Arthroplasty Today 27 (2024) 101397

Contents lists available at ScienceDirect

Arthroplasty Today

journal homepage: http://www.arthroplastytoday.org/

Original Research

Postoperative Continuous Passive Motion Does Not Improve the Range of Movement Achieved After Manipulation Under Anesthetic for Stiffness in Total Knee Replacement

Bernard H. van Duren, DPhil, FRCS[a, b, *], Katie Lee, BSc, MCSP, SRP[a], Amy M. Firth, FRCS[a], Efosa Imuetinyan, MD[a], Kevin Ilo, FRCS[a], Reshid Berber, PhD, FRCS[a], Hosam E. Matar, FRCS[a], Benjamin V. Bloch, FRCS[a]

[a] Nottingham Elective Orthopaedic Services, Nottingham University Hospitals NHS Trust, Nottingham, UK
[b] Leeds Institute of Rheumatic and Musculoskeletal Medicine, University of Leeds, Leeds, UK

ARTICLE INFO

Article history:
Received 19 December 2023
Received in revised form
25 March 2024
Accepted 2 April 2024

Keywords:
CPM
MUA
TKA
Stiffness
ROM

ABSTRACT

Background: Stiffness is a common complication following total knee arthroplasty. Manipulation under anesthesia (MUA) is an intervention that can potentially improve range of motion (ROM). Continuous passive motion (CPM) therapy has been utilized to enhance post-MUA ROM, but its effectiveness remains debated. This study assesses whether CPM therapy after MUA results in superior ROM outcomes compared to MUA alone.

Methods: A retrospective analysis included patients undergoing MUA for stiff primary total knee arthroplasty between 2017 and 2022. Demographics and ROM data were collected. Patients were in 2 groups: those who received inpatient CPM post-MUA and those who received day-case MUA alone. Complications and further interventions were noted.

Results: Of 126 patients, 39 underwent MUA only (day-case group), and 87 received CPM and MUA (inpatient group). Mean preoperative ROM was 69.4° (standard deviation [SD]:18.0°) and 73.9° (SD: 18.1°) for inpatient and day-case groups, respectively. Mean post-MUA ROM improved by 39.4° (SD: 17.7°) and 25.5° (SD: 11.1°) inpatient groups and day-case, respectively. The mean percentage of ROM gained at MUA maintained at final follow-up was 63.7% (40.8%) and 67.0% (47.5%) inpatient and day-case groups, respectively.

Conclusions: This study found no advantage in the routine use of CPM post-MUA for stiff total knee replacement patients, suggesting it may not provide sustained ROM improvements compared to MUA alone. Cost-effectiveness and patient selection merit further investigation.

Introduction

Total knee arthroplasty (TKA) is an established treatment for end-stage arthritis with excellent long-term survival and future numbers projected to grow [1–3]. However, despite this success, up to 20% of patients can remain dissatisfied following TKA [3,4]. Stiffness after TKA is a recognized factor contributing to dissatisfaction and is reported in up to 12% of all patients after having TKA [5,6]. Limitations to the knee's range of motion (ROM) can limit a patient's ability to undertake activities of daily living. Studies have shown that a knee flexion of 83°, 93°, and 106° are required to walk upstairs, sit on a chair, and tie shoelaces, respectively [7].

Several treatment options for treating stiff TKA include physical therapy, manipulation under anesthesia (MUA), arthroscopic debridement, open debridement, and revision surgery [8]. The treatment of stiffness after TKA remains a challenge with 4% of all TKA revisions performed for stiffness [1]. A commonly employed treatment modality is MUA. MUA accounts for 6%-36% of readmissions following TKA [9]. This procedure aims to overcome adhesions while flexing the knee forcefully.

* Corresponding author. Elective Orthopaedic Services, Nottingham City Hospital, Hucknall Rd, Nottingham NG5 1PB, UK. Tel.: +0115 969 1169.
E-mail address: b.h.vanduren@gmail.com

https://doi.org/10.1016/j.artd.2024.101397

Significant improvements in ROM can be achieved using MUA especially if performed within 3 months of surgery [10,11]. However, maintaining the improvement in range of movement post-MUA can be a challenge. Therefore, continuous passive motion (CPM) as an adjuvant therapy often used in an attempt to achieve this. In the United Kingdom, 68% of surgeons routinely use CPM postmanipulation [12]. Benefits of CPM such as improved ROM, minimization of joint stiffness and decreased hospital stay have been reported [13,14]. Although both MUA and CPM have been reported to a moderate extent in the literature, they remain the subject of debate.

We hypothesize that combining both would lead to more significant and sustained improvements in the ROM. However, to our knowledge, there are no published studies specifically evaluating the effectiveness of CPM post-MUA and whether its use is beneficial regarding maintaining ROM. This study aimed to establish if the use of CPM postoperatively after MUA undertaken for stiff TKA improved the ROM more than MUA alone.

Material and methods

The standard practice at our institution (a high-volume arthroplasty unit and tertiary referral center) for the management of stiffness post-TKA was to admit patients overnight in hospital when undergoing MUA. CPM would be administered overnight following MUA. Due to the coronavirus disease 2019 pandemic, hospital admissions were strictly limited to those that were absolutely necessary. As a result, during this period, MUA procedures were undertaken without subsequent overnight inpatient stay. Therefore, all MUAs performed were done as day-case procedures with no inpatient stay for CPM. We retrospectively compared 2 cohorts of patients treated for a stiff TKA in a 5-year period. One cohort received CPM post-MUA (inpatient CPM prepandemic) and the other received no CPM post-MUA (day-case MUA during the pandemic).

Institutional approval was obtained. We retrospectively identified all patients who underwent MUA for a stiff primary TKA between January 2017 and December 2022. Patients who underwent a revision total knee replacement (TKR) or had any neuromuscular condition affecting their mobility were excluded. All patients had undergone a primary TKA and experienced limitations to their ROM postoperatively. All patients had undertaken physiotherapy to improve their ROM and were assessed by a consultant orthopaedic surgeon or arthroplasty fellow prior to proceeding to MUA. All MUAs were performed under a general anesthetic and performed by a consultant orthopaedic surgeon or arthroplasty fellow. Only first-time MUA post primary TKA were included.

Patients who received CPM were immediately placed onto CPM after the MUA and the degree of flexion was adjusted to what the patient could tolerate. Constant CPM was continued for a total of 12-14 hours. Both cohorts of patients received intensive outpatient physiotherapy after MUA. Physiotherapy focused on active range of motion of the knee. Electronic patient records were analyzed to ascertain patient demographic data; age, gender, body mass index, premanipulation ROM, postmanipulation ROM, and ROM at the final follow-up (or before further intervention in the cases these were undertaken) were recorded for each patient. Records were consulted to confirm if the patient sustained any complications or required further management such as repeat MUA, arthroscopic/open arthrolysis or implant revision. Students t-test and Fisher's exact test were used to compare the outcomes between groups for significance. A P value of less than .05 was taken to represent a significant difference.

Results

In total, 126 MUA procedures on 126 patients meeting the criteria performed between 2017 and 2022 were identified. Thirty-nine patients had received MUA only (day-case group), and 87 had received CPM and MUA (inpatient group). The mean age was 65.2 years and 64.1 years for the inpatient and day-case groups, respectively. Mean time from primary TKR to MUA (mean days) was 403.7 and 373.1 for inpatient and day-case groups, respectively. Table 1 summarizes the demographics of the patients and procedures for the 2 groups.

Pre-MUA ROM

Preoperatively 45 (51.7%) of patients in the inpatient group and 26 (66.7%) in the day-case group had stiffness in extension of 5° or more. Sixty-three (72.4%) of patients in the inpatient group and 25 (64.1%) in the day-case group had stiffness in flexion achieving less than 90° with 30 (38.5%) and 13 (33.3%), respectively, having both stiffness in extension and flexion. The mean preoperative ROM was comparable for the 2 groups with the inpatient group having 69.4° (standard deviation [SD]: 18.0°) and the day-case group 73.9° (18.1°). There was no significant difference between the 2 groups (Table 2). Similarly, there were no significant differences in preoperative means for flexion and extension.

Post MUA ROM

The mean ROM recorded post-MUA was 108.8° (SD: 13.2°) and 98.42° (18.0°) for inpatient and day-case groups, respectively. This equated to a mean improvement in ROM of 39.4° (17.7°) and 25.5° (11.1°) at the time of MUA for inpatient and day-case groups, respectively (Table 3). Both mean post-MUA ROM and mean improvement were found to be statistically significant.

Final follow-up ROM

At final follow-up the majority of patients had not maintained the ROM achieved at MUA with 68 (80%) and 25 (69.4%) having reduced ROM for inpatient and day-case groups, respectively (Table 3). The mean ROM at the final follow-up was 93.4° (SD: 17.44°) and 89.7° (SD: 21.5°) for inpatient and day-case groups, respectively, which was not statistically significant (Table 2).

Effect of CPM on maintaining ROM post-MUA

The mean percentage of ROM gained at MUA maintained at the final follow-up was 63.7% (SD: 40.8%) and 67.0% (SD: 47.5%) for inpatient and day-case groups, respectively, which was not statistically significant. At the final follow-up for the day-case and inpatient CPM groups, respectively, 8.2% vs 5.6% improved, 14.1% vs

Table 1
Demographic data.

Variable	Inpatient (MUA + CPM)	Day-case (MUA only)	P value
No. of patients	87	39	
Mean age (at time of procedure)	65.2	64.1	.56
BMI (mean)	32.8	31.3	.43
Gender (% female)	64.4%	61.5%	.84
Days from TKA to MUA (mean)	403.7	373.1	.74

Table 2
Table summarizing mean ROM values for the inpatient and day-case groups.

	Inpatient (MUA + CPM)	Day-case (MUA only)	*P* value
Total n	87	39	
Extension stiffness n (%)	45 (51.7%)	26 (67.0%)	.13
Flexion stiffness n (%)	63 (72.4%)	25 (64.1%)	.4
Both n (%)	30 (34.5%)	13 (33.3%)	.99
Pre-MUA ROM mean (SD) [n = 87/39]			
Ext	6.0 (8.9)	7.7 (9.6)	.34
Flex	75.4 (18.0)	81.6 (18.4)	.08
ROM	69.4 (18.0)	73.9 (18.1)	.19
Post-MUA ROM (SD) [n = 86/38]			
Ext	2.4 (4.7)	4.1 (7.3)	.12
Flex	111.2 (12.0)	102.5 (16.3)	.001
ROM	108.8 (13.2)	98.4 (18.5)	<.001
ROM at final follow-up [n = 85/36]			
Ext	4.6 (8.4)	3.3 (6.7)	.43
Flex	97.7 (15.5)	93.1 (19.6)	.17
ROM	93.4 (17.4)	89.7 (21.5)	.33
Post-MUA and pre-MUA ROM difference [n = 85/36]			
Ext	−3.6 (5.95)	−3.7 (4.9)	.96
Flex	35.7 (17.7)	21.9 (11.3)	<.001
ROM	39.4 (17.7)	25.5 (11.1)	<.001
Final ROM and post-MUA difference [n = 85/36]			
Ext	2.1 (6.2)	0.6 (3.4)	.15
Flex	−13.4 (13.7)	−5.7 (25.5)	.03
ROM	−15.4 (15.0)	−6.3 (24.4)	.01

33.3% maintained, and 80% vs 69.4% regressed from the ROM achieved at MUA (Table 3).

Complications

There were no fractures, wound complications, or hematomas reported.

Further procedures

Further MUA was performed in 22 (25.3%) and 16 (41.0%) in the inpatient and day-case groups, respectively (Table 4). Fourteen (16.1%) of the inpatient group went onto (or are scheduled for) revision surgery as were 6 (15.4%) of the day-case group. Table 4 also includes an overview of the primary indications for revision.

Table 3
Table summarizing findings when maintenance of ROM achieved at MUA was looked at.

	Inpatient (MUA + CPM)	Day-case (MUA only)	*P* value
Total n	85	36	
Increase in ROM post-MUA (% of pre-op ROM)	68.8% (52.8)	38.1% (31.2)	<.001
ROM gained at MUA maintained at final follow-up (% of MUA final f/u/MUA ROM)	63.7% (40.8)	66.97 (47.5%)	.71
No. of patients improving on MUA ROM at final follow-up (%)	7 (8.2%)	2 (5.6%)	.72
No. of patients maintaining MUA ROM at final follow-up (%)	12 (14.1%)	12 (33.3%)	<.05
No. of patients with reduced ROM from MUA at final follow-up (%)	68 (80.0%)	25 (69.4%)	.24

Table 4
Table of further interventions required for recurrent stiffness.

Further interventions	Inpatient (MUA and CPM)	Outpatient (MUA only)
	No. patients (%)	No. patients (%)
MUA	22 (25.3%)	16 (41%)
Arthrolysis	3 (3.4%)	1 (2.6%)
Revision	14 (16.1%)	6 (15.4%)
Infection	4 (4.6%)	1 (2.6%)
Stiffness	3 (3.4%)	5 (12.8%)
Loosening	2 (2.3%)	-
Instability	2 (2.3%)	-
Progressive OA (patella resurfacing)	3 (3.4%)	-

Discussion

This work shows that at final follow-up there was no significant difference in ROM achieved with the use of CPM as an adjunct to MUA when compared to MUA alone suggesting that the use of CPM may be of no benefit. Greater improvement in ROM was achieved at MUA for the inpatient (MUA + CPM) group over the day-case group ($P < .001$); however, there was a significantly reduced retention of ROM post-MUA at the final follow-up. The inpatient group lost a mean of 15.4° (SD: 15.0°) from MUA as opposed to 6.3° (24.4°) in the day-case group ($P = .01$).

The existing body of literature lacks consensus on the efficacy of routine CPM administration post-TKR, with reports of CPM not providing any benefit [15,16]. Others report significant improvements in ROM can be achieved using MUA especially if performed within 3 months of surgery [10,11]. Once postoperative stiffness has been established, MUA is a widely adopted treatment approach aimed at breaking up adhesions and scar tissue that restrict joint mobility in TKR patients. CPM is routinely used by 68% of UK surgeons postmanipulation [12]. Following MUA, CPM is theoretically expected to preserve the ROM achieved during the procedure by preventing the reformation of adhesions. CPM offers passive joint motion without necessitating active muscle engagement, potentially proving beneficial during the early stages of rehabilitation when patients often experience diminished muscle strength or pain during active movements. Additionally, CPM therapy tends to be well-tolerated by patients and is believed to mitigate pain and discomfort associated with stiffness and surgical trauma [17]. However, despite these theoretical advantages, the prevalent use of CPM therapy post-MUA is not substantiated by the available evidence in medical literature. To our knowledge, no study comparing the effectiveness of CPM after MUA in patients with stiff TKA to MUA alone has previously been published.

Surprisingly, our results indicate that patients who underwent CPM therapy experienced a statistically significant reduction in ROM from that achieved at MUA, compared to those who did not receive CPM. Intriguingly, both groups had similar preoperative ROM, and all patients demonstrated an improvement in ROM post-MUA. Notably, the improvement was more pronounced in the inpatient group, possibly owing to their lower pre-MUA ROM, which allowed for more substantial gains. This difference may also be explained by the fact that the day-case group were procedures undertaken during the COVID pandemic period when the threshold for undertaking surgery was higher and as such only the most severe cases were treated with MUA. Furthermore, our study highlights that the ROM gained at MUA and maintained at the final follow-up was greater in patients who did not undergo CPM therapy post-MUA. In contrast to its intended function, our findings suggest that CPM may lead to a reduction in ROM maintained over

the long term. This aligns with previous studies indicating no clinically significant difference in ROM with the use of CPM post-TKR [18–20].

It is essential to acknowledge certain aspects of our study that may impact the interpretation of these results. The average time to MUA in our study exceeded 9 months, with a substantial proportion of patients undergoing MUA beyond the 3-month post-TKA period, which is recognized as the most effective timeframe [10,11]. In total 6 (15.4%) patients in the day-case group and 33 (37.9%) patients in the inpatient group had their MUA within 3 months of the primary procedure. The reasons for this are compound. Not all patients were presented with stiffness within 3 months of their primary surgery either due to delay in referral to tertiary services or delayed onset. Similarly delays in scheduling MUA may also have contributed to these timeframes; this is possibly illustrated by the low 15.4% being done within 3 months during the pandemic period. Despite the extended duration, both groups demonstrated substantial improvements post-MUA, therefore we do not believe that the time delay significantly affected the outcome of CPM therapy. Another factor is the average body mass index of the patients, which fell within the overweight category. It is well reported the negative effects body mass index has on TKA outcomes and postoperative ROM [21,22]. Increased thigh and calf circumference in obese patients can limit ROM, potentially impacting the effectiveness of CPM. Studies have also reported that obese patients showed significantly slower progress with CPM and that obesity has a negative effect on therapy [22]. This underscores the importance of considering patient-specific factors when implementing rehabilitation strategies.

Our results bring into question whether CPM therapy, particularly when administered in an inpatient setting, is a cost-effective intervention. The financial resources required for inpatient CPM, including the cost of the machine, the need for nursing staff and physiotherapists to manage the CPM machine, and the inpatient bed should be carefully considered in light of our findings. In times when healthcare resources are under strain, it is crucial to ensure that interventions deliver long-term benefits and potential cost savings associated with improved joint function and fewer complications. As such, the cost-effectiveness of CPM therapy comes into question, with some studies suggesting that the financial burden may outweigh the clinical advantages [18,23].

While our study found no complications associated with either MUA or CPM, it is important to note that CPM use itself is not without risk. Prolonged or overly aggressive CPM sessions can result in localized bruising, swelling, extensor lags, neuropraxia, and increased analgesia use [24,25]. Interestingly, our study did indicate that patients who received CPM required fewer interventions for persistent stiffness (Table 4). This finding contradicts our other results, which showed a reduction in ROM in the CPM group. This discrepancy highlights the need for further studies to identify specific patient profiles that may benefit from CPM.

While the CPM cohort achieved a greater improvement in ROM at the final follow-up, this advantage was not significant and can be attributed to the superior ROM achieved at MUA rather than the effect of CPM therapy. An analysis of the percentage of ROM gained at MUA and maintained at follow-up revealed that the majority of patients regressed from the ROM achieved at MUA in both groups, with those in the inpatient group maintaining 63.7% and those in the day-case group 67.0%. Our observation suggests that admitting patients for CPM after MUA does not improve the ROM achieved after MUA.

There are several limitations to our study. First, we did not record pre-TKR ROM, which could have provided valuable baseline data. Additionally, detailed information on each patient's specific CPM protocol, including duration, frequency, and patient compliance, was not available. Variations in CPM protocols and patient adherence may have contributed to the observed results. Further research is warranted to determine the optimal CPM parameters for stiff TKR patients post-MUA. The retrospective nature of the study introduces the possibility of selection bias and confounding variables. Given the limited number, particularly in the day-case group, our study is likely underpowered and as such we did not explore potential subgroups of patients who might benefit from CPM post-MUA, which may exist within the broader cohort. The scope of our study did not investigate other factors that could potentially influence ROM post-TKA, such as changes in mechanical alignment.

Conclusions

In conclusion this study found no advantage in the routine use of CPM post-MUA for stiff TKR patients challenging the routine use of CPM following MUA. This highlights the need for further investigation to refine CPM parameters and identify specific patient populations that may benefit. Moreover, a comprehensive evaluation of the cost-effectiveness of CPM should consider both short-term costs and long-term outcomes, including patient satisfaction and functional improvement.

Conflicts of interest

Consultancy fees are received by some of the authors from DePuy Synthes, Zimmer Biomet, Ethicon. Authors have received institutional research funding from DePuy Synthes and Medacta International for unrelated projects. Open-access publication was funded by the Nottingham University Hospitals Charity's Trauma & Orthopedics Postgraduate Fund.

For full disclosure statements refer to https://doi.org/10.1016/j.artd.2024.101397.

CRediT authorship contribution statement

Bernard H. van Duren: Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Katie Lee:** Writing – review & editing, Data curation. **Amy M. Firth:** Writing – review & editing, Validation, Investigation. **Efosa Imuetinyan:** Data curation. **Kevin Ilo:** Writing – review & editing, Methodology. **Reshid Berber:** Writing – review & editing, Supervision. **Hosam E. Matar:** Writing – review & editing, Supervision, Conceptualization. **Benjamin V. Bloch:** Writing – review & editing, Supervision, Methodology, Conceptualization.

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