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A prospective randomised comparison of earlier function after total hip arthroplasty with a mini posterior approach or supercapsular percutaneously-assisted total hip approach: a gait analysis study

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Abstract

Background: The supercapsular percutaneously-assisted total hip (SuperPATH) approach is a muscle sparing surgical technique for total hip arthroplasty (THA). The literature reports good clinical and functional results of the SuperPATH technique in the short term. We aimed to compare early outcomes and gait analysis of THA using the mini posterior approach (MPA) and supercapsular percutaneously-assisted total hip (SuperPATH) approach.

Methods: 44 patients who underwent THA, were randomly allocated to either MPA or SuperPATH. The data were then collected prospectively (preoperatively and postoperatively at 6 weeks). Plain anteroposterior radiographs of the pelvis and instrumental gait analysis were obtained. The visual analogue scale (VAS), Harris Hip Score (HHS) and Hip disability and Osteoarthritis Outcome Scores (HOOS) were used to assess functional and clinical outcomes.

Results: No significant difference was found in patients' surgical outcomes. Patients in the SuperPATH group had less pain according to the VAS score at follow-up than the MPA group ($p < 0.01$). There was also a significant improvement in HHS and HOOS scores for all patients ($p < 0.001$) with the SuperPATH group showing superior changes. The comparison of mean differences in gait velocity between preoperative and 6 weeks postoperative result, revealed improvement in the SuperPATH group over the MPA group ($p = 0.06$). Limping was more persistent in the MPA group. Kinematic parameters demonstrated improved hip joint excursion slightly higher in the MPA group. There was no significant improvement in kinetic and kinematic parameters at different walking moments for all patients at 6 weeks compared to preoperative gait patterns.

Conclusions: SuperPATH and MPA both show excellent results. This study reveals that the SuperPATH technique was associated with lower postoperative pain levels, and higher physical function and quality of life. Improved functional outcomes allowed earlier postoperative rehabilitation and faster recovery. Specific improvement in gait patterns were identified with nonsignificant differences between the 2 approaches at 6 weeks follow-up.

Keywords

Gait analysis, minimally invasive surgery, mini posterior approach, SuperPATH, total hip arthroplasty

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Introduction

Modern total hip arthroplasty (THA), in addition to significant pain alleviation, function restoration and biomechanical hip correction, should provide satisfactory long-term results regardless of patients' age or activity level.[1,2] The surgical approach is a significant predictor of patient-reported pain, function and satisfaction, even after controlling for patient-specific factors. The posterior approach was associated with better gait patterns, less self-reported pain and better function when compared to the anterolateral approach.[3] Improvements in the mini posterior approach (MPA) technique has made it more comprehensible, increased reproducibility and provided better self-reported results.[4] The supercapsular percutaneously-assisted total hip (SuperPATH) approach allows maximal tissue sparing through preservation of external rotators, minimising stretching of the gluteus medius and preservation of the iliotibial band via the superior incision. The SuperPATH technique combines a series of elements assembled in the specialised instrumentation, including a navigation system for assisted, easy implant positioning which are usable for the standard approach as well. The SuperPATH technique requires neither a special operative table nor forced dislocation. In comparison, the SuperPATH has been associated with shorter length of stay, decreased inpatient rehabilitation, and decreased overall complication rates.[5–7]

Many patients have difficulties in achieving normal gait patterns after THA. The effect of THA on muscle function and static restraints around the hip may prevent gait pattern from returning to normal. Thus, variations in the surgical approach are factors in postoperative gait normalisation. Previous studies have used quantitative gait analysis to investigate changes after THA using different approaches.[8–10]

To our knowledge, there has been no study evaluating preoperative and postoperative gait parameters of patients undergoing THA with MPA and SuperPATH techniques.

This study aimed to test our hypothesis that patients undergoing THA using the SuperPATH technique will achieve improved gait parameters with better functional and clinical results than patients operated on using the MPA. We also aimed to evaluate patients' hip kinetics and kinematic changes in walking performance.

Materials and methods

In this prospective, randomised clinical trial (RCT) patients undergoing THA at a single centre, the Privolzhsky Research Medical University Clinic, from July 2018 to March 2019 were enrolled. The G*Power Version 3.1.9.4 was used to perform the sample size determination for the study. The time to discontinued use of walking aid was considered as the primary outcome variable. Previous literature reports time to discontinued use of walking aid using MPA as 28.5 days.[11] The total sample size of 52 patients (26 patients per group) with the probability of alpha errors at 0.05, with aand power of 0.80 is sufficient to detect differences between groups.

The Michael et al.[12] protocol was used as guidance for this study. The study protocol was approved and conducted under the local medical ethics committee (Reference 26/07/18.09-02). Written informed consent was obtained from all patients.

All patients had unilateral hip disease, were included if they were >20 years of age, with non-inflammatory degenerative joint disease, if they were able and available to attend follow-up and were willing to sign the informed consent form. Exclusion criteria were as follows: a body mass index (BMI) >40 kg/m^2, rapid disease progression, and neuromuscular diseases.

Patients who met the inclusions criteria were randomly assigned to either the MPA or SuperPATH group according to a computed randomisation list, with numbered and sealed envelopes opened before the operation.

Thus, of 65 patients assessed for eligibility, 49 patients were allocated and underwent surgery using one of the two approaches (Figure 1). Patients were as follows: 22 in the SuperPATH group and 27 in the MPA group. Within the SuperPATH group, 2 patients were lost to follow-up. Thus 20 patients were available for analysis. In the MPA group, 3 patients were not available: 2 patients chose not to participate, 1 patient was still using a walking aid at 6 weeks follow-up.

All procedures were performed by a fellowship-trained surgeon; patients were managed with the same multimodal anaesthesia and analgesia protocol.

Patients in the SuperPATH group were treated according to the technique introduced by Chow et al.[5] and described by Della Torre et al.[6] MPA THAs were operated on as reported by Inaba et al.[4]

All patients received the cementless acetabular component Dynasty® PC Shell and femoral component Profemur Z CLASSIC FEMORAL STEM with a cobalt chrome femoral head on Ultra high molecular weight Dynasty A-CLASS POLY LINER (MicroPort Orthopedics, Inc. Arlington, TN, USA). A 32-mm diameter head was used in 19 cases and 28-mm in 1 case of the SuperPATH group, whereas in the MPA group, the 32-mm head was used in 23 cases and the 28-mm in 1 case. Standardised anteroposterior (AP) and lateral view radiographs were performed pre- and postoperatively during templating and implant alignment assessment. Cup inclination, anteversion angles and stem coronal alignment were measured. Cup anteversion was assessed using the cross table lateral radiography technique.[13] All patients were weight-bearing as tolerated on the day of surgery regardless of approach. Patients in the MPA group were given standard postoperative precautions to prevent dislocation, whereas SuperPATH group was not given any restrictions.

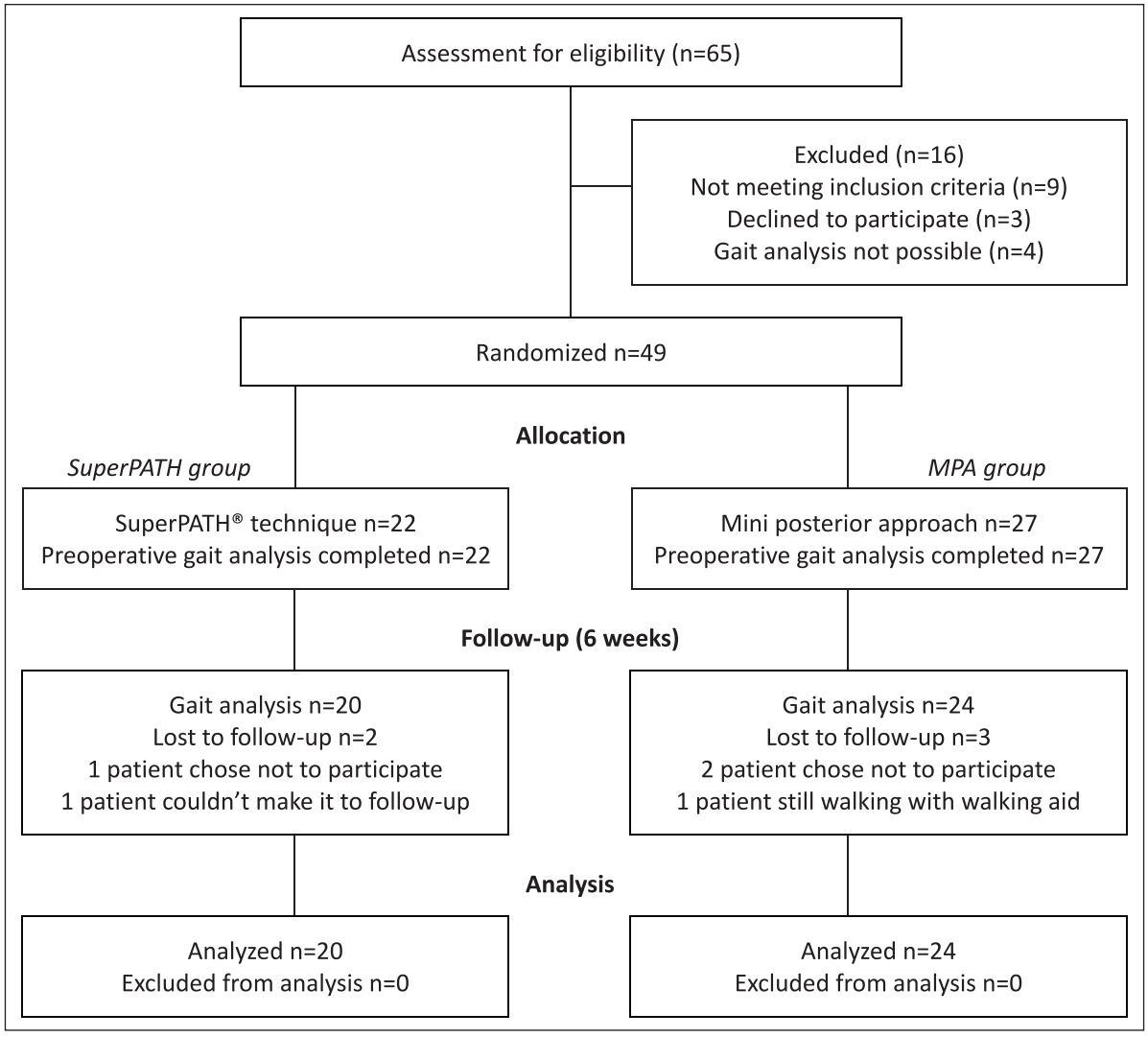

Figure 1. Flow diagram of patients' enrolment through the study.

Early postoperative rehabilitation was the same for both groups and was performed by the same physiotherapy team at the same institution and started the first day after surgery. Upon discharge, patients were advised to resume activities as they could tolerate.

Data on patient demographic characteristics were collected, including age, gender, BMI and diagnosis. Recorded perioperative and postoperative data included incision length, estimated blood loss, operation time, postoperative hospital stay and complications. Intraoperative blood loss was estimated by measuring the volume of blood in the suction bottle and weighing the used swabs. Patient-reported outcome scores included the visual analogue scale (VAS), Harris Hip Score (HHS), and Hip disability and Osteoarthritis Outcome Scores (HOOS).[14] Minimally invasive surgery (MIS) in THA is related to early functional recovery. Some authors have suggested that there is no evidence of differences between MIS and conventional surgical procedures after 6 weeks postoperatively.[11,15,16] Therefore, all patients were followed-up in the same centre, and postoperative outcomes were assessed at 6 weeks. 2 unbiased biostatisticians, blinded to patient attribution and outcome, performed the statistical work.

Gait analysis

To determine joint kinematics patterns, all patients underwent gait analysis on the day before surgery and 6 weeks postoperatively. Gait analysis was undertaken by an independent researcher with expertise in gait analysis, who was blinded to patients' allocation, at the clinic biomechanical laboratory. A Simi Aktisys (SIMI Reality Motion System, Unterschleissheim, Germany) was used to collect kinematic data with 8 cameras, operating at 100 Hz to capture the position of the reflective markers that defines the joint centres of rotation over the greater trochanter, the

Table 1. Patient demographic characteristics.

Variable	Total $n = 44$	Approach		p-value
		SuperPATH ($n = 20$)	MPA ($n = 24$)	
Gender				
Male	21	10	11	0.78
Female	23	10	13	
Age (years)	56.86 ± 12.9 (20–78)	56.75 ± 12.86 (20–70)	56.96 ± 13.2 (32–78)	0.96
Height (cm)	165.6 ± 13.5 (105–186)	167.2 ± 8.18 (150–180)	164.4 ± 16.9 (105–186)	–
Weight (kg)	82 ± 20 (46–182)	78.75 ± 11.2 (58–104)	84.8 ± 25 (46–182)	–
BMI (kg/m^2)	28.66 ± 4.7 (20.2–39.9)	28.2 ± 4.51 (22.5–39.4)	29.04 ± 4.91 (20.2–39.9)	0.55
Disease duration (months)	70 ± 48.22 (12–180)	70.15 ± 41.35 (24–180)	69.91 ± 54.16 (12–180)	0.98
VAS preoperatively	5.5 ± 1.9 (2–8)	5.7 ± 2.03 (2–8)	5.4 ± 1.81 (2–8)	0.63
HHS preoperatively	46.6 ± 11.1 (24–79)	45.6 ± 11.3 (32–79)	46 ± 11 (24–67)	0.79
HOOS preoperatively	40.7 ± 13.4 (11.25–78.75)	40.1 ± 10.3 (24.37–66.25)	41.3 ± 15.7 (11.25–78.75)	0.75

BMI, body mass index; VAS, visual analogue scale; HHS, Harris hip score; HOOS, Hip disability and Osteoarthritis Outcome Score.
Note: Values are given as the mean and standard deviation, with the range in parentheses.

iliac crest, lateral femoral condyle, medial and lateral malleolus bilaterally. Patients were instructed to look straight and walk at self-selected speed on a 6 metres walkway.[17,18]

Static and dynamic calibration was carried out before each measurement session. The start of the gait cycle was at heel strike, and ended at same leg next heel strike. All data were collected 3 times, and the average of the 3 trials was used for further analysis. The spatio-temporal variables analysed included gait velocity and double step length. Joint sagittal plane kinetic and kinematic of the hip were defined during the stance phase of gait, and at initial contact, mid-stance, peak hip extension and toe-off, as well. Currently, the few existing pieces of research have reported reliability and comparability between the 2D and 3D gait video analysis methods of kinematic analysis, especially when evaluating sagittal plane joint displacement. The hip sagittal plane kinematics is also a key feature regarding postoperative rehabilitation, for gait pattern improvement.[19–23]

Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics 20 software for Windows. Pre- and postoperative continuous variables were compared using the paired Student *t*-test when values showed normal distribution; otherwise, the non-parametric Wilcoxon test was used. Continuous variables between the 2 groups were compared using the bilateral non-paired Student *t*-test or Mann–Whitney *U*-test. We used the chi-square test for the nominal variables and a Fisher exact test when the theoretical numbers were less than 5.

All gait parameters were tested using a two factor ANOVA with factors being group and time. Bonferroni corrections were applied to planned post-hoc comparisons where applicable. The level of statistical significance was set at $p < 0.05$.

Results

49 patients were included and randomised in this study, 44 of whom completed the study protocol and the follow-up. Patient demographic characteristics and preoperative levels of symptoms and function were comparable, except for the BMI being slightly higher in the MPA group (Table 1).

All incisions ranged from 7 to 11 cm, no significant differences were found in operation time, postoperative hospital stay, estimated blood loss, haemoglobin, or haematocrit values; no blood transfusions were required, and no major complications were observed in either group (Table 2).

The cup anteversion in degrees averaged 18° (16–21°), inclination was 43° (32–48°), and stem alignment was neutral in all cases in the SuperPATH group. In the MPA group, cup anteversion in degrees averaged 19° (16–24°), inclination was 44° (31–49°), and stem alignment was neutral in 96%, and 4% was >2° in varus. No significant differences were observed between the 2 groups in the cup anteversion angle, inclination angle orand the stem positioning.

Patients in the SuperPATH group had significantly less pain according to the VAS score at follow-up than in the MPA group ($p < 0.001$). Significant improvement was observed in the HHS and HOOS scores of the SuperPATH group compared toover the MPA group (Table 3). Overall, all the patients were satisfied with the results.

Gait velocity was preoperatively comparable for both groups with 3.02 ± 0.72 km/h for the SuperPATH group and 2.92 ± 0.85 km/h in the MPA group ($p = 0.66$). Comparison of the mean differences in gait velocity between preoperative and the 6 weeks postoperative

Table 2. Patient surgical outcomes.

Variable	SuperPATH group ($n = 20$)	MPA group ($n = 24$)	p-value
Operation time (min)	63.2 ± 9.87 (50–80)	61.7 ± 14.1 (40–90)	0.33
Estimated blood loss (ml)	177.5 ± 54.95 (100–300)	204.16 ± 83.29 (50–450)	0.1
Hemoglobin (g/ml)			
Preoperative	136.3 ± 15.19 (110–166)	139.29 ± 18.93 (106–173)	0.56
Postoperative day 5	110.15 ± 14 (81–138)	117 ± 18.85 (90–154)	0.17
Hematocrit (%)			
Preoperative	42 ± 3.87 (35–52.6)	41.19 ± 6.13 (28.2–52.3)	0.56
Postoperative day 5	32.89 ± 4.51 (24.1–43.6)	35.2 ± 5.91 (27–46.7)	0.14
Hospital stay (days)	8.85 ± 1.66 (5–13)	8.66 ± 1.63 (6–13)	0.35
Stay after op. (days)	6.2 ± 1.28 (3–8)	6.1 ± 1.55 (3–11)	0.39

The values are given as the mean and the standard deviation, with the range in parentheses.

Table 3. Clinical and functional outcomes.

Variable	Follow-up time	SuperPATH group	MPA group	p-value
VAS	Preoperatively	5.7 ± 2.03	5.4 ± 1.81	0.63
	6 weeks	0.85 ± 0.58	1.87 ± 1.2	0.001
HHS	Preoperatively	45.6 ± 11.3	46 ± 11	0.79
	6 weeks	78.6 ± 9.18	68.8 ± 15.1	0.01
HOOS	Preoperatively	40.1 ± 10.3	41.3 ± 15.7	0.75
Symptoms		44.5 ± 11.2	46.8 ± 16.6	0.57
Pain		46 ± 11.3	43.3 ± 18.3	0.55
FDL		43.1 ± 12.1	44.6 ± 18.8	0.06
FSR		26.8 ± 21.9	32 ± 25.7	0.47
QL		20 ± 12.4	25 ± 19.7	0.31
HOOS	6 weeks	81.3 ± 10.9	72.47 ± 13.5	0.01
Symptoms		86.7 ± 10.3	79.8 ± 12.2	0.04
Pain		89.1 ± 9.7	80.4 ± 15.3	0.02
FDL		80.4 ± 11.9	71.7 ± 15.3	0.04
FSR		80.3 ± 21.7	74 ± 27.3	0.39
QL		60.3 ± 17.9	45.05 ± 23.6	0.01

VAS, visual analogue scale; HHS, Harris hip score; HOOS, Hip disability and Osteoarthritis Outcome Score; FDL, function - daily living; FSR, function - sport and recreational activities; QL, quality of life.
Note: Values are given as the mean and the standard deviation.

outcome, revealed improvement in the SuperPATH group over the MPA group ($p = 0.06$).

Limping on the non-painful contralateral side was revealed in both groups. In comparison to the contralateral side preoperatively there was significant lengthening of the stance phase. The SuperPATH group had 65.13% ± 5.25% on the involved side, and 69.36% ± 4.46% on the contralateral side ($p = 0.009$), the MPA group showed 65.63% ± 4.27% on the involved side, and 68.89% ± 3.93% on the contralateral side ($p = 0.01$). At 6 weeks follow-up, the SuperPATH group demonstrated reduced limping, the stand phase was 66.01% ± 4.2% for the involved side, and 68.47% ± 5.35% for the contralateral side, with a better-balanced gait cycle. Whereas limping was still observed in the MPA group, the stand phase was 68.36% ± 6.17% for the involved side and 70.95% ± 8.35%, with unbalanced walking ability.

For kinematics, flexion/extension range of motion (ROM), hip joint excursion significantly improved in the SuperPATH group, compared to the MPA group ($p = 0.04$). Knee joint excursion consequently improved for the SuperPATH group ($p = 0.31$), (Table 4).

All patients had asymmetric gait patterns for operated and non-operated hips on comparison.

Kinetic and kinematic mean curves during gait cycle (Figure 2) demonstrate improvement in dynamic range of motion and at different walking moments for both groups at 6 weeks follow-up, but without significant differences between groups, compared to preoperative gait patterns.

Discussion

This prospective randomised study demonstrates that the SuperPATH approach is associated with better clinical and

Table 4. Spatio-temporal parameters of gait.

Parameter	SuperPATH group	MPA group	p-value
Gait velocity (km/h)			
Preoperatively	3.02 ± 0.72	2.92 ± 0.85	0.66
6 weeks	3.00 ± 0.92	2.69 ± 1.00	0.28
Stance phase (%)			
Preoperatively	65.13 ± 5.25	65.63 ± 4.27	0.73
6 weeks	66.01 ± 4.20	68.36 ± 6.17	0.14
Swing phase (%)			
Preoperatively	34.01 ± 5.78	34.37 ± 4.27	0.82
6 weeks	33.99 ± 4.20	31.64 ± 6.17	0.14
Double step length			
Preoperatively	1.00 ± 0.19	1.01 ± 0.22	0.84
6 weeks	1.03 ± 0.22	0.94 ± 0.26	0.26
ROM hip			
Preoperatively	25.66 ± 6.74	27.26 ± 8.01	0.47
6 weeks	26.29 ± 5.46	25.79 ± 6.20	0.77
ROM knee			
Preoperatively	51.95 ± 8.66	50.88 ± 9.21	0.69
6 weeks	51.59 ± 9.70	48.58 ± 10.28	0.32
ROM ankle			
Preoperatively	24.99 ± 6.70	24.82 ± 4.08	0.92
6 weeks	26.07 ± 6.22	27.12 ± 4.83	0.53

ROM, range of motion.
Note: Values are given as the mean and the standard deviation.

functional results. These findings are similar to those reported by Xie et al.,[24] in term of surgical results, and are also comparable to results reported by Inaba et al.[4] Clinical and functional outcomes of the SuperPATH and MPA are encouraging.

Gait analysis in the current study did not reveal absolute significant differences between the SuperPATH and MPA approaches. However, we have noticed improvement of gait parameters in the SuperPATH group over the MPA group.

The results of different gait analysis studies following THA using different approaches remain controversial, with some reporting significant and others insignificant improvements. However, similar alterations in certain gait patterns in approach-based analysis were reported in different studies.

In the current study, gait velocity improved for all patients with slight superiority of the SuperPATH group. Minimally invasive approaches might have a distinct impact on gait parameters due to early functional recovery.[16] There was an overall improvement of all gait parameters. Indeed, it has been suggested that temporal parameters improve regardless of surgical approach.[9]

The sagittal plane gait parameters were reported to highlight hip excursion with more distinct gait alterations.[23] Hip excursion during the gait cycle in the MPA group was highly improved from preoperative values. The release of the capsule and the external rotators performed in the MPA group allows an extended hip ROM. Queen et al.[25] reported no significant differences in the investigated gait parameters between the direct lateral, the posterior, and the anterolateral approaches at 6 weeks follow-up. An increase in peak hip extension was the only significant finding in the study. Thus, it was suggested that the capsular releases provide an increased laxity and additional extension of the hip ROM.[25] The majority of studies including the posterior approach have noted the effect of capsular and external rotators release on the hip ROM.[10,25,26] Therefore, alterations of gait patterns are quantifiable, but with limited statistical significance. In contrast, the SuperPATH group gait cycle tends to be normalised since no forced dislocation is needed, and no release of muscle attachments. However, hip excursion was significantly improved. The comparison of gait patterns after THA of the direct anterior and the posterior approaches conducted by Rathod et al.[26] reported no significant improvement of the gait parameters. They concluded that gait parameters were similar at 6 months postoperatively, except for internal and external rotation that may be related to the external rotators release and repair in the posterior approach group.[26] This common finding raises the possibility that different surgical groups might have specific gait patterns alterations.[8,16]

Lateral trunk inclination may reveal possible abductor weakness. In the current study limping was found in all patients preoperatively. At 6 weeks control, limping was significantly reduced in the SuperPATH group, with a better-balanced gait cycle, whereas in the MPA group limping persisted, with unbalanced walking ability. The sparing muscle technique and the patients' early functional recovery may have directly contributed to the early normalisation and balanced gait cycle of the SuperPATH group. Madsen et al.[8] found that the anterolateral group had the largest trunk inclination angle and small hip ROM in comparison with the posterolateral group, demonstrating a normal gait at 6 months follow-up. The study design of Petis et al.[9] was aimed to detect differences in contralateral pelvic tilt as an indicator of lateral trunk lean. No difference in peak abduction moments was found between the anterior, posterior and lateral approaches. Therefore, abductor mechanism insufficiency may make alterations undetectable.[9] Mayr et al.[16] found that the investigated variables of abductor muscle weakness are insufficient due to patient-specific compensatory mechanisms. Studies investigating the anterolateral approach expect more deviation from normal gait then others. Unfortunately, the hypothesis has not always been confirmed. Additionally, most authors state that the clinical significance of the results remains undetermined.[8,25]

Study limitations

The limitations of this study, such as short-term follow-up, should be considered because they may affect further data collection and late complications. Patients could not be

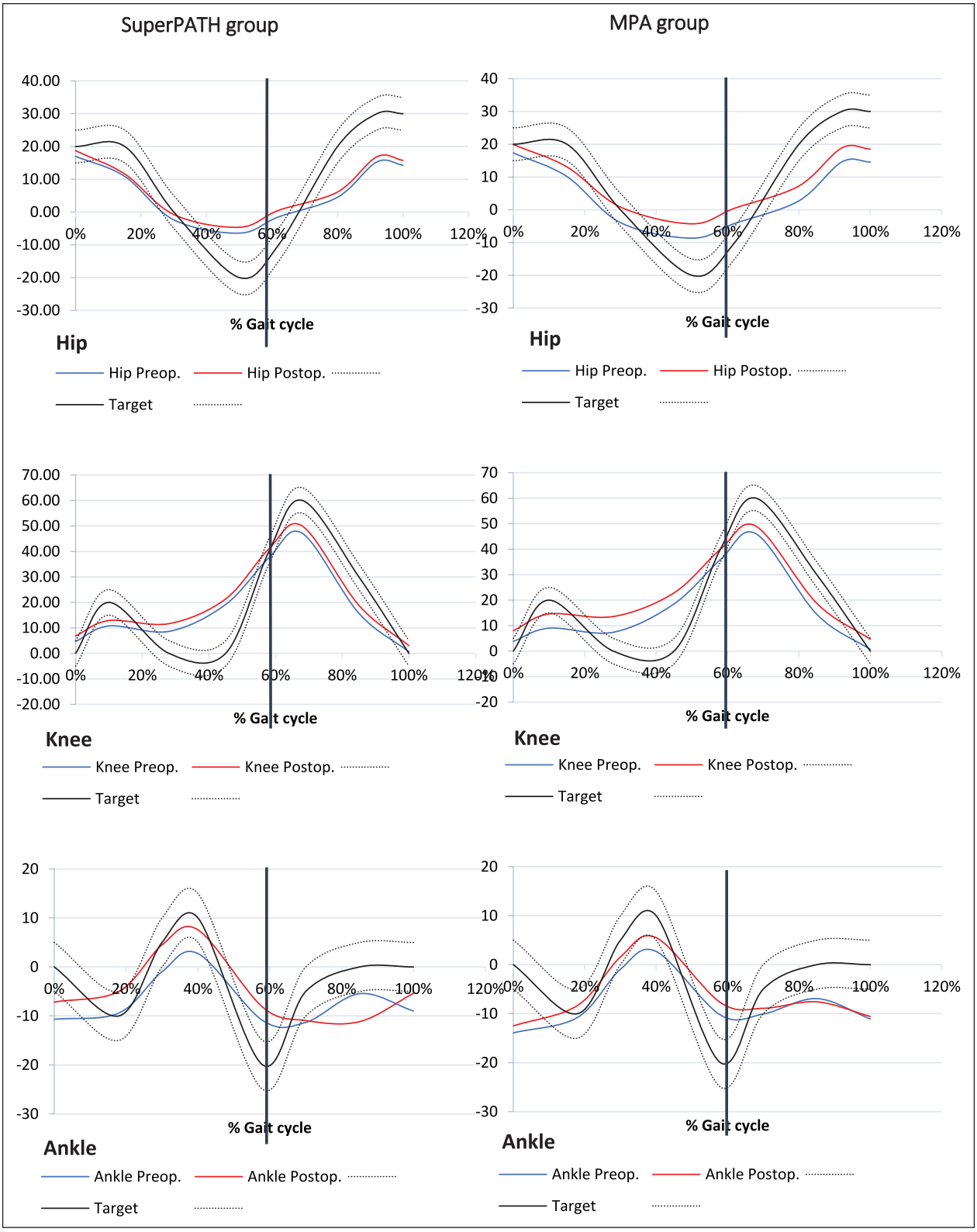

Figure 2. Mean of dynamic range of motion and moments (joints kinematics) in sagittal plane during a gait cycle, at a self-selected speed for the SuperPATH and MPA groups, pre- and postoperatively.

blinded to the approach and had to be instructed concerning the postoperative precautions and behaviour. Gait parameters were collected in the sagittal plane only, while frontal and transversal planes should be included for comprehensive analysis. The lack of a healthy control group makes it difficult to determine if gait patterns were restored

after the THA in both groups. However, the aim of the study was to compare differences of gait parameters recovery after MPA and SuperPATH for THA.

Conclusion

Both SuperPATH and MPA techniques showed excellent results. The SuperPATH technique was associated with lower postoperative pain, higher physical function and greater quality of life. Significantly improved functional outcomes allowed earlier postoperative rehabilitation and faster recovery. The results of gait analysis did not correspond to the significant functional and clinical outcomes; specific improvement in gait patterns were identified with insignificant differences between the two approaches at 6 weeks follow-up. Spatio-temporal parameters slightly favored the SuperPATH technique. Patient expectations of THA are to relieve pain and restore function; modern THA aims for better implant survivorship by balanced loading, enhanced function and biomechanical joint correction. These specific alterations need advanced diagnostic and analysis instruments, adapted to detect those alterations combined with cross-sectional imaging at different follow-up terms.

Declaration of conflicting interests

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