stiffness	1.57±0.96	1.84±1.21	0.144
Physical function	5.10±5.42	8.31±8.38	0.006
1 year postoperative			
Total score	6.50±6.64	10.52±10.23	0.014
Pain	1.09±1.89	1.67±2.17	0.144
Stiffness	1.34±1.10	1.6±1.12	0.241
Physical function	4.07±4.53	7.26±7.82	0.008

In terms of SF-36, At 3 months postoperatively, the TG reconstruction group exhibited better scores in bodily pain, general health, and vitality compared to the control group. However, there were no significant differences between the two groups in any aspect of SF-36 scores at 6 months and 1 year postoperatively (Tables 5 & 6).

Table 5. Comparison of SF-36 scores between the two groups (2 weeks postoperative, 6 weeks postoperative).

	TG reconstruction group	Control group	*P* Value
2 weeks postoperative			
Physical functioning	37.57±18.16	35.96±24.30	0.732
Role-physical	12.16±24.02	14.91±30.20	0.642
Bodily pain	56.43±17.46	55.11±17.71	0.722
General health	69.32±12.72	67.82±18.40	0.655
Vitality	68.78±18.12	68.6±14.47	0.956
Social functioning	64.86±16.09	64.25±18.05	0.868
Role-emotional	34.15±32.77	30.47±29.19	0.569
Mental health	74.59±13.34	76.21±17.60	0.635
Health transition	32.43±15.43	40.79±22.47	0.051
6 weeks postoperative			
Physical functioning	56.11±15.68	49.73±21.24	0.129
Role-physical	31.94±39.91	26.39±38.54	0.516
Bodily pain	61.72±13.40	57.24±13.41	0.128
General health	76.13±15.19	65.58±20.61	0.005
Vitality	71.92±16.24	67.18±22.07	0.262
Social functioning	75.34±16.49	70.00±15.36	0.126
Role-emotional	38.84±34.57	32.23±39.52	0.348
Mental health	75.04±17.31	69.48±23.59	0.166
Health transition	25.00±16.98	28.08±24.31	0.498

Table 6. Comparison of SF-36 scores between the two groups (3 months postoperative, 6 months postoperative, and 1 year postoperative).

	TG reconstruction group	Control group	*P* Value
3 months postoperative			
Physical functioning	63.53±22.54	55.66±19.79	0.056
Role-physical	44.39±40.26	45.65±43.50	0.876
Bodily pain	68.94±16.44	62.15±12.36	0.016
General health	73.24±16.30	65.44±18.49	0.025
Vitality	72.25±20.50	62.42±22.95	0.018
Social functioning	71.46±20.35	67.33±19.25	0.285
Role-emotional	60.08±32.64	57.32±39.92	0.703
Mental health	72.78±16.21	66.30±22.85	0.104
Health transition	28.80±33.73	25.79±28.02	0.612
6 months postoperative			
Physical functioning	66.59±19.16	66.25±21.29	0.939
Role-physical	72.11±39.96	70.00±43.19	0.816
Bodily pain	76.89±9.62	77.13±10.67	0.914
General health	67.69±15.63	65.25±16.96	0.492
Vitality	68.84±17.11	67.63±19.41	0.759
Social functioning	79.00±19.72	80.62±19.80	0.706
Role-emotional	79.41±32.70	75.75±37.69	0.634
Mental health	70.60±20.29	72.20±20.53	0.719
Health transition	23.86±24.68	27.50±25.19	0.506
1 year postoperative			
Physical functioning	66.91±16.68	67.63±20.32	0.844
Role-physical	69.49±39.31	69.74±43.16	0.976
Bodily pain	76.66±9.28	77.50±10.60	0.673
General health	70.12±15.77	65.39±16.64	0.150
Vitality	71.91±14.78	69.47±18.29	0.457
Social functioning	90.99±22.63	91.44±20.97	0.919
Role-emotional	78.35±32.42	76.23±37.85	0.763
Mental health	73.00±19.85	73.47±20.96	0.908
Health transition	19.85±23.08	25.00±25.33	0.290

One patient in the experimental group experienced early periprosthetic joint infection, which was resolved after debridement and liner exchange. No further infections occurred during follow-up. No further infections occurred during follow-up. Two patients in the experimental group and two in the control group experienced delayed wound healing postoperatively, which improved after outpatient wound care. There were no significant differences between the two groups in terms of postoperative complications at 1 year postoperatively (Table 7).

Table 7. Incidence of postoperative complications.

Adverse events	TG reconstruction group (N)	Control group (N)	*P* Value
Prosthetic joint infection	1	0	0.314
Poor wound healing	2	2	0.992
Total	3	2	0.624

4. Discussion

By preoperative planning, we personalized the rotation of the femoral component and reconstructed the preoperative trochlear groove. Our study results demonstrate that this personalized preoperative planning can improve knee joint function in patients, particularly evident in advanced activities such as squatting. Lisa Spahn Lundgren *et al.*'s research indicates that in robot-assisted total knee arthroplasty (TKA), surgical planning, especially femoral component alignment and rotation, significantly affects postoperative joint function [22]. Personalized surgical planning has been shown to be beneficial [22].

Our research results also show that, by reconstructing the patellar groove trajectory of patients, the postoperative patellofemoral index and patellar tilt angle of patients in the TG reconstruction group are better than those in the control group. In preoperative planning, we focus on matching the prosthetic patellar groove with the patient's original patellar groove to restore the patient's original patellar groove morphology, referred to as the "kinematic patellofemoral line". This may enable patients in the experimental group to achieve a more "native" patellar trajectory, thereby improving their joint function and range of motion.

Knee joint range of motion is a critical indicator of postoperative joint function in TKA [27] and significantly influences patient-reported outcomes [28]. Yang Yang *et al.*'s study results suggest that robot assisted TKA outperforms traditional surgery in knee joint range of motion at 6 months postoperatively (118.5° vs 112.2°) [29]. Yunus Demirtas *et al.* demonstrated that at 1 year postoperatively, patients undergoing robot assisted TKA achieved a knee joint range of motion of 125.2° [30], which is similar to our study. The rotation of the femoral component will affect the patellar stress, thereby significantly influencing knee joint function and range of motion [31, 32], even a 2.5 mm displacement can lead to a 20° change in knee joint range of motion [33]. Although robot-assisted total knee arthroplasty can provide more precise alignment, it may not necessarily lead to better results in terms of postoperative function and joint range of motion [33]. Therefore, a more individualized alignment of the component, rather than a uniform alignment standard, may be a further solution. We believe that setting individualized rotational alignment for each patient to restore their trochlear groove morphology may lead to higher joint function. As shown in (Figure 2), the distribution of the femoral component relative to the transepicondylar axis rotation angle is quite wide, not a fixed value, highlighting the importance of individualized surgical plans.

Squatting is a key indicator of high flexion knee joint activity [34]. Aditya K Aggarwal *et al.* found that on average, 17% of patients could squat at an average of 5.5 years postoperatively [26]. Matthew S Hepinstall *et al.* reported that 41% of patients could squat at 1 year postoperatively [34]. Our study shows that at 1 year postoperatively, 43% of patients in the experimental group could squat, slightly better than previous studies. This improvement may be attributed to our personalized preoperative planning, which restored the patellofemoral status to preoperative conditions, thereby enhancing joint function. Periklis Tzanetis *et al.* demonstrated that appropriate adjustments in preoperative planning can help maximize the restoration of pre-disease joint status [35], aligning with our research concept. Additionally, our study results show that at 1 year postoperatively, the TG reconstruction group had higher KSS scores than the control group, with a statistically significant difference greater than the clinical minimal difference (5 points) [36]. In terms of WOMAC scores, the experimental group outperformed the control group at 6 months and 1 year postoperatively. The score differences between the two groups mainly stemmed from difficulties in physical function. This suggests that patients in the experimental group had better joint function, though there were no significant differences in pain and stiffness scores between the groups.

In the 5xSST, the experimental group performed better than the control group, although the difference did not reach the minimum clinically important difference (3 seconds) [37]. Regarding SF-36 scores, the TG reconstruction group was superior to the control group at 6 weeks postoperatively, indicating a potential early recovery advantage. However, there were no significant differences in SF-36 scores between the two groups at 1 year postoperatively.

Our study also has limitations. First, we did not study postoperative patellar trajectory in patients. Second, we only included patients undergoing MAKO robot-assisted TKA, and further research should encompass more robotic-assisted systems. Third, our follow-up duration was relatively short, necessitating longer-term observations to evaluate patient joint function and prosthetic status.

5. Conclusion

Our study found that personalized adjustment of the femoral component rotation angle using robot-assisted total knee arthroplasty restores the patient's physiological trochlear groove morphology, leading to improved joint function. This underscores the importance of personalized preoperative planning in robot-assisted total knee arthroplasty.

Conflicts of Interest

None.

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