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COMPARISON OF DIFFERENT SURGICAL APPROACHES IN TOTAL KNEE ARTHROPLASTY REGARDING THE EARLY POSTOPERATIVE REHABILITATION OUTCOMES

PhD thesis

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Table of contents

List of Abbreviations

CI - Confidence interval
KSS – Knee Society Score

MCID - minimal clinically important difference

MD - Mean difference

MP – Medial parapatellar

MV – Midvastus

NSAID - Non-steroidal anti-inflammatory drugs

OA – Osteoarthritis

PICO - Population, Intervention, Comparator, Outcome

QS – Quadriceps sparing

RCT - Randomized controlled trial

ROM - Range of motion

SD - Standard deviation

SLR - Striaght leg raise

SV – Subvastus

THA - Total hip arthroplasty

TKA - Total knee arthroplasties

US – United States

VAS - Visual Analalogue Scale

WOMAC - Western Ontario and McMaster Universities Osteoarthritis Index

1. Introduction

Osteoarthritis (OA), colloquially referred to as the "wear and tear" disease, predominantly affects the elderly and is increasing in prevalence globally. As of 2019, OA had a global prevalence of 7.09% and an incidence rate of 536 per 100,000 individuals.(1) This condition significantly impacts quality of life, leading to chronic pain and disability. Consequently, joint arthroplasties, particularly total hip arthroplasties (THA) and total knee arthroplasties (TKA), have become the most successful treatment options. These procedures have not only increased in frequency but are projected to rise further due to the aging population and the durability challenges of prosthetic components. Musculoskeletal disorders, such as knee osteoarthritis, are major contributors to the loss of healthy life years due to disability.(2,3) The increasing incidence and prevalence of osteoarthritis are driving the rise in total joint arthroplasties globally, imposing a growing socioeconomic burden on healthcare systems.

Concurrently, younger patients are increasingly undergoing these procedures. In Germany, between 2008 and 2018, there was a 46.3% increase in primary knee arthroplasties among patients younger than 65 years.(4) Between 2005 and 2018, Germany recorded a total of 2,151,448 primary TKAs. During this period, the annual number of TKA procedures increased from 128,932 in 2005 to 170,494 in 2018, representing a 32.4% increase.(5)

The lifetime risk of undergoing primary TKA in the United States (US) was calculated 7.0% (95% CI: 6.1% to 7.8%) for males and 9.5% (95% CI: 8.5% to 10.5%) for females in 2013 and the overall prevalence of TKA among US adults aged fifty and older was estimated at 4.2% (95% CI: 3.7% to 4.6%).(6) In 2008, 615,050 TKA procedures were performed in the United States, representing a 134% increase from 1999, while the population grew by 11%. Notably, the number of TKAs more than tripled among individuals aged 45 to 64, despite a 29% population growth in this age group.(7)

Between 2003 and 2013, there was a 105% increase in the utilization of TKA procedures in Australia. In 2003, the TKA rate was 123 per 100,000 population, rising to 213 per 100,000 population by 2013. The most significant absolute growth in TKA procedures occurred among individuals aged 40–69 years, while the number of procedures for those under 40 years remained relatively unchanged. The total cost of TKA escalated from AUD 448 million in 2003 to AUD 905 million in 2013.(8)

The prevalence of TKA in Finland increased from 1.1% in 2000 to 2.6% in 2010 and 4.0% in 2020, reflecting a 270% rise between 2000 and 2020 and a 56% increase from 2010 to 2020. The total number of TKA implants escalated from 7,535 in 1990 to 34,884 in 2000, and further to 162,711 in 2020.

The future burden of THA and TKA is immense, with a notable increase in revision surgeries due to the aging demographic. Over the last two decades, several studies have predicted a surge in primary procedures some of the different projections estimate a surge up to 250% in the need for total knee prosthetic implants.(5,9–13)

Various methodologies have been employed to project the future volume of arthroplasties, resulting in differing estimates. One of the most impactful studies by Kurtz et al. in 2007 projected a 673% increase in primary TKA demand and a 174% increase in THA by 2030 in the United States.(14) According to an other estimation the number of TKAs performed annually in the United States is expected to increase by 143% from 2012 to 2050, reaching approximately 1.5 million cases per year by mid-century.(11) Compared to the 2014 National Inpatient Sample (NIS) data, the total annual utilization of primary total knee arthroplasty (TKA) in the United States is projected to increase by 56% in 2020, 110% in 2025, 182% in 2030, and 401% by 2040.(10)

Based on recent growth trends regarding Australia, the incidence of (TKA) for (OA) is projected to rise by 276% by 2030. If current surgical trends for OA persist, Australia will face an unsustainable burden of joint replacements by 2030, posing significant implications for the healthcare budget and workforce.(8)

Germany is one of the leading countries in the prevalence of total knee arthroplasty (TKA), with a projected increase of 43% in TKA cases by 2050, reaching an incidence rate of 299 per 100,000 people.(5)

Hamilton et al. estimated that the lifetime risk of knee arthroplasty in the UK is approximately 10%, with the rates continually rising due to increased longevity and eventual prosthesis failure.(15) Evans et al. analysed TKA survival rates and found that approximately 18% of procedures required revision within 25 years, thus significantly contributing to the increasing procedural volume.(16) The most significant growth in TKA cases is expected among those aged 40-69, with a 269% increase projected for 40-

49 year-olds, a 94% increase for 50-59 year-olds, and a 43% increase for 60-69 year-old.(17) These trends highlight the multifaceted reasons behind earlier joint failures, including lifestyle factors and the physical demands on younger patients.

Similar studies have been conducted worldwide, but there is a gap in the comprehensive analysis of the global burden, particularly concerning revision procedures and their impact on the overall increase in surgical volume.

Based on our calculations, in Hungary, the annual number of primary knee replacements nearly tripled between 2010 and 2019, increasing from 4,241 to 12,058 procedures. For THA, this increase was approximately 50%, with the annual number of procedures rising from 10,189 to 14,903.

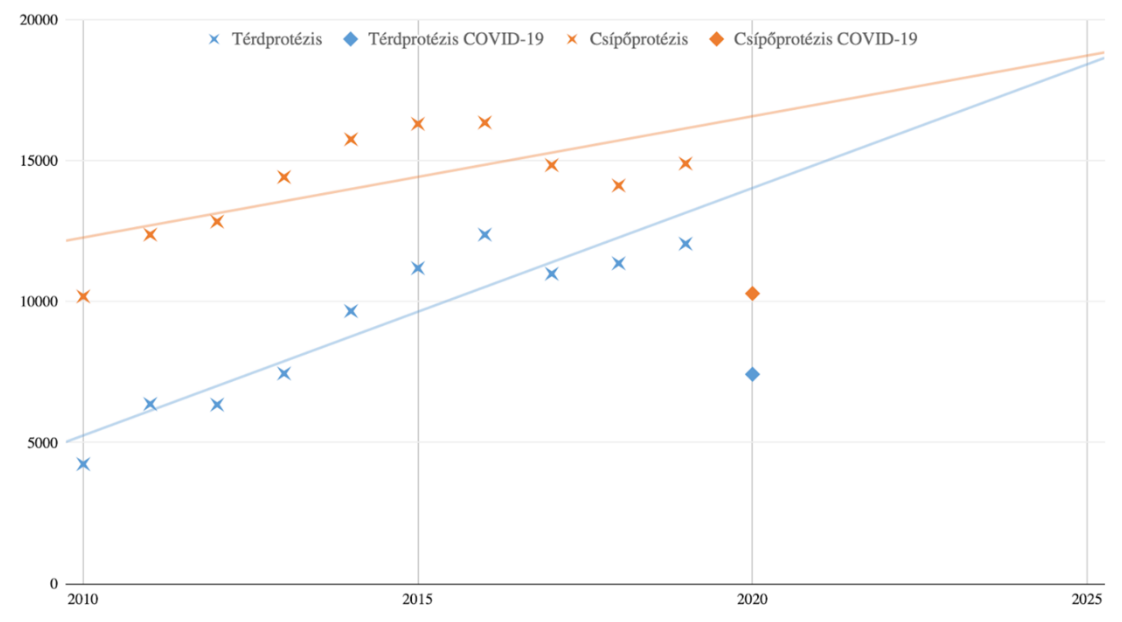

Figure 1. – Annual number of TKAs and THAs in Hungary between 2010 and 2020

The increasing need for primary TKA and their revisions significantly contributes to the increasing volume of procedures. The rising number of joint arthroplasties can be attributed to the expanding age range of patients undergoing these surgeries. Increased life expectancy means more elderly patients are living beyond 80 years and requiring joint replacements.

1.1. Surgical approaches

Contemporary registry and meta-analytic evidence underline the exceptional performance of total knee replacement: more than 80 % of implants remain functional after 25 years, with 10- and 15-year revision rates of only 3–4 %.(16,18) Large PROM cohorts show rapid, clinically meaningful improvements in pain, function and overall quality of life, with roughly four in five patients reporting satisfaction with the outcome.(19,20) Despite TKA being one of the most successful orthopedic surgeries, there remains no consensus on the most effective surgical approach.(21–25) The most frequently used approaches in TKA are the standard medial parapatellar (MP) and the quadriceps-sparing (QS) approaches, including subvastus (SV), midvastus (MV), minimal invasive medial parapatellar (mini-MP), minimal invasive subvastus (mini-SV), and minimal invasive midvastus (mini-MV). Each method presents unique advantages and disadvantages, with quadriceps-sparing techniques such as the subvastus (SV) and midvastus (MV) approaches frequently cited in recent literature for their clinical efficacy and potential superiority over the medial parapatellar (MP) approach, particularly concerning early clinical outcomes.(21,26,27)

During the MP approach, the quadriceps tendon is incised, which can compromise the extensor mechanism, potentially resulting in a prolonged and more challenging postoperative rehabilitation period. Berstock et al. conducted a comprehensive meta-analysis, indicating that 93% of orthopedic surgeons in the United Kingdom favor the medial parapatellar technique, while only 1% employ the subvastus approach for TKA.(28) The subvastus approach, initially described by Erkes in 1929, (29) gained substantial recognition following the publication by Hofmann et al.(30) The key advantages of the subvastus approach include the preservation of the quadriceps muscle, which may contributes to improved postoperative muscle strength and function, maintenance of patellar blood supply, enhanced postoperative patellar mechanics, and reduced postoperative pain. These benefits collectively facilitate accelerated rehabilitation and reduced hospital stay durations.(31–35) In the midvastus (MV) approach, the vastus medialis obliquus muscle is incised along its fibers, starting from the superior-medial border of the patella and extending medially toward the intermuscular septum. (36)

Migliorini et al. found that the mini-SV approach could offer the best results, although their study included both randomized and non-randomized trials, leading to no definitive superiority among the approaches.(21) Zhao et al. reported different superiorities depending on outcomes: mini-MP was most effective in reducing pain, SV had the shortest operation time, and MP provided the highest range of motion values.(22) Bouché et al. investigated range of motion and quality of life scores but could not determine a single most favorable surgical approach.(25) Despite the extensive literature on TKA, there remains a notable lack of research specifically addressing early postoperative rehabilitation.(23–25,37)

1.2. Hypothesis

Based on the existing literature and our clinical experience, we hypothesized that the choice of surgical approach in total knee arthroplasty (TKA) has a significant impact on early postoperative rehabilitation outcomes. Specifically, we anticipated that quadriceps-sparing techniques—such as the subvastus and midvastus approaches—would lead to improved early functional recovery, including greater range of motion, reduced postoperative pain, faster achievement of key rehabilitation milestones (such as straight leg raise and 90 degrees of knee flexion), and decreased analgesic requirements, when compared to the standard medial parapatellar approach. We further hypothesized that these benefits would be most pronounced in the early postoperative period, potentially enabling a faster return to normal activities and an overall more efficient rehabilitation process.

2. Objectives – Clinical observation

The objective of our study was to evaluate clinical outcomes, particularly in the early postoperative period, across different surgical approaches employed in TKA, with the aim of identifying the most effective and rapid method for restoring patients to their normal lives. This objective was pursued through two complementary research approaches: a single-center, post-hoc clinical analysis and a systematic review and network meta-analysis.

A single-center, post-hoc analysis of prospectively collected clinical data was conducted at the Department of Orthopaedics, Semmelweis University. This study specifically compared the safety and efficacy of the SV and standard MP approaches, with a focus on the early postoperative period. The outcomes reported in this study include ROM in degrees, pain levels during both rest and active movement as measured by a VAS ranging from 0 to 10, the ability to perform a straight leg raise (SLR), and the requirement for pain medication.

3. Methods – clinical analysis

3.1. Study design and settings

We report our study following the STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) 2007 statement.(38) The data collection was approved by the Hungarian Scientific and Research Ethics Committee of the Medical Research Council (Number of supporting decision: BMEÜ/1624-3/2022/EKÜ).

3.2. Participants

Patients are referred to knee specialists based on their health complaints and pain intensity, with referrals determined by the availability of the specialists. Typically, neither the doctors nor the patients have the ability to influence the selection process, ensuring that patients remain unaware of the surgical approach to avoid any potential bias. Although patient selection does not adhere to the strict principles of randomization, it can be considered a quasi-randomized method, as defined by the Cochrane Dictionary.(39)

The inclusion criteria for patient selection were as follows: (1) patients diagnosed with gonarthritis via X-ray, presenting with pain unresponsive to conservative treatment; (2) a body mass index (BMI) below 35 kg/m²; (3) no history of lower limb trauma; (4) a valgus angle under 15 degrees; (5) age between 55 and 85 years; and (6) knee flexion greater than 90 degrees. The exclusion criteria included: (1) osteoarthritis of traumatic or autoimmune origin; (2) a hip prosthesis on the same side; (3) total joint arthroplasty on the contralateral side within 24 months; (4) use of alternative anaesthesia methods; and (5) surgeries conducted without a tourniquet.

The surgeries were performed by four orthopaedic surgeons, each with 20-25 years of experience. Two surgeons performed the SV approach, while the other two utilized the standard MP approach. All patients undergoing TKA at the clinic were subjected to the same data collection and follow-up protocols. Patients were admitted to the Department of Orthopaedics at least one day before surgery and were required to spend the night of the surgery in the sub-intensive care unit for close monitoring. Following this, patients were transferred to the standard joint arthroplasty unit, where they remained for five additional nights for further observation and rehabilitation. In total, patients spent six days hospitalized post-surgery before being discharged. Data were collected during the entire hospitalization period, with "Day 0" defined as six hours post-surgery, and "Days 1-6" corresponding to the mornings following the day of surgery.

For TKA, cemented posterior cruciate ligament-retaining implants were used without patellar resurfacing called Legion CR manufactured by Smith and Nephew plc. The preoperative preparation was standardized for all patients, and the anaesthetic method employed was spinal anesthesia combined with a peripheral nerve block. In all cases, a tourniquet was applied, inflated immediately before the incision, and deflated after the cement had hardened. The use of a drain was determined at the discretion of the operating surgeon; however, in all cases the duration did not exceed 24 hours.

3.3. Outcomes

In this study, we present outcomes including ROM measured in degrees, pain levels during rest and active movement assessed using a VAS(40) from 0 to 10, the ability to perform a straight leg raise (SLR), and the necessity for pain medication. Data on ROM, pain, and other movement parameters were meticulously collected each morning by medical doctors and physiotherapists, both of whom were blinded to the surgical approach employed.

Postoperative pain management was governed by a structured five-level ordinal medication protocol, as outlined in Table 1. Pain relief began on day 1 and was carefully adjusted according to the pain levels reported by patients. Should the initial medication be inadequate, the next tier of the protocol was administered, ensuring that effective pain control was achieved for all patients. The protocol started with non-steroidal anti-inflammatory drugs (NSAIDs), with the specific type selected in consultation with the patient (level 1). This was followed by paracetamol (level 2), tramadol (level 3), and nubain (level 4), with level 0 denoting that no pain medication was required. A study nurse was responsible for the daily evaluation and documentation of the medication level needed for each patient, ensuring that analgesic needs were appropriately addressed based on the subjective pain levels reported by the patients (Table 1). A dedicated study manager within the department was entrusted with the responsibility of ensuring that patient care and data collection protocols remained current and practically feasible. All colleagues involved as investigators were required to pass an examination to demonstrate their theoretical knowledge and practical competence.

Table 1. - Five-level analgesic escalation protocol used post-operatively. Level 0 = no medication needed; Level 1 = NSAID; Level 2 = paracetamol 500 mg; Level 3 = oral tramadol 50 mg; Level 4 = nalbuphine 10 mg/ml. VAS ranges (0–2, 3–5, 6–7, 8–9, 10) triggered progression to the next level.

Drug name	Active agent	Packaging	Affective group	VAS	Level
No need for painkiller	-	-	-	0-2	0
Donalgin	Niflumin acid	250 mg capsule	NSAID	3-5	1
Diclofenac-ratiopharm	Diclofenac-sodium	50 mg pill	NSAID	3-5	1
Voltaren	Diclofenac-sodium	75 mg pill	NSAID	3-5	1
Algopyrin	Metamizole-sodium	500 mg pill	NSAID	3-5	1
Rubophen	Paracetamol	500 mg pill	Minor analgesic	6-7	2
Tramalgic	Tramadol-hydrochloride	50 mg capsule	Opioid	8-9	3
Nubain	Napbuphine-hydrochloride	10mg/ml	Opioid	10	4

3.4. Study size and statistical analysis

We aimed to include 50 patients in each study group, ceasing patient selection once the desired sample size was reached, following the exclusion of non-eligible participants. A post-hoc power analysis was conducted to validate the sample size of 50 patients per group. Assuming a standard deviation of 15 degrees and a significance level of 0.05, the analysis indicated that this sample size was sufficient to detect a difference of 5.94 degrees with 80% power. This threshold aligns with the reported minimal clinically important difference (MCID) for ROM in the literature, validating the cohort size used in this study.

A linear mixed-effects model was employed to analyze the data, with ROM and VAS values serving as the dependent variables. The variation in these outcomes was primarily attributed to several key factors: the type of surgical aproach, the specific medication regimen, and the number of days post-surgery. Additionally, adjustments were made for various patient characteristics, including sex, age, body mass, initial ROM, and VAS values, as well as the treatment protocol applied on the first day. We also explored the interaction effect between the type of surgery and the duration post-surgery. To account for individual variability, random intercepts were included for each subject, with the progression over time (days) modelled as a random slope. The analysis confirmed that there were no significant multicollinearity issues, and diagnostic plots indicated that the model fit the data adequately. The level of significance was set at 5%.

We further investigated whether a linear correlation existed between ROM and VAS scores, both during activity and at rest. To determine the correlation between these variables, we employed a repeated measures correlation approach, which allowed us to assess the strength and direction of the association between RoM and VAS scores over multiple observations.(41)

Additionally, we conducted an analysis on the time required for patients to achieve 90 degrees of knee flexion and perform a straight leg raise (SLR) following surgery. A Cox proportional hazards model was utilized to evaluate the time-dependent recovery process, comparing the two surgical methods while accounting for patient-specific factors such as sex, age, and body mass.

All statistical analyses were conducted using R software (Version 4.0.4).(42)

4. Results – Clinical analysis

Over the six-month period under review, a total of 174 TKAs were performed at our department. Following the application of our predefined exclusion criteria, 74 patients were excluded from the study (Figure 2). All participating patients were thoroughly informed about our clinical data collection practices during their preoperative outpatient consultations. The demographic characteristics of the patients included in the study are detailed in Table 2, and no significant differences were identified between the two study groups.

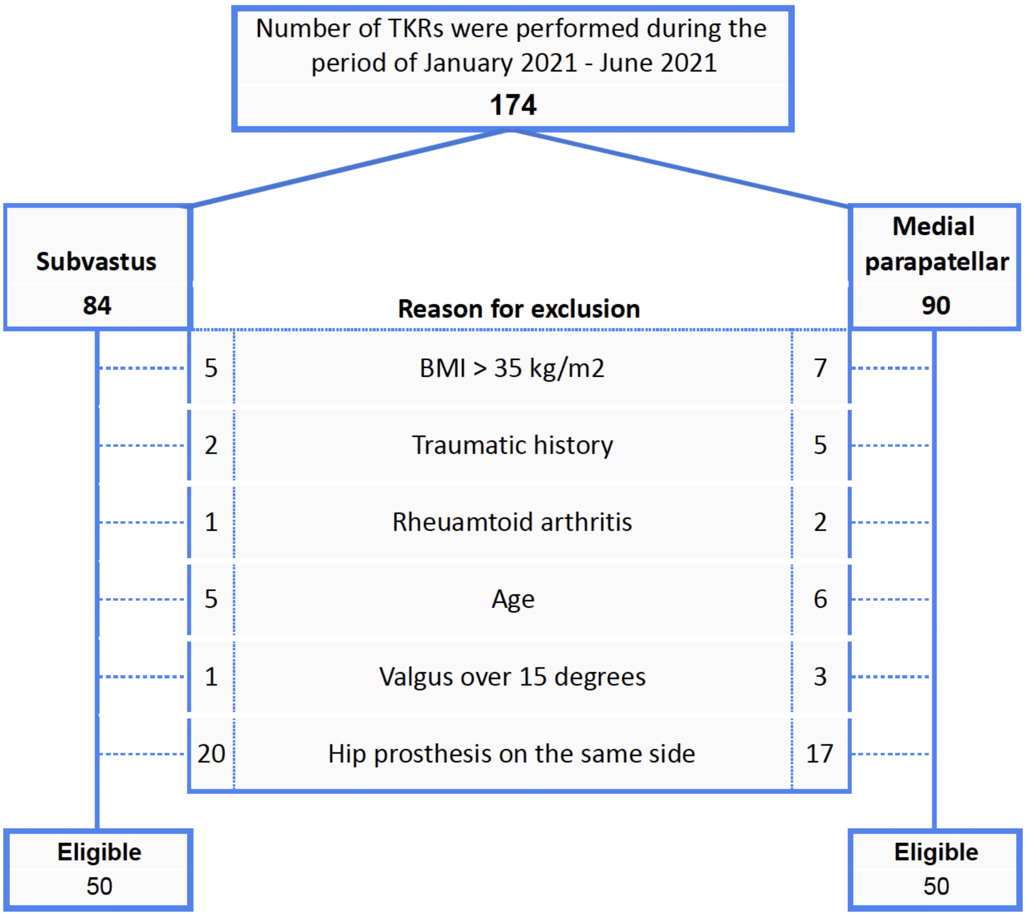

Figure 2. – Patient selection flowchart for the prospective clinical cohort.

A total of 174 primary total knee arthroplasties (TKAs) were screened; 74 procedures were excluded. The final analysis includes 100 knees (50 medial parapatellar (MP) approach, 50 subvastus (SV) approach).

Table 2. - Preoperative demographic data of the study groups.
Values are mean ± SD as specified.

	MP (N=50)	**SV (N=50)**
Sex		
Female	32 (64.0%)	33 (66.0%)
Male	18 (36.0%)	17 (34.0%)
Mass		
Mean (SD)	88.8 (15.8)	85.8 (12.4)
Median (IQR)	86.0 (19.8)	85.0 (19.5)
Height		
Mean (SD)	168 (9.51)	166 (8.62)
Median (IQR)	168 (14.8)	166 (13.3)
BMI		
Mean (SD)	31.6 (4.26)	31.2 (4.34)
Median (IQR)	31.9 (4.55)	31.2 (6.25)
Age		
Mean (SD)	68.4 (8.59)	70.8 (8.03)
Median (IQR)	68.8 (13.5)	72.3 (10.0)

4.1. Range of motion

The initial ROM (ROM_0) indicated a higher mean for the SV group (53.00±24.9) compared to the MP group (44.40±26.4). Subsequent days revealed a consistent and statistically significant advantage in ROM for the SV group, commencing from day 1 ($p<0.001$) and persisting through day 6 ($p<0.0012$). Specifically, from day 1 (ROM_1) onwards, the SV group's ROM was significantly greater than that of the MP group, with the mean differences becoming less pronounced. By the end of the observed period (ROM_6), the mean ROM for the SV group reached 88.80±9.82 compared to 81.40±12.1 for the MP group ($p<0.0012$). The absolute difference in mean ROM between the two groups appears to decrease over time, but the differences remain statistically significant at each time point. The ROM mean value change at the time, the effect of type of surgery, and their interaction were significant ($p<0.05$). The data do not provide sufficient evidence to conclude that the employed medication protocol exerts a statistically significant effect on the average ROM values. (Figure 3, Table 3)

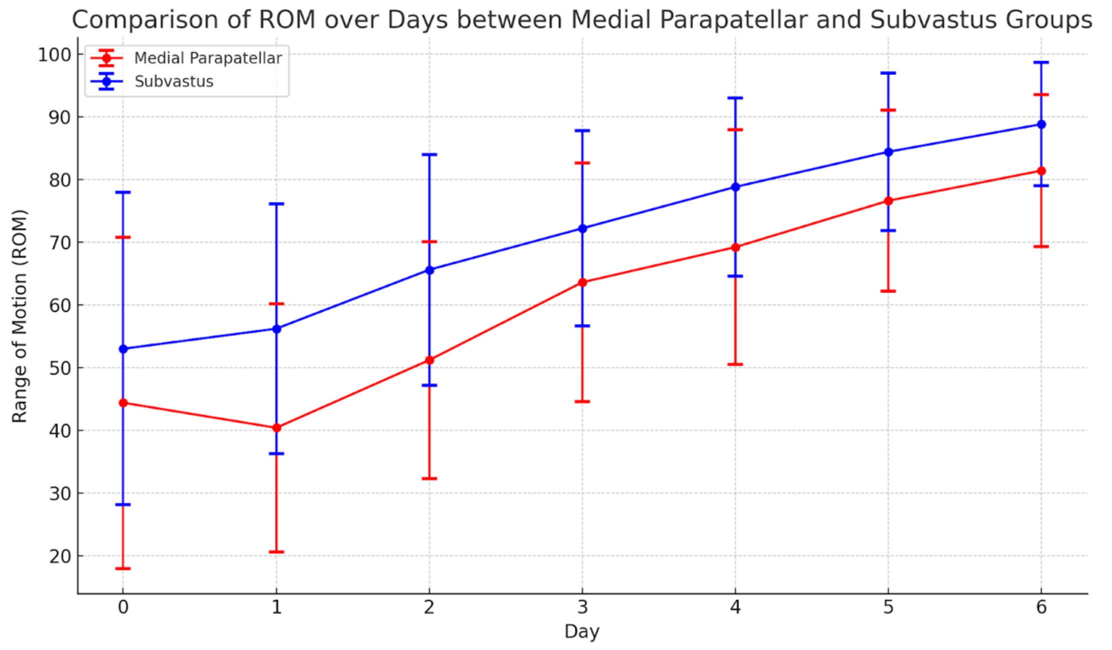

Figure 3. - Postoperative knee range of motion (ROM) during the first 6 days after TKA.

Mean ± SD flexion degrees for 50 MP and 50 SV knees.

4.2. Pain in rest and during active movement

We conducted a comparative analysis of postoperative pain levels, quantified by the VAS during rest and active movement (VAS_R and VAS_A). On the day of surgery (VAS_R_0), patients who underwent the SV approach exhibited significantly lower pain levels at rest (mean VAS_R = 4.30, SD = 2.67) compared to those who underwent the medial parapatellar (MP) approach (mean VAS_R = 5.70, SD = 3.01), with a p-value of <0.0156. This trend of reduced pain in the SV group persisted consistently throughout the six-day postoperative period, with statistically significant differences observed between the two groups at each time point (Figure 4). By postoperative day 6, the SV group reported a mean VAS_R_6 score of 2.26 (SD = 1.51), while the MP group reported a mean VAS_R_6 score of 2.92 (SD = 1.55), maintaining a statistically significant difference ($p < 0.0334$).

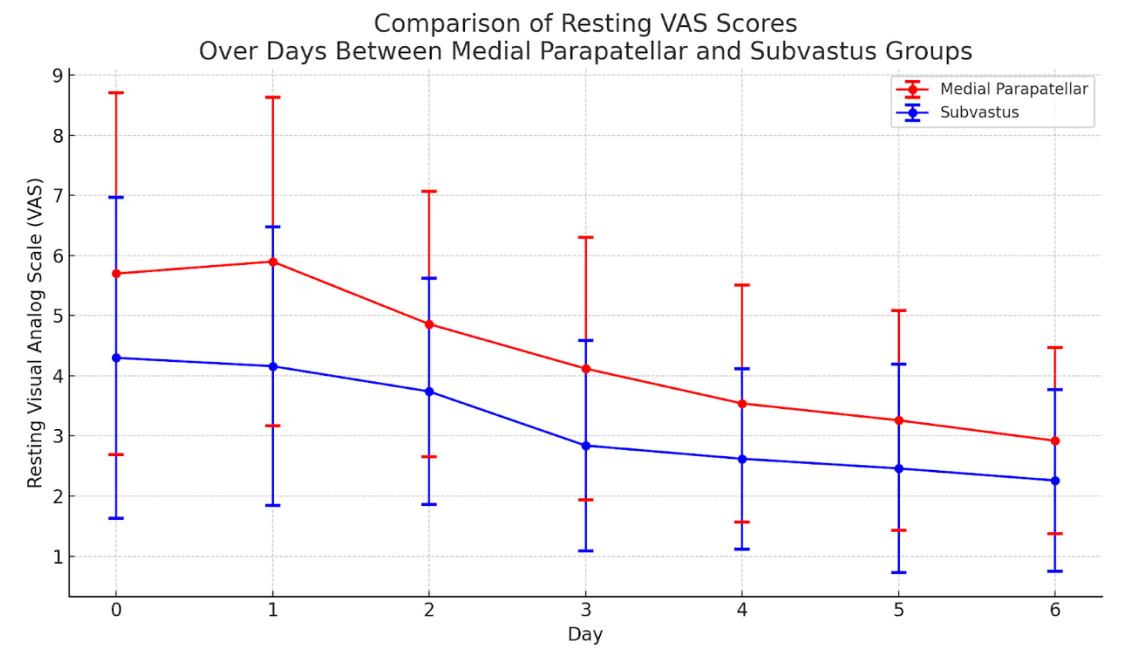

Figure 4. - Pain at rest (VAS_R) over the first week following TKA.

Visual Analogue Scale 0–10; mean ± SD for 50 MP vs 50 SV knees. Lower scores indicate less pain.

To evaluate the efficacy of the two surgical approaches on postoperative pain management, we analyzed VAS scores during active movement (VAS_A) (Table 3, Figure 5). The data indicated that the SV group experienced lower pain levels during active movement as early as the first postoperative day, with a mean VAS_A score of 6.28 (SD = 2.30), compared to the MP group, which reported a mean VAS_A score of 7.78 (SD = 2.06). This initial difference was statistically significant ($p < 0.001$) and persisted throughout the six-day postoperative period, with the SV group consistently reporting lower pain scores (Figure 5). Notably, the decline in VAS_A scores in the SV group was more pronounced, exhibiting a steeper negative trajectory. By postoperative day 6, the mean VAS_A score for the SV group had decreased to 3.48 (SD = 1.96), while the MP group reported a mean score of 4.56 (SD = 1.90). The difference between the groups remained statistically significant at this time point ($p < 0.0062$). The analysis also revealed a temporal decrease in mean VAS_A scores following surgery, with higher body mass index (BMI) emerging as a significant factor influencing postoperative pain during active movement ($p < 0.0023$).

Table 4 provides the correlation coefficients along with their 95% confidence intervals (CI) and corresponding p-values. The analysis revealed a significant negative correlation between range of motion (ROM) and VAS_A scores, with a correlation coefficient of $r = -0.59$ (95% CI: -0.65 to -0.53), and a p-value < 0.001. Similarly, the correlation between ROM and VAS_R scores was also negative and statistically significant ($r = -0.52$, 95% CI: -0.58 to -0.46, $p < 0.001$). Additionally, a stronger positive correlation was observed between the active and resting VAS scores ($r = 0.72$, 95% CI: 0.68 to 0.76, $p < 0.001$). These findings indicate that ROM is significantly correlated with both VAS_A and VAS_R scores, with comparable magnitudes of correlation. The stronger correlation between VAS_A and VAS_R scores suggests a close relationship between the pain experienced by patients during activity and at rest, indicating that these pain experiences may influence one another.

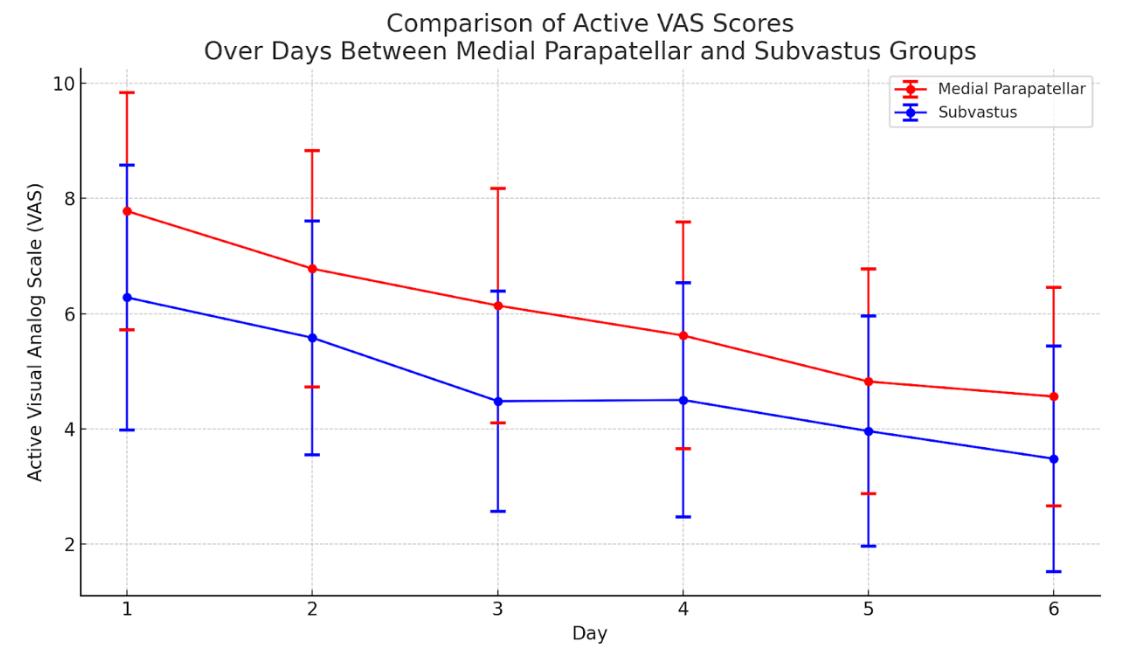

Figure 5. - Pain during active knee movement (VAS_A) on postoperative days 0–6.

Visual Analogue Scale 0–10; mean ± SD for 50 MP vs 50 SV knees. Lower scores indicate less pain.

4.3. Use of painkillers during the hospitalization time

Our findings, as detailed in Table 3 and illustrated in Figure 6, reveal that the SV group consistently exhibited lower pain management requirements compared to the MP group across all postoperative days. On postoperative day 1, the SV group reported a mean pain management level of 1.60 (SD = 0.86), which was significantly lower than the MP group's mean level of 1.98 (SD = 0.87), with a p-value < 0.03. This trend persisted through to day 6, at which point the SV group's mean level further decreased to 0.94 (SD = 0.89), while the MP group's mean level was 1.48 (SD = 1.05), maintaining a statistically significant difference ($p < 0.0068$). The analysis of the data does not indicate that the level of medication required on any given postoperative day has a predictive effect on analgesic requirements for subsequent days.

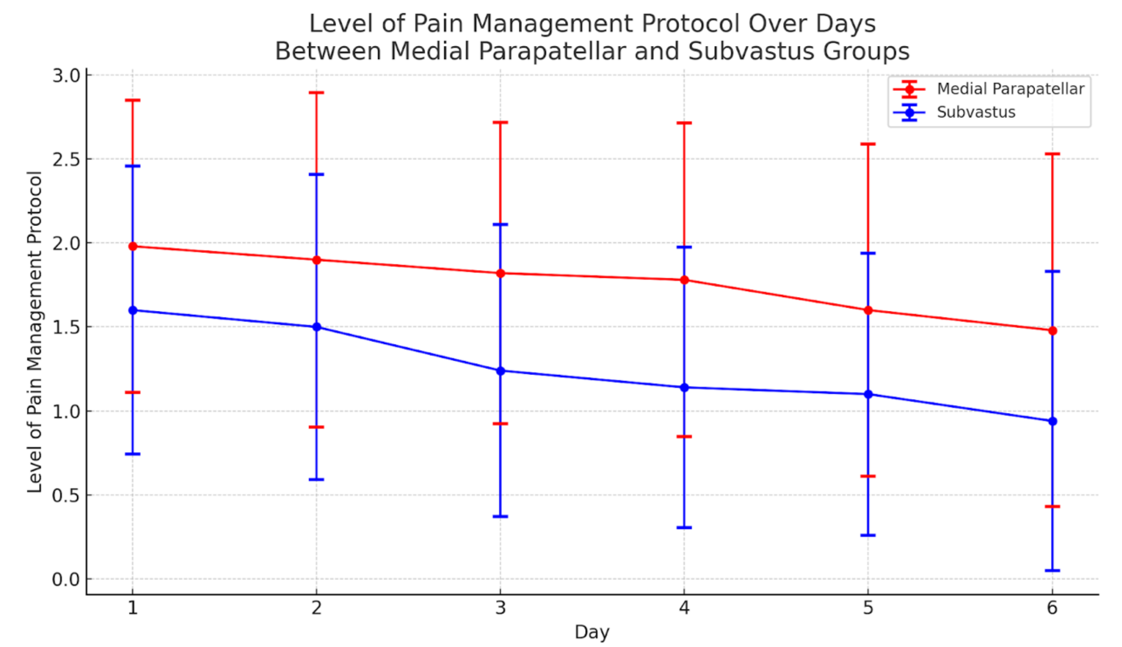

Figure 6. - Ordinal pain-medication level required each day after surgery (0 = none, 4 = intravenous opioid).

SV needed lower analgesic escalation on every day ($p < 0.05$)

4.4. The ability of straight leg raise and 90 degrees of knee flexion

In the comparative analysis of postoperative functional recovery, specifically regarding the ability to perform an SLR, a statistically significant difference was observed between the two surgical approaches. Patients who underwent the SV approach achieved SLR in a significantly shorter time (mean = 0.64 days, SD = 0.56) compared to those who underwent the MP approach (mean = 2.44 days, SD = 2.04, $p < 0.001$). Remarkably, all patients in the SV group were able to perform an SLR by the second postoperative day at the latest.

Furthermore, the time required to attain 90 degrees of knee flexion was also measured. On average, patients who received the SV approach achieved this degree of flexion in 4.56 days (SD = 2.48), whereas those who underwent the MP approach required 5.58 days (SD = 2.36, $p < 0.0377$) to reach the same milestone (Table 3).

Table 3. - Primary clinical outcomes: ROM, pain scores, straight-leg-raise (SLR) time, and time to 90° flexion.

Values are mean ± SD; *p* values compare MP vs SV by mixed-effects model. ROM_0–6 = post-operative day; VAS_A/R = Visual Analogue Scale active/rest; ROM90 = days to reach 90° flexion.

	MP (N=50)		**SV (N=50)**		**P-value**
	Mean	**SD**	**Mean**	**SD**	
ROM_0	44.40	(26.4)	53.00	(24.9)	0.0969
ROM_1	40.40	(19.8)	56.20	(19.9)	**<0.001**
ROM_2	51.20	(18.9)	65.60	(18.4)	**0.0002**
ROM_3	63.60	(19.0)	72.20	(15.6)	**0.0152**
ROM_4	69.20	(18.7)	78.80	(14.2)	**0.0049**
ROM_5	76.60	(14.4)	84.40	(12.6)	**0.0049**
ROM_6	81.40	(12.1)	88.80	(9.82)	**0.0012**
VAS_R_0	5.70	(3.01)	4.30	(2.67)	**0.0156**
VAS_R_1	5.90	(2.73)	4.16	(2.32)	**<0.001**
VAS_R_2	4.86	(2.21)	3.74	(1.88)	**0.0076**
VAS_R_3	4.12	(2.18)	2.84	(1.75)	**0.0017**
VAS_R_4	3.54	(1.97)	2.62	(1.50)	**0.0101**
VAS_R_5	3.26	(1.83)	2.46	(1.73)	**0.0268**
VAS_R_6	2.92	(1.55)	2.26	(1.51)	**0.0334**
VAS_A_1	7.78	(2.06)	6.28	(2.30)	**<0.001**
VAS_A_2	6.78	(2.05)	5.58	(2.03)	**0.0041**
VAS_A_3	6.14	(2.04)	4.48	(1.91)	**<0.001**
VAS_A_4	5.62	(1.97)	4.50	(2.03)	**0.0062**
VAS_A_5	4.82	(1.95)	3.96	(2.00)	**0.0317**
VAS_A_6	4.56	(1.90)	3.48	(1.96)	**0.0062**

SLR	2.44	(2.04)	0.640	(0.563)	**<0.001**
Day of ROM - 90	5.58	(2.36)	4.56	(2.48)	0.0377
Day_1	1.98	(0.869)	1.60	(0.857)	0.0300
Day_2	1.90	(0.995)	1.50	(0.909)	0.0384
Day_3	1.82	(0.896)	1.24	(0.870)	0.0014
Day_4	1.78	(0.932)	1.14	(0.833)	**<0.001**
Day_5	1.60	(0.990)	1.10	(0.839)	0.0077
Day_6	1.48	(1.05)	0.940	(0.890)	0.0068

Table 4. - Repeated-measures correlation between range of motion (ROM) and pain scores (VAS).

	r	**95% CI lower**	**95% CI upper**	**p-value**
ROM - VAS_A	-0.59	-0.65	-0.53	**<0.001**
ROM - VAS_R	-0.52	-0.58	-0.46	**<0.001**
VAS_A - VAS_R	0.72	0.68	0.76	**<0.001**

5. Objectives – Systematic review and meta-analysis

The objective of our systematic review and network meta-analysis was to evaluate the clinical outcomes of various surgical approaches in TKA, with a particular emphasis on the early postoperative period. By examining cross-sectional data, we aimed to identify the most effective and expedient method for returning patients to their normal lives.

We employed the Population, Intervention, Comparator, Outcome (PICO) framework to structure our research question (43–45):

- P (Population): Patients undergoing TKR
- I (Intervention): Standard medial parapatellar approach
- C (Comparator): Various quadriceps-sparing (QS) approaches, including subvastus (SV), midvastus (MV), mini-SV, mini-MV, and mini-medial parapatellar (mini-MP)
- (Outcomes): Range of motion (ROM), pain measured by the Visual Analogue Scale (VAS), ability of straight leg raise (SLR), operation and tourniquet time, blood loss, and the results of two scores, the Knee Society Score (KSS)(46) and the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC)(47).

Through this comprehensive analysis, we sought to determine the optimal surgical approach that enhances early rehabilitation and accelerates patient recovery.

6. Methods – Systematic review and meta-analysis

Our systematic review and network meta-analysis were conducted in accordance with the PRISMA 2020 guidelines (48) and the Cochrane Handbook.(39,49,50) The study protocol was registered on PROSPERO (registration number: CRD42021286986), and we strictly adhered to all stipulated procedures and recommendations.

6.1. Eligibility criteria

We planned to include exclusively eligible randomized controlled trials (RCTs) and exclude all other types of articles in strict adherence to the PRISMA protocol.(48) RCTs were considered eligible if they reported results for at least one of the planned outcomes. We included studies comparing at least two different surgical approaches and aimed to analyze data reported at various cross-sectional times within the first two years postoperatively. Only published RCTs were deemed eligible, with no exclusion criteria based on language or year of publication. Additionally, there were no exclusion criteria concerning study populations.

Studies with poor data quality, such as those reporting only mean values without standard deviations or those providing only minimum and maximum ranges, were excluded. We attempted to contact all authors to obtain any missing data. Furthermore, studies with undefined surgical approaches were also excluded.

6.2. Information sources and search strategy

Our systematic search was executed on October 2, 2021, across multiple databases including Medline (via PubMed), Embase, and the Cochrane Central Register of Controlled Trials (Central). We updated our search with the same strategy on April 11, 2023. During our systematic search, we utilized the following search key: (total knee arthroplasty OR total knee replacement OR knee prosthesis) AND (medial parapatellar OR subvastus OR midvastus OR quadriceps sparing OR MIS TKR OR Minimally invasive knee surgery OR minimally invasive approaches OR southern approach OR mini-subvastus approaches OR quadriceps-sparing OR minimally invasive medial approach OR mini-medial parapatellar approach OR mini-medial parapatellar OR minimally invasive medial parapatellar approach). No language or other filters were applied in order to ensure a comprehensive retrieval of relevant studies.

6.3. Selection process

The selection process was conducted by two independent reviewers following the removal of duplicates. The identified studies were initially screened by title and abstract, and subsequently by full text. Abstracts with insufficient information were also screened by full text. Any disagreements were resolved through consensus, involving a senior reviewer when necessary. Papers published in different languages were translated by the Department of Languages for Specific Purposes at Semmelweis University. Cohen's Kappa value was calculated to assess inter-rater reliability during the title, abstract, and full-text selection stages (39,51) (Figure 7).

The following data were meticulously extracted: first author, year of publication, surgical approach utilized, sample size, statistical methods employed, types of clinical outcomes (range of motion (ROM), visual analogue scale (VAS) for pain, straight leg raise (SLR), Knee Society Score (KSS), Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), blood loss, operation time, tourniquet time), follow-up duration, and mean and standard deviation values.

6.4. Data items

Clinical outcomes served as the dependent variables. ROM was measured in degrees, pain assessment was conducted using the VAS on a scale from 0 (no pain) to 10 (extremely high pain) (52,53), and SLR was recorded in days. KSS was reported either as a total score or divided into function and knee scores. Operation and tourniquet times were measured in minutes, while blood loss was documented in milliliters. Due to insufficient RCT data on WOMAC scores, statistical analysis for this outcome was not feasible.

To ensure compatibility of the extracted data, follow-up times, initially provided in various units, were standardized: a year was considered as 365 days, half a year as 182 days, a month as 30 days, and a week as 7 days. Data were harmonized for analysis by grouping time intervals as follows: 12-14 days, 1 month (30 days) - 4 weeks (28 days), 12-13 weeks (84-91 days) - 3 months, and 24-26 weeks (168-182 days) - half a year (182 days).

The primary aim of our analysis was to compare the different surgical approaches based on clinical outcomes and follow-up times, without conducting any subgroup analyses.

The risk of bias assessment was performed using the "Revised Cochrane risk-of-bias tool for randomized trials (RoB 2). (54)

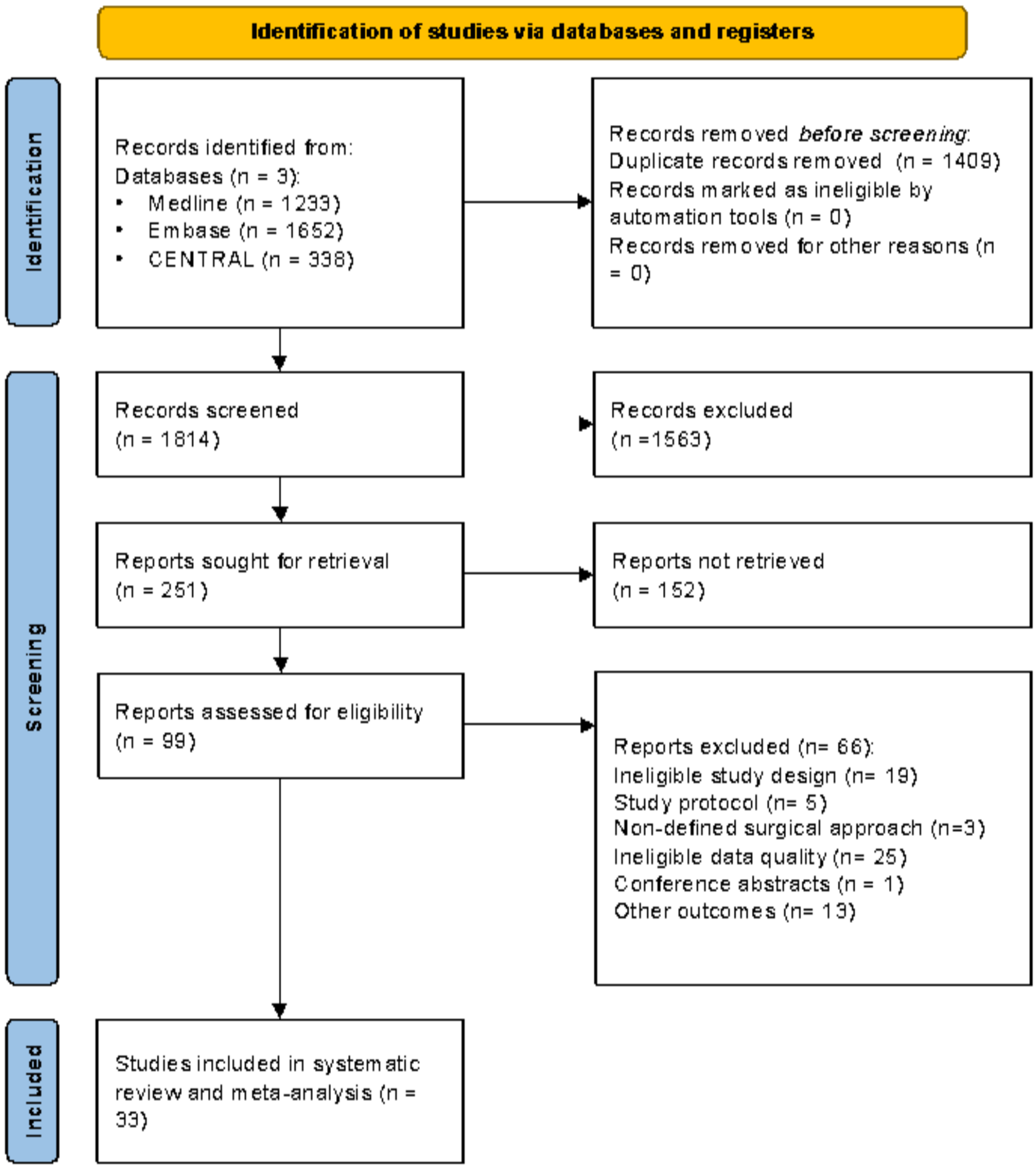

Figure 7. - PRISMA 2020 flowchart for the systematic review.

1,118 records identified; 33 RCTs included in network meta-analysis.(55)

6.5. Synthesis method

Primary data extraction and organization were conducted using Microsoft Excel. Comparative analysis was performed utilizing a frequentist random effects network meta-analysis, implemented through the {meta} (v5.2.0), {netmeta} (v2.1.0), and {dmetar} (v0.0.9000) packages in R (R Core Team 2022, v4.1.3). The network graph was constructed using the {qgraph} (v1.9.2) R package.(56–59) Outcomes were assessed based on follow-up/end-point or changes to baseline mean differences (MD).

7. Results – Systematic review and meta-analysis

Initially, we identified 1,118 records prior to the removal of duplicates. The detailed overview of the screening process is illustrated in Figure 7. Following the screening, 85 articles were selected for full-text review, and ultimately, 33 randomized controlled trials (RCTs) were deemed eligible for the final analysis. (26,27,60–88) We compared all surgical approaches to the MP approach. (Table 5.)

Table 5. – Basic characteristics table.(55)

Author	Country	Intervention	Sample size (knee)	Age	Gender (f/m)	Follow-up	Outcome
Cho et al. 2013	Korea	med_parapat	33	67.0±5.7	31/2	365	KSS function, knee, blood loss, op time
		mini_mv	33	65.5±5.1	32/1		
Bourke et al. 2012	Australia	subvastus	36	68.1±8.2	19/17	540	KSS function and knee, ROM, VAS, SLR, op and tourniquet time
		med_parapat	40	67.7±6.5	26/14		
Karpman et al. 2009	USA	subvastus	20	73±7.4	12/8	182	ROM, VAS, blood loss; op time
		midvastus	20	74±7.7	13/7		
		med_parapat	19	73±5.1	10/9		
Madadi et al. 2021	Iran	subvastus	50	64.8±3.7	46/4	365	ROM, VAS
		med_parapat	50				
Verburg et al. 2016	Netherlands	mini_mv	50	66±7.5	35/15	1825	KSS function and knee, ROM, blood loss, op time
		med_parapat	50	68±5.8	32/18		
Bonutti et al. 2010	USA	mini_sv	51	70 (54 - 87)	42/9	730	KSS function and knee, ROM
		mini_mv	51				
Feczko et al. 2016	Netherlands	mini_mv	36	65.14±8.35	23/13	182	KSS knee, ROM, blood loss, op time, WOMAC
		med_parapat	33	64.88±6.78	22/11		
Zora et al. 2020	Turkey	mini_mv	27	65.1±6.4 (52-81)	26/1	84	ROM, op time, WOMAC
		med_parapat	27	63.2±6.3 (51-73)	24/3		
Tomek et al. 2014	USA	med_parapat	65	64.8±9.3	F: 67.7%	91	KSS total, VAS
		subvastus	62	63.7±9.7	F: 62.3%		
Thienpont et al. 2013	Belgium	mini_mp	150	68±7.6(56-83)	45/105	730	KSS function
		med_parapat	150	69±7.2(52-84)	50/100		
	Germany	subvastus	26	69.7±9.1	7/19	13	ROM, SLR, blood loss, op time

Weinhardt et al. 2004		med_parapat	26	73.7±6.8	12/14		
Wegrzyn et al. 2012	USA	mini_sv	19	67±8	3.5/1	60	KSS function and knee
		med_parapat	18	64±7	3.5/1		
Jousponis et al. 2008	Lithuania	mini_mv	35	75±5.5	30/5	84	KSS function and knee, ROM, op time
		med_parapat	35	71.4±5.04	30/6		
Engh et al. 1997	USA	midvastus	61	68±8.5(46-93)	36/25	42	ROM, SLR, op time
		med_parapat	57	70±8.9(46-88)	41/16		
Li et al. 2018	China	mini_sv	25	69.9±4.3(58-76)	16/9	365	KSS function and knee, ROM, VAS, SLR, blood loss, op and tourniquet time
		med_parapat	25	68.1±4.9(57-77)	16/9		
Varela et al. 2010	Spain	subvastus	50	68.02±8.14	36/14	1095	KSS total, function and knee, ROM
		med_parapat	50	70.64±7.88	37/13		
Pongcharoen et al. 2013	Thailand	mini_mv	30	67±4.9(54-73)	25/5	365	KSS knee, VAS, blood loss, op time
		med_parapat	30	67±6.0(60-79)	23/7		
Yao et al. 2018	China	med_parapat	51	NI	NI	1825	KSS total, ROM, VAS, SLR, blood loss, op time
		mini_sv	49	NI	NI		
Nutton et al. 2014	UK	med_parapat	16	70±8	8/8	182	ROM, SLR, tourniquet time
		midvastus	12	73±8	4/8		
Han et al. 2008	Korea	med_parapat	15	64±6.4	28/2	7	ROM, blood loss, tourniquet time
		mini_mp	15	66±3.8	2862		
Bridgman et al. 2009	UK	med_parapat	111	70.9±8.1	56/59	365	KSS total, function and knee, ROM, WOMAC
		subvastus	115	70.1±8.0	56/60		
Jhurani et al. 2021	India	subvastus	93	64.6±7.9(44-75	61/32	365	KSS total, ROM, VAS, SLR, blood loss, tourniquet time, WOMAC
		med_parapat	93	64.6±7.8(48-74)	63/30		
Sastre et al. 2009	Spain	subvastus	52	NI	NI	365	ROM, VAS
		med_parapat	48	NI	NI		
Jung et al. 2009	Korea	subvastus	21	NI	NI	1095	ROM
		med_parapat	19	NI	NI		
Shukla et al. 2017	India	med_parapat	28	62.21±10.58	M:42.85%	365	KSS total, function and knee, blood loss, op time
		midvastus	24	60.42±7.37	M:41.66%		
Guy et al. 2012	UK	med_parapat	40	69.1	42/38	-	op time
		mini_mv	40	71.2			
	Germany	med_parapat	10	60.6±6.1	7/3	182	KSS total

Layher et al. 2015		midvastus	11	68.3±8.4	5/6		
Lee et al. 2010	Korea	mini_mp mini_mv	30 30	67(54-73)	28/2	182	ROM, VAS
Nestor et al. 2010	USA	mini_mv med_parapat	27 27	66.7±9.6	2/1	84	ROM, VAS, tourniquet time
Koh et al. 2016	Korea	med_parapat subvastus	50 50	65(56-75)	47/3	7	VAS
Dutka et al. 2011	Poland	subvastus med_parapat	97 83	70.3±6.1 71±5.1	41/48 35/45	730	KSS total, function and knee, ROM, VAS
Hemert et al.. 2010	Netherlands	subvastus med_parapat	20 20	70.3±11.8 70.9±7.1	14/6 13/7	91	VAS
Geng et al. 2022	China	med_parapat mini_sv	31 27	65±5.11	50/8	30	VAS, ROM, SLR, op time

7.1. Study characteristics and grade evaluation

The data extraction encompassed 2,797 knees from 14 different countries, with the most frequent comparison being between the medial parapatellar and subvastus approaches (Table 5). The GRADE evaluation was conducted using the CINEMA software for range of motion (ROM) on day 3, visual analogue scale (VAS) for pain on day 1, and Knee Society Score (KSS) for function on day 42, as these cross-sectional times allowed for the inclusion of the most articles.(89,90) The analysis suggests moderate evidence for ROM and high evidence for both VAS and KSS outcomes.

7.2. Range of motion

The range of motion (ROM) was analyzed first as the primary outcome. (Figure 8). The number of studies varied across different postoperative days. During the initial 14 days, except for day 3, the SV approach consistently yielded the best results. Significant differences were observed between the SV and MP approaches on day 1 (MD: 6.99; 95% CI: 1.08, 12.89), day 3 (MD: 8.65; 95% CI: 1.76, 15.54), day 4 (MD: 27.01; 95% CI: 18.09, 35.92), and day 6 (MD: 27.22; 95% CI: 18.38, 36.07). Although significant differences persisted later on, the mean differences decreased over time. The most substantial sample sizes were observed on day 42, with 1,145 participants from 10 RCTs, and on day 365, with 1,052 participants from nine RCTs. On day 42, the mini-MP approach showed the most superior outcomes (MD: 15.00; 95% CI: 8.11, 21.89), although this finding was derived from a single study. By day 365, the mini-SV approach demonstrated the most favorable results (MD: 2.60; 95% CI: -6.55, 11.75).

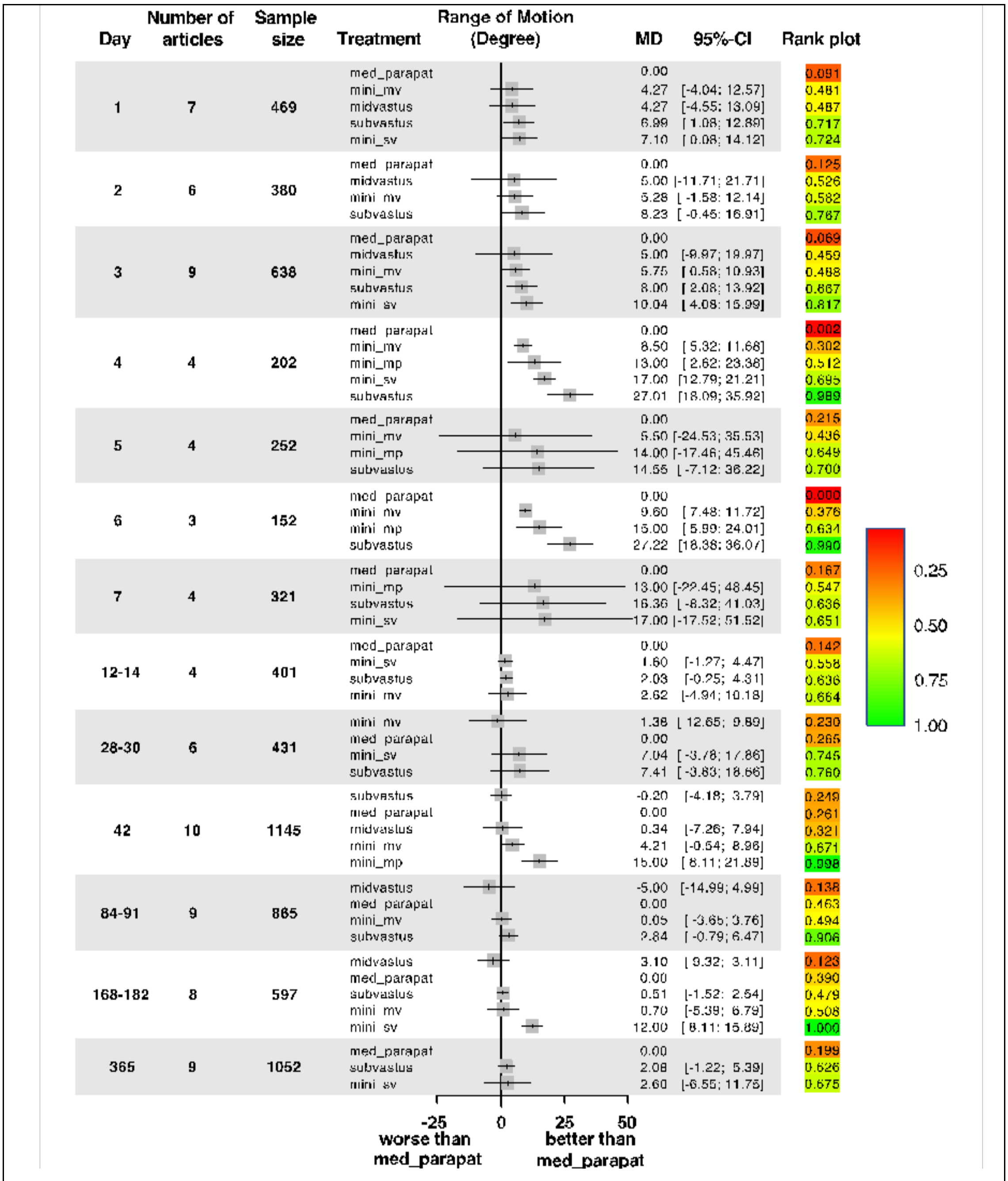

Figure 8. - Summary figure of network graphs, rank plot, and forest plots for range of motion (ROM) on different days post-surgery.(55)

7.3. Pain measured by the Visual Analogue Scale

On the first postoperative day, the mini_SV approach demonstrated significantly lower pain values (MD = -1.98; 95% CI: -2.93, -1.03). Throughout the subsequent days, extending up to one year post-surgery, the mini_SV approach continued to show significantly lower pain values at various time points: day 3 (MD = -0.85; 95% CI: -1.49, -0.22), day 7 (MD = -1.90; 95% CI: -2.23, -1.57), and day 30 (MD = -1.20; 95% CI: -1.54, -0.86). Although the differences in pain values diminished over time during the later stages of rehabilitation, our analysis indicates that the QS approaches—particularly the mini_SV and SV—consistently resulted in superior pain management compared to the MP approach. (Figure 9)

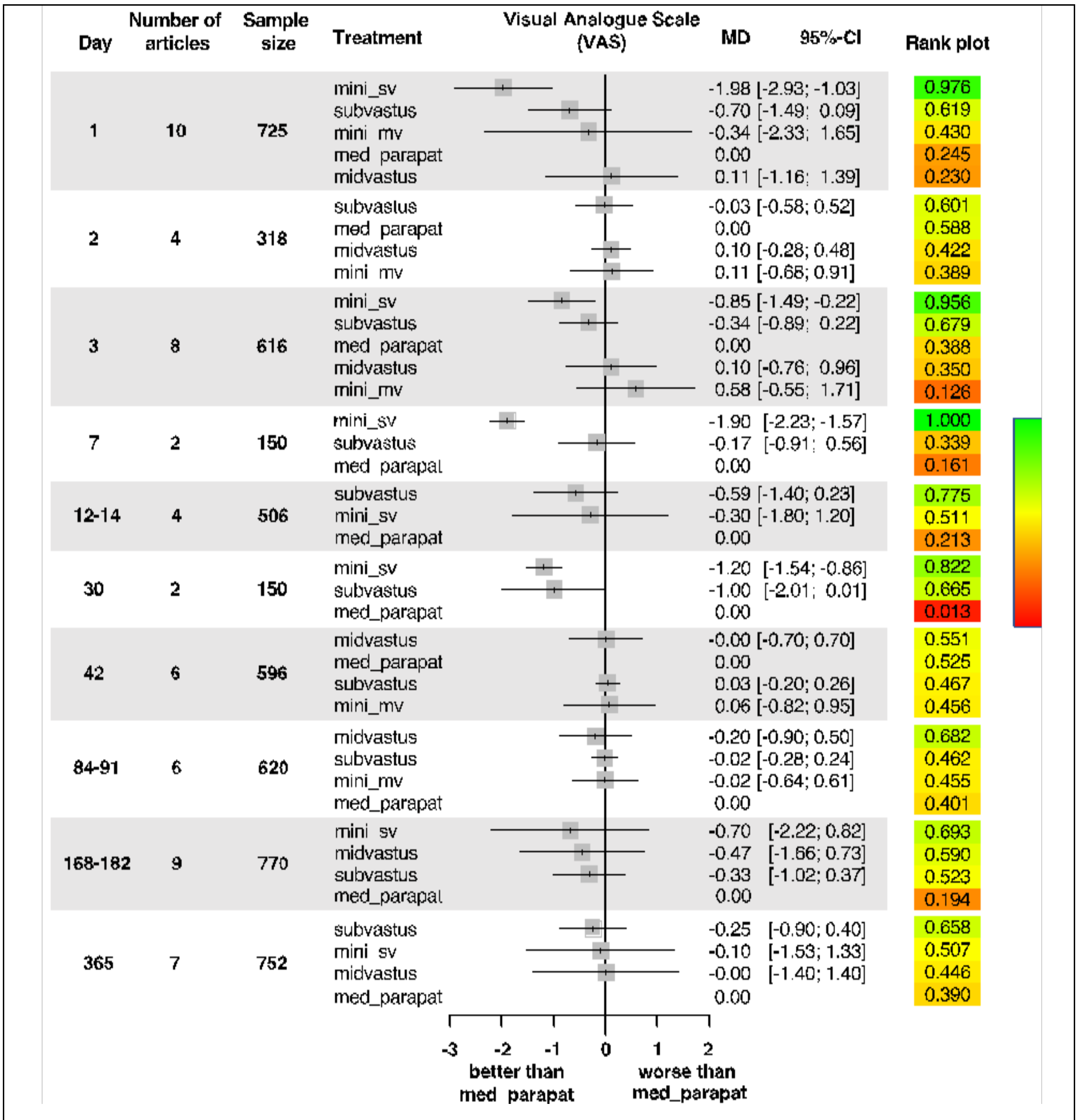

Figure 9. - Summary figure of network graphs, rank plot, and forest plots for visual analog scale (VAS) on different days post-surgery.(55)

7.4. Knee Society Scores

Our objective was to analyze various quality of life scores, specifically the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC)(47) and the Knee Society Score (KSS)(46). Due to insufficient reporting of WOMAC values, we focused solely on KSS values. As depicted in Figure 10, significant differences in function KSS values were observed on the 28th-30th follow-up day for the analyzed quadriceps-sparing (QS) approaches: mini-midvastus (mini_MV) (MD = 12.6; 95% CI: 7.16, 18.04), mini-subvastus (mini_SV) (MD = 13.6; 95% CI: 9.43, 17.77), and subvastus (S) (MD = 18.74; 95% CI: 11.68, 25.80). No significant differences were found in the total KSS, although the subvastus approach showed a discernible advantage. The observed differences diminished over the follow-up period.

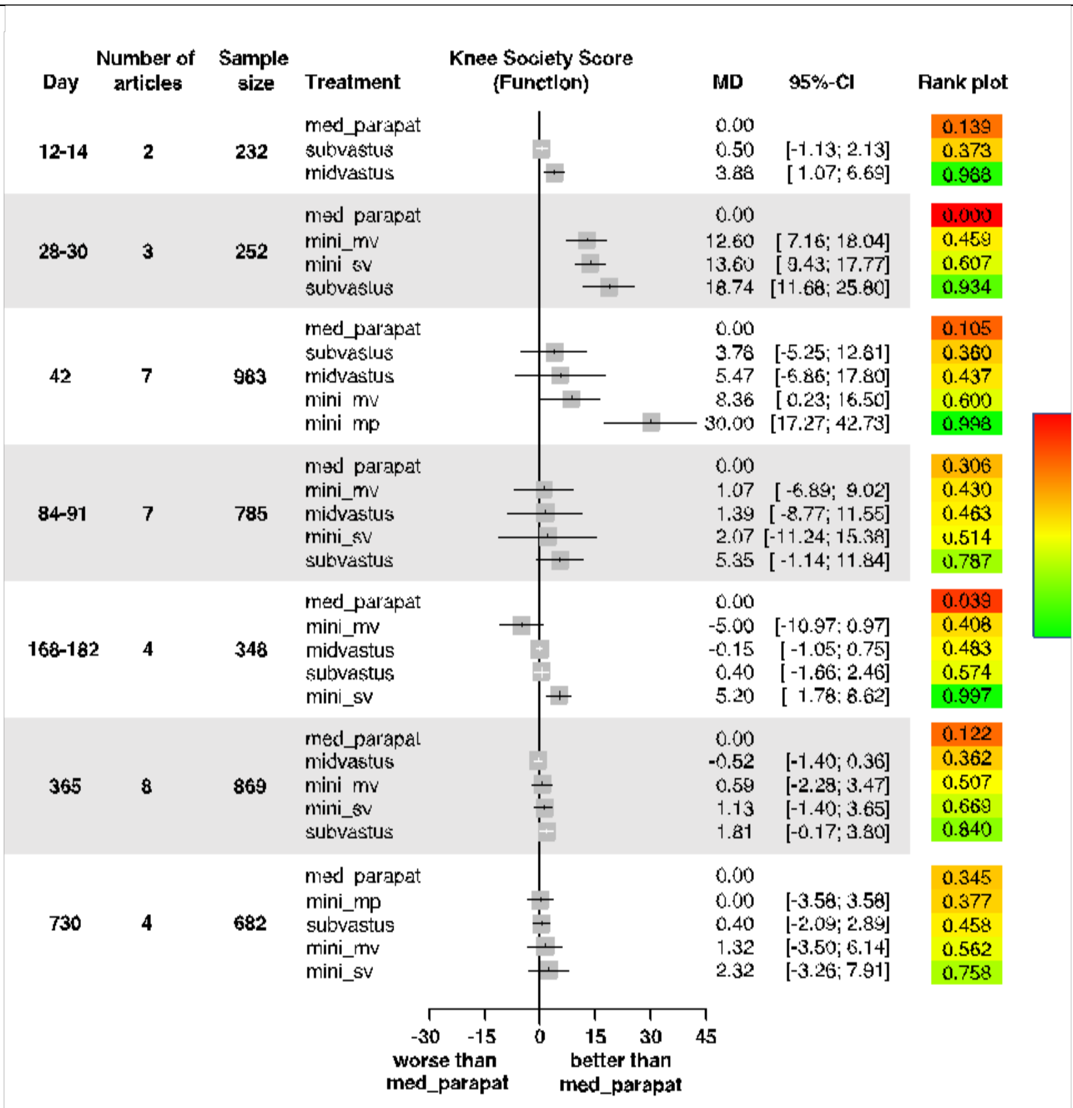

Figure 10. - Summary figure of network graphs, rank plot, and forest plots for Knee Society Score (KSS) function on different days post-surgery.(55)

7.5. Secondary outcomes

The ability to achieve a SLR on the first postoperative day is a frequently reported outcome in the literature. Our analysis, based on data from eight different studies involving four surgical approaches and a total sample size of 665, is illustrated in Figure

11. Using the MP approach as a standard, both the MV (MD = -3.40; 95% CI: -5.18, -1.61) and mini_SV (MD = -2.33; 95% CI: -3.63, -1.03) approaches demonstrated a significant advantage over the MP approach.

A total of 13 studies with a combined sample size of 880 provided data on operation times. Our findings indicate that the MP approach required the shortest operation time. Conversely, the mini_MV (MD = 10.96; 95% CI: 3.14, 18.78) and mini_SV (MD = 10.64; 95% CI: 0.79, 20.48) approaches required significantly longer operation times, as shown in Figure 11.

Tourniquet time, reported in eight studies with a total sample size of 785, was shortest with the MV approach (MD = -12.00; 95% CI: -25.99, 1.99) (Figure 10).

Intraoperative blood loss was documented in 12 studies with a total sample size of 1,124, with the mini-medial parapatellar (mini_MP) approach appearing the most favorable (Figure 11).

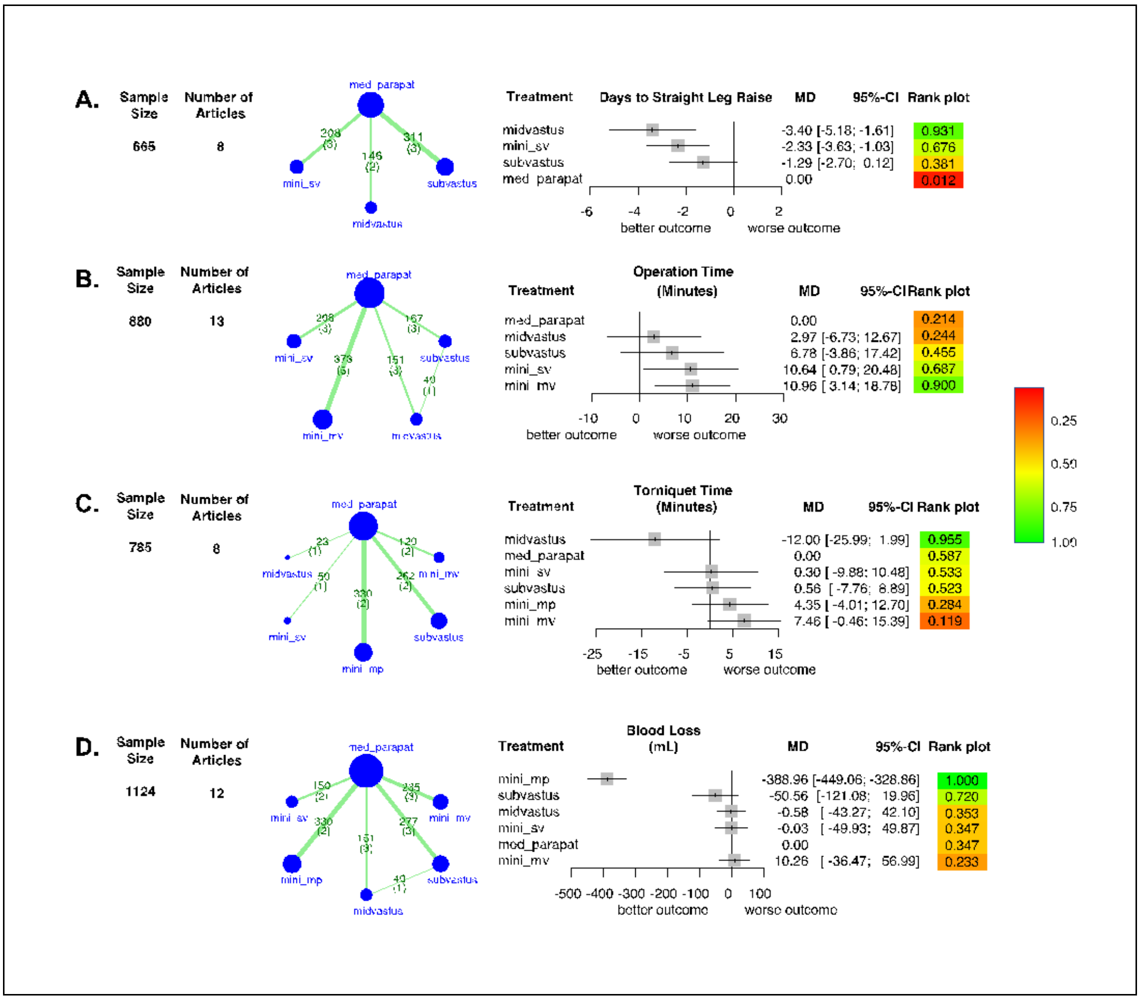

Figure 11. - Summary figure of network graphs, rank plot, and forest plots for a) straight leg raise, b) operation time, c) tourniquet time, and d) blood loss on different days post-surgery.(55)

8. Discussion

Both our clinical analysis and meta-analysis concentrated on early rehabilitation outcomes associated with different surgical approaches in TKA. Our research demonstrates that QS approaches consistently outperform the standard MP approach.

The meta-analysis evaluated the efficacy of various surgical approaches by examining different outcomes at multiple cross-sectional times. The results indicate that QS approaches, particularly the SV approach, offer superior clinical outcomes in the early postoperative period. Over time, the differences between the surgical approaches diminish, suggesting that QS approaches provide better conditions for faster and more effective postoperative rehabilitation, enabling patients to return to their normal lives or achieve the expected quality of life more rapidly. Referring to the most recent systematic reviews and meta-analyses, there remains no consensus on which surgical approach most effectively facilitates rehabilitation.(25,37) Most of these studies suggest that surgeons should master their chosen approach to achieve the best possible outcomes for their patients.(25) Another meta-analysis reported increased malalignment with QS approaches but found no clinical relevance.(37) Conversely, a subsequent meta-analysis in 2019 indicated that QS approaches could accelerate rehabilitation without an increased risk of malalignment.(24) Notably, none of the recent meta-analyses have investigated our primary outcomes segmented into cross-sectional times following rehabilitation.

Our clinical analysis revealed that during the initial week of postoperative rehabilitation, the SV approach significantly outperformed the MP approach in terms of range of motion (ROM), pain levels, and medication requirements. Additionally, the SV approach demonstrated marked improvements in patients' ability to perform a straight leg raise (SLR) and achieve a 90-degree ROM. These findings align with recent outcomes reported in the latest randomized controlled trials and meta-analyses.(21,26,27,67,69,86)

Evaluating our results regarding ROM values, we found a clear superiority for the SV approach. Our analysis spanned thirteen different time points, with the SV approach demonstrating the highest ROM values, particularly during the first postoperative month; however, the differences diminished over time. Similarly, Bouché et al., in their meta-analysis, concluded that the SV method was superior to all other approaches.(25) Conversely, Kazarian et al., who did not categorize the quadriceps-sparing (QS) approaches into distinct groups as we did, reported no significant differences in ROM after a 16-24 month follow-up.(37) In our clinical investigation, the SV group demonstrated a statistically significant improvement in range of motion ROM from postoperative day 1 to day 6 compared to the MP group. These findings are consistent with several RCTs that have examined early postoperative ROM. Weinhardt et al. identified a notable increase in flexion values for the SV approach during the first 13 postoperative days.(69) Specifically, the SV group achieved 90 degrees of knee flexion by postoperative day 7.0 ± 2.4, compared to day 11.0 ± 4.2 in the MP group, a significant difference ($p < 0.01$).(69) Bridgman et al. documented a 7.44-degree ROM advantage ($p < 0.039$) for the SV group one week post-surgery.(76) In a comparative study of the SV (referred to as QS), MV, and MP approaches, Karpman et al. observed that the SV approach resulted in superior knee flexion on the first postoperative day, although the results did not reach statistical significance.(62) Conversely, Bourke et al. reported no significant differences in overall ROM or at specific time points.(26)

Regarding pain values, our findings indicate an advantage for the mini_SV and SV approaches. However, it is crucial to consider that the included RCTs did not specify the timing of pain assessment using the VAS in relation to the administration of painkillers, physiotherapy sessions, or the time of day, which could influence the interpretation of these results. The results of our clinical investigation suggest a potential preference for the SV approach over the MP approach in terms of pain management, both at rest and during active movement. The SV group exhibited a notable reduction in postoperative pain, indicating its efficacy as a more favorable surgical technique in this context. Although Bourke et al. did not report statistically significant differences in pain scores measured by the VAS between the two groups, they did observe slightly lower pain scores on the first postoperative day in the SV cohort (mean 3.1, SD ± 1.8) compared to the MP group (mean 3.8, SD ± 1.8).(26) Similarly, Karpman et al. identified certain advantages associated with the SV approach, although these benefits did not reach statistical significance until the final day of hospitalization, at which point the SV group demonstrated significantly better outcomes.(62) Research by Tomek et al. also highlighted the advantages of the SV approach in terms of pain scores at rest and during movement, with significant differences emerging on the first day at rest (SV mean: 2.79, SD ± 0.29; MP mean: 3.64, SD ± 0.28; $p < 0.036$) and on the third day during activity

(SV mean: 4.15, SD ± 0.34; MP mean: 5.10, SD ± 0.32; $p < 0.042$).(67) In contrast, Koh et al. reported comparable pain scores between the two approaches on days 1, 3, and 7 post-surgery.(85) Collectively, these findings suggest the potential of the SV approach to enhance pain management in the immediate postoperative phase.

The superior straight leg raise (SLR) values observed in our clinical investigation suggest an accelerated recovery of quadriceps muscle function, favoring the SV approach. These findings are supported by Bourke et al., who reported a significant advantage for the SV approach over the MP approach (MP: 2.76 ± 1.89 vs. SV: 1.92 ± 1.59, $p < 0.044$). (26) Although Weinhardt et al. noted a longer time to achieve SLR in the MP group (day 12.0 ± 3.1) compared to the SV group (day 8.3 ± 2.8), this difference did not reach statistical significance.(69) Similarly, Jhurani et al. reported comparable timelines for SLR between the two surgical methods (SV: 3.8 ± 1.5 days, MP: 3.8 ± 1.4 days, $p < 0.9$).(77) Our systematic literature analysis revealed that the mini_SV approach yielded the most favourable outcomes for SLR. However, the operation time was significantly longer in both the mini_SV and mini_MV groups compared to the MP group. While we calculated tourniquet time, it is important to note that the starting and ending points of tourniquet application were often not clearly defined, rendering the data insufficiently reliable for accurate reporting.

Concerning the Knee Society Score (KSS) values, both the SV and MV approaches achieved the minimal clinically important difference (MCID)(91) by the end of the first two weeks. Although statistically significant differences were observed later, they did not reach the MCID. When evaluating functional KSS, a strong significant advantage was noted for the SV, mini_SV, and mini_MV approaches by the end of the first month.

The primary rationale for performing a QS surgical approach, such as the SV or MV approaches, is to minimize damage and preserve the integrity of the extensor muscles, thereby promoting faster and more effective postoperative rehabilitation. During the MP approach, the quadriceps tendon is incised, which compromises the extensor mechanism and potentially disrupts the patellar blood supply. This disruption can result in a longer and more challenging rehabilitation period. Studies, including our own meta-analysis and clinical analysis, have shown that the QS approaches facilitate a superior early postoperative recovery, with patients experiencing less pain and improved ROM compared to those undergoing the MP approach. The QS techniques maintain the quadriceps muscle's natural structure and function, leading to better early clinical outcomes and enabling patients to return to their normal activities more rapidly.

8.1. Strength and limitations

One of the key strengths of our analysis lies in the meticulous adherence to our preregistered study protocol(92), alongside the application of a comprehensive and rigorous methodological framework.

A notable limitation of our network meta-analysis is the restricted number of articles, cases, and comparisons that could be incorporated. Our analysis underscores the inherent challenges in achieving precise and stringent randomization in elective surgical treatments. Although we identified 33 papers for inclusion, the heterogeneity in measurement times impeded our ability to compare as many articles at specific cross-sectional dates, thereby reducing the number of articles available for our matrix analyses. Furthermore, the majority of studies focused on comparisons between the SV and MP approaches, limiting the scope of our comparisons. Another significant constraint is the absence of detailed information regarding pre- and perioperative anesthesia, as well as pre- and postsurgical rehabilitation protocols, which could profoundly impact the efficiency of rehabilitation. Additionally, our study did not investigate prosthesis malalignments or address the learning curves and times associated with different surgical approaches, which represent further limitations of our analysis.

Our clinical study was subject to a methodological limitation stemming from the absence of a sample size calculation specifically tailored to our research question. Nevertheless, the cohort size we utilized is consistent with standard practices in the extant literature on these surgical techniques, where studies of this nature typically enroll approximately 50 patients per group. To mitigate the limitations identified in prior research, we rigorously adhered to our study protocol, thereby enhancing the reliability of our findings. It is important to acknowledge, however, that patient allocation to the study groups was not randomized, and the data analysis was conducted post-hoc on a prospectively collected dataset. Furthermore, neither patients nor physicians were permitted to select the surgical approach, which may introduce an element of bias. Another significant challenge was the difficulty in conducting long-term follow-ups, which are critical for a more thorough understanding of the enduring effects of the surgical methods under investigation.

9. Conclusions

In summary, the global increase in the prevalence and incidence of osteoarthritis is driving a significant rise in TKA procedures, exerting substantial pressure on healthcare systems worldwide. The selection of the optimal surgical approach in TKA continues to be a subject of considerable debate, with QS approaches, particularly the SV approach, demonstrating notable advantages in early postoperative outcomes.

Our research findings consistently show that the SV approach outperforms the MP approach, yielding superior results in ROM, VAS pain scores, and KSS. Although the differences between surgical approaches tend to diminish over the long term, the SV approach offers distinct benefits in the early postoperative period.

Our clinical findings are corroborated by the international literature and our meta-analysis. While our data strongly support the SV approach as the preferred method, particularly during the critical early stages of recovery, the variability in postoperative recovery rates observed in the literature emphasizes the need for continued research. Further studies are essential to definitively determine the impact of different surgical approaches on patient rehabilitation, ultimately enhancing recovery trajectories and improving the quality of life for individuals undergoing these vital procedures.

This advantage enables patients to initiate physiotherapy and rehabilitation sooner, potentially accelerating their return to normal life activities. Additionally, SV approach may provide economic benefits by reducing rehabilitation time and minimizing the need for pain management interventions.

While our data strongly support the SV approach as the preferred method, particularly during the critical early stages of recovery, the variability in postoperative recovery rates observed in the literature emphasizes the need for continued research. Further studies are essential to definitively determine the impact of different surgical approaches on patient rehabilitation, ultimately enhancing recovery trajectories and improving the quality of life for individuals undergoing these vital procedures.

9.1. Statements

1. Our results clearly demonstrate that the subvastus approach provides superior early functional recovery after TKA, as evidenced by greater range of motion, lower postoperative pain scores (both at rest and during activity), and faster

achievement of key rehabilitation milestones such as straight leg raise and 90 degrees of knee flexion.

2. Patients undergoing the SV approach required less analgesia and had a shorter time to functional independence during the early postoperative period compared to those receiving the MP approach.
3. The advantages of the SV approach were most pronounced in the early stages of rehabilitation and were consistent with international findings, supporting its consideration as a preferred technique—especially for younger, more active patients seeking rapid recovery.
4. By highlighting the potential for reduced hospital stays and lower analgesic needs, our findings underscore the relevance of the SV approach in healthcare models that emphasize efficiency and early discharge, such as fast-track and outpatient pathways.
5. The network meta-analysis adds robust evidence to the international literature by systematically comparing all major surgical approaches for TKA and confirming the early benefits of quadriceps-sparing techniques, particularly the SV method.

10. Summary

This thesis presents an in-depth investigation into the comparative efficacy of different surgical approaches in TKA, with a specific focus on early postoperative rehabilitation outcomes. The research is structured around two primary components: a detailed clinical analysis and a systematic review complemented by a network meta-analysis. The primary objective was to assess the effectiveness of QS techniques, such as the SV and MV approaches, in comparison to the standard MP approach.

The clinical analysis, which involved a rigorous examination of postoperative outcomes, revealed that the SV approach consistently demonstrated superior results in several key areas. Patients who underwent the SV approach exhibited greater ROM and experienced lower pain levels, as measured by the VAS, both during rest and active movement. Moreover, the SV group achieved significant functional recovery milestones, such as the ability to perform an SLR and attaining 90-degree knee flexion, more rapidly than those in the MP group. These early gains in recovery suggest that the SV approach offers a more efficient path to rehabilitation, potentially leading to an expedited return to daily activities.

The systematic review and network meta-analysis provided further support for the clinical findings, reinforcing the advantages of QS approaches over the MP approach in the early stages of postoperative recovery. The meta-analysis, which synthesized data from a range of RCTs, consistently showed that the SV approach was associated with better early clinical outcomes, including reduced pain and improved ROM. These findings align with the broader literature, which increasingly recognizes the benefits of QS techniques in enhancing patient recovery after TKA.

Despite the promising results, the thesis also acknowledges several limitations. One of the primary challenges was the difficulty in achieving precise randomization in a clinical setting, which may introduce variability into the findings. Additionally, the heterogeneity in the reporting of outcomes across different studies posed a challenge to the meta-analysis, potentially affecting the generalizability of the results. Furthermore, the long-term outcomes of the various surgical approaches were not within the scope of this study, leaving questions about the sustained benefits of QS techniques over time.

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12. Bibliography of the candidate's publications

12.1. Publications in relation to the thesis

Stubnya, Bence Gusztáv ; Mercedes Schulz ; Szilárd Váncsa ; Gábor Sándor Szilágyi ; Attila Szatmári ; Zoltán Bejek - *Global Trends in Joint Arthroplasty: A Systematic Review and Future Projections* JOURNAL OF CLINICAL MEDICINE. 14(22):8214. (2025)

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12.2. Other publications

Stubnya Bence Gusztáv, Kozák Anna, Ádám Szilvia, Cserháti Zoltán, Vámosi Péter, Kovács Eszter - *Az orvoshiány kihívásai Közép és Kelet Európában – körkép a kirendelés és vezénylés vonatkozásában* IME – EGÉSZSÉGÜGYI VEZETŐK SZAKLAPJA – TUDOMÁNYOS FOLYÓIRAT XXIV. Évfolyam 2025/2. SZÁM (2025)

Kocsis, K. ; Stubnya, B. ; Váncsa, S. ; Kói, T. ; Kovács, N. ; Hergár, L. ; Hetthéssy, J. ; Holnapy, G. ; Hegyi, P. ; Pap, K. - *Diagnostic accuracy of ultrasonography in acute lateral ankle ligament injury: A systematic review and meta-analysis* INJURY: INTERNATIONAL JOURNAL OF THE CARE OF THE INJURED 55 : Supplement 3 Paper: 111730 , 8 p. (2024)

Tél, Bálint ; Stubnya, Bence ; Gede, Noémi ; Varjú, Péter ; Kiss, Zoltán ; Márta, Katalin ; Hegyi, Péter Jenő ; Garami, András ; Hegyi, Eszter ; Szakács, Zsolt - *Inflammatory Bowel Diseases Elevate the Risk of Developing Acute Pancreatitis: A Meta-analysis* PANCREAS 49 : 9 pp. 1174-1181. , 8 p. (2020)

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