Postoperative pain as a risk factor for stiff knee following total knee arthroplasty and excellent patient-reported outcomes after manipulation under anesthesia

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Background and purpose — Manipulation under anesthesia (MUA) is the first-choice treatment for stiffness following total knee arthroplasty (TKA) unresponsive to pain management and physiotherapy. Some of the predisposing factors and patient-reported outcome measures (PROMs) following MUA remain poorly studied. We retrospectively investigated the etiological risk factors and the outcomes of MUA.

Patients and methods — 391 TKA patients from a randomized trial comparing the use of a tourniquet and anesthesia (spinal or general) were analyzed, and patients needing MUA were identified (MUA group). We evaluated in-hospital opioid consumption, Oxford Knee Score (OKS), range of motion (ROM), and pain assessed by the Brief Pain Inventory-short form with a 1-year follow-up.

Results — 39 (10%) MUA patients were identified. The MUA patients were younger (60 years vs. 64 years, difference –4, 95% CI –6 to –1) and had higher postoperative oxycodone consumption (66 mg vs. 51 mg, median difference 11, CI 1–22) than the no-MUA patients. The proportion of MUA patients who contacted the emergency department within 3 months because of pain was larger than that of non-MUA patients (41% vs. 12%, OR 5, CI 3–10). At the 1-year follow-up, the ROM was improved by 39° following MUA, but the total ROM was worse in the MUA group (115° vs. 124°, $p < 0.001$). No difference was found in the OKS between the MUA and no-MUA patients.

Interpretation — Higher postoperative pain seems to predict MUA risk. MUA performed 3 months postoperatively offers substantial ROM improvement and comparable PROMs to no-MUA patients 1 year after TKA.

Some patients will experience painful and functionally impaired stiff knees following total knee arthroplasty (TKA) (1). Several reasons for post-TKA stiffness have been proposed, with a low preoperative range of motion (ROM) described as the most important (2,3). Young age, prior surgeries on the target knee, lack of compliance, poor pain management, genetic factors, female sex, obesity, and tobacco smoking are also previously described risk factors (2-4). Additionally, component malalignment and oversizing have been described as causes of decreased function and ROM (2,5). The incidence of post-TKA stiffness has varied in recent studies, ranging from 0.5 to 16.6% (4,6-9).

The primary treatment for a stiff knee unresponsive to physiotherapy is manipulation under anesthesia (MUA) (2). MUA is a relatively safe procedure with a complication rate of < 1% (2,10,11). The optimal time point for MUA is a matter of debate. Several optimal time points for MUA, from 2 weeks to 4 months, have been suggested to achieve satisfactory results. However, MUA within the first 12 postoperative weeks is considered the most beneficial timing (2,4). The data regarding patient-reported outcome measures (PROMs), prolonged pain, and patient satisfaction after MUA is limited (2).

We aimed to identify the predisposing factors for postoperative stiff knee requiring MUA and MUA outcomes in a prospective patient cohort with 1 year of follow-up.

Patients and methods

Patients

We conducted a retrospective comparative analyses with regard to MUA for 391 patients who had undergone fast-track

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TKA in a randomized trial comparing the use of a tourniquet and two anesthesia methods (spinal or general) with a 1-year follow-up (12,13).

The original study was conducted at a single tertiary university hospital between October 2016 and December 2019. Patients aged 18–75 years with Kellgren–Lawrence grade 3–4 knee osteoarthritis, BMI ≤ 40, and ASA physical status class I–III who were eligible for TKA were included in the original study. Exclusion criteria were prior major surgery on the same knee, severe malalignment in mechanical axis (MA) radiograph (> 15°), severe extension (> 20°) or flexion (< 90°) deficits, and ongoing strong opioid usage.

Methods

We examined patient demographics and medical history, and the preoperative and 3- and 12-month outcome data. The outcome measures included Oxford Knee Score (OKS), OKS minimal important change (MIC) ≥ 6.5 points (14), Brief Pain Inventory short form (BPI-sf) (15), ROM measured using a goniometer, patient satisfaction with TKA assessed using a numerical rating scale (NRS 9–10 defined as satisfied with TKA and 0–8 defined as dissatisfied/other) and Patient Acceptable Symptom State (PASS; OKS ≥ 37 denotes satisfactory outcome with TKA) (16), and 15D health-related quality of life (HRQoL, 15D). We also examined the surgical and tourniquet times, anesthesia method, in-hospital oxycodone consumption, postoperative in-hospital pain with the NRS, length of stay (LOS), complications, and contacts with the emergency unit for any reason. A radiologist who was blinded to the outcomes evaluated the preoperative MA, postoperative tibio-femoral (TF) angle, and component position in terms of the femoral component medial angle (FMA), femoral component flexion angle (FFA), tibial component medial angle (TMA), and posterior tibial slope (PTS) from the preoperative and postoperative radiographs. Post-TKA stiffness and indication for MUA was defined as of flexion < 90° 3 months after surgery when infections, obvious malalignments, and component malpositions were ruled out.

All TKAs were performed through a midline incision and medial parapatellar approach with a single type of cemented cruciate-retaining total knee system (Triathlon, Mahwah, Kalamazoo, MI, USA) with patellar resurfacing. Implantation was performed according to the Triathlon measured resection technique targeting straight limb alignment (MA technique). No drains were used. All participating arthroplasty surgeons were experienced (at least 100 cemented Triathlon TKAs performed before entering the original study) (17).

All patients received standardized fast-track care, including multimodal analgesia and immediate ambulation without any restrictions. For the first 24 hours, patients could self-administer intravenous oxycodone via the patient-controlled analgesia (PCA) pump, and the amount of oxycodone used was recorded. Additionally, daily doses of 3 x 400–800 mg ibuprofen and 1 g paracetamol were administered. Following PCA, 5–15 mg extended-release oxycodone was given. We used 2 x 75–300 mg pregabalin as rescue medication if intolerable pain (NRS > 5) existed despite repeated doses of immediate-release oxycodone. From the second postoperative day, patients' multimodal analgesia comprised paracetamol, non-steroidal anti-inflammatory drugs, and codeine or tramadol (17). Postoperative anticoagulation was carried out with subcutaneous enoxaparin 40 mg once daily for 2 weeks unless the patient's comorbidities required other anticoagulation. All patients received a personal preoperative and postoperative physiotherapy consultation and instructions for post-discharge home-based knee exercises. After discharge, patients were advised to contact the operating unit if any problems arose. Postoperative outpatient clinic visits were scheduled at 3 and 12 months according to the original study plan (17).

At the 3-month follow-up visit, we measured passive ROM with a goniometer until the patient described discomfort. The ROM threshold for MUA was flexion < 90°. We also offered MUA for patients with flexion ≥ 90° if they reported insufficient ROM. We ruled out infection, malalignment, and component malposition clinically and by evaluating postoperative radiographs. MUA was performed as a closed procedure for all patients under general anesthesia with mask ventilation and a muscle relaxant. With the hip flexed to 90°, gentle and steady force was applied to the knee until audible separation of adhesions no longer occurred. Stability and ROM were investigated before and after MUA. Every patient received intra-articular bupivacaine following MUA. Immediate ambulation was performed with multimodal analgesia. All the MUA patients received a postoperative physiotherapist consultation and were given a home-based knee exercise manual.

Statistics

We divided the patients into 2 groups based on whether they underwent MUA (i.e., MUA and no-MUA). Normally distributed data were expressed as means (SD), non-normally distributed variables as medians (range), and differences for both with 95% confidence intervals (CI). Categorical data were expressed as frequencies and percentages with odds ratios (OR) and CI. To examine the differences in the continuous variables between the groups, we used the independent samples t-test and Mann–Whitney U-test. Fisher and chi-square tests and binary logistic regression were used to analyze the categorical data. We used IBM SPSS Statistics 27 (IBM Corp, Armonk, NY, USA) for all analyses, which were verified by an independent professional biostatistician.

Ethics, funding, and conflict of interest

The original study was approved by HUS Helsinki University Hospital and the Helsinki and Uusimaa District Ethics committee (June 8, 2016, ref: HUS1703/2016) and the Finnish Medicines Agency Fimea (June 8, 2016, ref: HUS1703/2016 and May 20, 2016, ref: KL72/2016). The original study was registered in EudraCT (May 12, 2016, ref: 2016-002035-15).

Table 1. Patient characteristics. Values are count (%) unless otherwise specified

Characteristic	MUA (n = 39)	No MUA (n = 352)	Odds ratio (95% CI)	Mean difference (95% CI)
Female sex	29 (74)	220 (63)	1.7 (0.8–3.7)	
BMI, mean (SD)	30 (4)	31 (5)		–0.7 (–2.1–0.8)
ASA score I–III, mean (SD)	2.1 (1)	2.2 (1)		–0.2 (–0.4–0.0)
Current smoking	3	41	0.6 (0.2–2.2)	
Alcohol use, median doses/week (range)	1 (0–16)	1 (0–30)		0 (0–0.5) [a]
Diabetes mellitus	6	58	0.9 (0.4–2.3)	
Medication for hypertension	16	198	0.5 (0.3–1.1)	
Previous PE/DVT	1	18	0.5 (0.1–3.8)	
Antithrombotic medication	7	73	0.8 (0.4–2.0)	
Asthma or COPD	4	49	0.7 (0.2–2.1)	
Sleep apnea (also suspected)	1	38	0.2 (0.0–1.6)	
Depression	1	26	0.3 (0.0–2.5)	
Tourniquet in use	23 (59)	174 (49)	1.5 (0.8–2.9)	
Spinal anesthesia	14 (36)	184 (52)	0.6 (0.3–1.0)	
General anesthesia	25 (64)	168 (48)	2.0 (0.98–3.9)	
Prior surgery to target knee [b]	12 (32)	144 (41)	0.7 (0.3–1.4)	
Reason for operation				
Primary arthrosis	36 (92)	329 (94)	0.8 (0.2–2.9)	
Rheumatoid/psoriatic arthritis	2	10	1.9 (0.4–8.8)	
Post-traumatic arthrosis	1	7	1.3 (0.2–11)	

MUA = manipulation under anesthesia; COPD = chronic obstructive pulmonary disease; PE = pulmonary embolism; DVT = deep vein thrombosis.
[a] Hodges–Lehman estimate for median difference.
[b] Minor surgery includes debridement or partial meniscectomy of the knee.

Signed informed consent was collected from every patient before participating in the original study (17). The study was funded by Helsinki University Hospital Finnish Government Science Grant, Helsinki University Hospital Grant, the Päivikki and Sakari Sohlberg Foundation, the Finnish Medical Foundation, the Research Foundation for Orthopaedics and Traumatology, and the Finnish Arthroplasty Association. The funders of the study had no role in the study design, data collection, data analysis, data interpretation, or writing of the report. The authors declare no conflicts of interest.

Results

The incidence of MUA was 10% (39/391). 5 patients with ROM < 90° (patients with extension deficit between 0° and 20° and knee flexion between 90° and 105°) at 3 months declined MUA. Every MUA patient completed the PROM questionnaires 1 year after TKA, and ROM was measured in 37 of the 39 patients. In the control group, the PROMs were completed by 343–346 of the 352 patients and ROM measured from 338 patients at the 1-year follow-up.

Patients needing MUA were significantly younger than the no-MUA patients (MUA 60 years [SD7] vs. no-MUA 64 years [SD7], mean difference –4, CI –6 to –1). No clinically significant differences were found regarding sex, BMI, alcohol or tobacco use, comorbidities, prior surgery on the target knee, or preoperative OKS, ROM, BPI-sf, and 15D (Tables 1 and 2). Surgical and tourniquet times, oxycodone consumption in the first 24 hours with PCA, postoperative pain at 24 hours, and LOS were similar between the 2 groups (Tables 3 and 4). However, in-hospital per oral oxycodone consumption (MUA 25 mg vs. no-MUA 20 mg, median difference 10, CI 0–20), and total postoperative in-hospital oxycodone consumption (MUA 66 mg vs. no-MUA 51 mg, median difference 11, CI 1–22) were significantly higher in the MUA group. The radiological evaluation revealed no differences between the groups in terms of the preoperative MA angle or postoperative TF angle, component sizing, or positioning (Table 5).

At the 3-month follow-up, prior to MUA, the OKS, ROM, and BPI-sf pain scores differed significantly, favoring no-MUA patients (Table 2). The proportion of MUA patients who contacted the emergency department because of pain was larger than that of non-MUA patients (MUA [16/39] vs. no-MUA [43/352], OR 5, CI 3–10). The groups were similar in terms of other complications (Table 6). The average time between index surgery and MUA was 13 weeks (SD 3, range 9–27). Following MUA, the patients were discharged on the day of MUA (34/39) or the first postoperative (5/39) day.

At 12 months, the improvement in OKS and the final OKS were similar. Additionally, no clinically important differences were noted regarding pain assessed using the BPI-sf (Table 2). Moreover, no statistically significant differences were found regarding the proportion of patients reaching OKS MIC (MUA [29/37] vs. no-MUA [299/341], OR 0.5, CI 0.2–1.2) or OKS PASS (MUA [27/38] vs. no-MUA [282/344], OR 0.5, CI 0.3–1.2). However, satisfaction with TKA was significantly greater in the no-MUA group (MUA [30/39] vs. no-MUA [298/337], OR 0.4, CI 0.2–0.99). The ROM was improved by 39° following MUA at the 1-year follow-up. The final ROM at 12 months was < 90° in only 1 patient in the MUA group and 1 patient in the no-MUA group (80° and 85°, respectively; Table 2). None of the MUA patients needed a second MUA, arthroscopic arthrolysis, or revision (Table 6). No complications related to MUA were noted.

Discussion

We found that postoperative pain was associated with stiffness, suggesting an unfavorable biological response to surgery or pain tolerance in this group. Additionally, we found that MUA performed 3 months after TKA is effective with a

Table 2. Patient-reported outcomes, knee range of motion, and changes in scores and knee motion between 0 and 12 months. Values are mean (SD) unless otherwise specified

Factor	No. of patients MUA/ No-MUA	MUA	No-MUA	Mean difference (95% CI)	p-value
OKS					
preoperatively	38/349	24 (7)	26 (56)	–2 (–4 to 0)	0.06
at 3 months	39/350	28 (8)	36 (7)	–8 (–11 to –6)	< 0.001
at 12 months [a]	38/343	42 (19–48)	43 (12–48)	–1 (–3 to 0) [b]	0.2
mean change [c]	37/341	15 (9)	15 (8)	–0.5 (–3 to 2)	0.7
ROM (°)					
preoperatively	39/351	113 (19)	113 (15)	0 (–5 to 5)	0.9
range		75–140	68–150		
at 3 months	39/350	76 (13)	115 (12)	–39 (–43 to –35)	< 0.001
range		35–90	80–140		
at 12 months	37/338	115 (13)	124 (11)	–9 (–13 to –6)	< 0.001
range		80–138	85–150		
Extension deficit (°)					
preoperatively	39/351	5 (5)	6 (6)	–1 (–3 to 1)	0.2
at 3 months	39/350	6 (6)	1 (3)	4 (3 to 5)	< 0.001
range		0–20	0–20		
at 12 months	37/338	1 (3)	0 (2)	1 (0 to 1)	0.03
range		0–10	0–15		
Flexion (°)					
preoperatively	39/351	118 (16)	119 (12)	–1 (–5 to 3)	0.6
at 3 months	39/350	81 (11)	116 (10)	–35 (–38 to –31)	< 0.001
range		40–95	90–140		
at 12 months	37/338	116 (12)	124 (10)	–9 (–12 to –5)	< 0.001
range		85–138	90–150		
BPIsf pain severity					
preoperatively	38/349	4.4 (1.9)	3.8 (1.7)	0.6 (0.0 to 1.2)	0.04
at 3 months [a]	39/349	3.3 (0.0–8.8)	1.8 (0.0–8.3)	1.0 (0.3 to 1.8) [b]	0.002
at 12 months [a]	39/346	2.0 (0.0–8.8)	1.3 (0.0–7.3)	0.0 (0.0 to 0.8) [b]	0.3
mean change [c]	38/343	2.1 (2.2)	2.0 (2.1)	0.1 (–0.6 to 0.8)	0.8
BPIsf pain interference					
preoperatively	39/345	4.6 (2.0)	4.4 (2.2)	0.2 (–0.5 to 0.9)	0.5
at 3 months [a]	39/348	3.4 (0.0–8.6)	1.6 (0.0–9.9)	1.6 (0.7 to 2.4) [b]	< 0.001
at 12 months [a]	39/345	1.3 (0.0–7.3)	0.7 (0.0–8.4)	0.3 (0.0 to 1.3) [b]	0.02
mean change [c]	39/338	2.0 (2.6)	2.9 (2.5)	–0.8 (–1.7 to 0.0)	0.05
15D					
preoperatively	38/348	0.87 (0.063)	0.86 (0.068)	0.007 (–0.016 to 0.030)	0.5
at 3 months	39/347	0.86 (0.067)	0.89 (0.075)	–0.032 (–0.057 to –0.007)	0.01
12 months	39/346	0.89 (0.085)	0.91 (0.077)	–0.017 (–0.043 to 0.009)	0.2
mean change [c]	38/342	0.019 (0.076)	0.044 (0.067)	–0.025 (–0.048 to –0.003)	0.03

[a] Values are median range
[b] Hodges–Lehman estimate for median difference.
[c] 0–12 months
MUA = manipulation under anesthesia; OKS = Oxford Knee Score; ROM = range of motion; BPIsf = Brief Pain Inventory short form (scale 0–10) with minimal important difference 1.0 points; 15D = a validated and generic 15-dimensional tool assessing health-related quality of life. 15D score range is 0 (death) to 1 (full health); average value is 0.9 or higher in randomly selected Finnish population (30 years or older). 15D minimal important difference and minimal important change are ≥ 0.015. Change in 15D score with Global Assessment Scale: > 0.035 = "much better," 0.015–0.035 = "slightly better," > –0.015 and < 0.015 = "the same," –0.035 to –0.015 = "slightly worse," and < – 0.035 = "much worse."

39° mean improvement in the ROM, resulting in comparable PROMs compared with the no-MUA group at 1 year. No complications occurred with the MUA, aligning with the rare incidence of complications described in previous studies (2,10).

Postoperative pain has previously been postulated to cause a decrease in ROM, thereby increasing the likelihood of MUA. In a retrospective study of 1,136 TKA patients by Lavernia et al., multimodal analgesia decreased the MUA incidence from 5% to 2% (18). However, in a recent study by Harmer et al., no relationship between in-hospital postoperative pain and decreased ROM was noted (19). In contrast, our study found that patients needing MUA required more opioids during the in-hospital period and had substantially more pain during the first 12 postoperative weeks than the no-MUA group. These findings implies that postoperative pain is a critical etiological factor in stiffness, even with standardized and up-to-date multimodal pain management.

The different timing, ROM thresholds, and surgeons' and patients' perceptions of adequate ROM in clinical practice affect the incidence of MUA (4). The choice to perform MUA for individual patients remains unclear in many retrospective studies, and a lack of consensus regarding the optimal timing and ROM thresholds for MUA exists (4,8,11,20). If a very early time point for MUA is chosen, many patients may receive unnecessary procedures, possibly increasing the complication rate (21). On the other hand, if a very late timepoint is selected, the benefit of MUA may be meager (20). However, a threshold of < 90° flexion at 12 weeks postoperatively can be considered the most usual indication for MUA (2,4,19).

In a recent retrospective study, the incidence of MUA in fast-track TKA was reported to be 2% (22). However, in a post hoc analysis of a randomized study of 476 TKAs comparing cemented and non-cemented cruciate-retaining TKA by Esler et al., a 10% (47/476) incidence of MUA was found when using a threshold of 80° flexion at 11 weeks as an indication for MUA. In addition, 21 patients meeting the 80° threshold declined MUA, raising the true incidence of stiffness to 14% (23). Our results and that study by Esler et al. suggest the true incidence of post-TKA stiffness is higher than previously reported if consistent thresholds for MUA are used. The differences in the MUA rates in these randomized controlled trials and retrospective data are substantial, indicating variance in the indications for different surgeons and institutions.

Table 3. Surgical and tourniquet times, and length of stay. Values are mean (SD) unless otherwise specified

Factor	No. of patients MUA/No-MUA	MUA	No-MUA	Mean difference (95% CI)
Surgical time, minutes	39/352	85 (17)	89 (20)	–4 (–11–2)
Tourniquet time, minutes	23/174	76 (14)	80 (17)	–4 (–12–3)
Length of stay, hours [a]	38/352	71 (45–147)	52 (44–525)	2 (0–5) [b]

[a] Values are median range
[b] Hodges–Lehman estimate for median difference.
MUA = manipulation under anesthesia.

Table 4. Postoperative opioid consumption and pain. Values are mean (SD) unless otherwise specified

Factor	No. of patients MUA/No-MUA	MUA	No-MUA	Mean difference (95% CI)
Oxycodone [a]	39/352	43 (0–110)	39 (0–186)	3 (–5–10) [b]
Pain 24 h postoperatively [c]				
at rest	39/352	3.8 (2.6)	3.3 (2.2)	0.45 (–0.29–1.2)
knee flexed 45°	38/350	6.6 (2.6)	6.1 (2.3)	0.49 (–0.29–1.3)
after walking 5 m	35/337	5.5 (2.5)	5.4 (2.2)	0.10 (–0.68–0.88)

[a] Values are median range mg/24 h patient-controlled analgesia
[b] Hodges–Lehman estimate for median difference.
[c] Assessed by the numerical rating scale (NRS = 0–10).
MUA = manipulation under anesthesia.

Table 5. Limb alignment and component positions. Values are mean (SD)

Factor	No. of patients MUA/No-MUA	MUA	No-MUA	Mean difference (95% CI)
Preoperative MA° [varus]	39/351	5 (6)	5 (6)	0 (–1.9–2.1)
Postoperative TFA° [valgus]	39/352	3 (2)	3 (2)	0 (–1.2–0.4)
Component FMA° [valgus]	39/351	4 (2)	4 (2)	0 (–0.8–0.3)
Component FFA° [flexion]	39/350	2 (3)	2 (3)	0 (–1.0–1.2)
Component TMA° [varus]	39/350	1 (2)	1 (2)	0 (–1.1–0.2)
Component PTS° [posterior]	39/351	6 (3)	5 (3)	1 (–0.2–1.9)
Tibial component ML overhang, mm	39/351	0 (1)	0 (1)	0 (–0.6–0.2)

Angles are presented in degrees with direction from zero-axis [direction].
MUA = manipulation under anesthesia; MA = mechanical axis; TFA = tibio-femoral angle; FMA = femoral component medial angle; FFA = femoral component flexion angle; TMA = tibial component medial angle; PTS = posterior tibial slope; ML = medio-lateral.

Regarding the effect of surgeons' perception to perform MUA, Vun et al. found that the number of surgeons performing MUA varies from 46% routinely performing to 11% never performing it, affecting the overall number of MUAs performed (24). Ultimately, the surgeon usually decides to perform MUA, which may be influenced by the surgeon's and patient's perspectives regarding acceptable outcomes, especially during the early recovery period. In addition, the proportion of patients with stiff knees who decline or otherwise do not end up having MUA remains elusive. Anecdotally, the 5 patients in our study with ≤ 90° ROM at 3 months who declined MUA ended up with ROM 0–90°, 15–105°, 15–100°, 0–120°, and 0–140° at the 12-month follow-up. To our knowledge, the natural course of the stiff knee remains unexplored.

The previous retrospective case series or matched case-cohort studies have focused mainly on MUA incidence concerning predisposing comorbidities while using ROM as a functional outcome. We found only one previous study reporting PROMs following MUA (25). This study, by Dzaja et al., found comparable PROMs between the MUA patients and the patients not requiring MUA. However, the previous data regarding the outcomes of MUA is confounded in multiple ways. These confounders include differences in TKA performance and implant design, a lack of information on postoperative pain management, inconsistent ROM and time thresholds for MUA, and a lack of information regarding the number of patients declining or not offered MUA.

Our study has several limitations. First, our findings present retrospective analyses of the results of a randomized controlled trial that had complications as a secondary outcome. Thus, the results may possibly be underpowered for a definitive conclusion regarding MUA incidence. Second, we could not evaluate the effects of patellar resurfacing (26), component rotational alignment, or the implant's single radius design on the risk for MUA. Third, the study population was limited to patients aged no more than 75 years without previous major surgery on the target knee, severe flexion or extension deficits, or malalignment, including only patients with ASA I–III and BMI ≤ 40.

This study's strengths were the prospective data collection with standardized surgery, anesthesia, and perioperative care creating a comparable control group to the MUA group. Additionally, standardized time and ROM thresholds for MUA were used. Neither group of patients had previous use of strong opioids, preventing the confounding effect of opioid use in interpreting the results. The study included up-to-date fast-track rehabilitation protocols with multimodal pain management, ensuring adequate pain management and rehabilitation. Furthermore, only one implant design with patellar resurfacing was used for all patients and implanted by experienced surgeons, further decreasing the risk of confounders. Moreover, we evaluated the effect of preoperative MA and postoperative component positioning on the risk for MUA.

Conclusions

According to our results, MUA performed 3 months postoperatively improves ROM and results in comparable PROMs

1 year after TKA compared with patients without stiffness. Patients at risk of severe postoperative pain should be screened and offered more targeted and enhanced pain management to avoid postoperative stiffness. MUA performed with consistent time, and ROM thresholds, may possibly decrease the future risk of revision because of stiffness. Future pragmatic prospective studies are needed to evaluate the natural course of postoperative stiffness and the incidence of MUA more accurately.

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