Better outcomes after mini-subvastus approach for primary total knee arthroplasty: a Bayesian network meta-analysis

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Abstract
Introduction Alternatives to the classical medial parapatellar (MPP) approach for total knee arthroplasty (TKA) include the mini-medial parapatellar (MMPP), mini-subvastus (MSV), mini-midvastus (MMV) and quadriceps-sparing (QS) approaches. The best approach has been not fully clarified. The purpose of the present study was to conduct a Bayesian network meta-analysis comparing these approaches.

Materials and methods The present analysis was carried out according to the PRISMA extension statement for reporting systematic reviews incorporating network meta-analyses of healthcare interventions. The databases search was performed in October 2019. All clinical trials comparing two or more approaches for primary TKA were considered for inclusion. The baseline comparability was evaluated through the analysis of variance (ANOVA) test. The statistical analysis was performed through the STATA software/MP. A Bayesian hierarchical random-effects model analysis was adopted in all the comparisons.

Results Data from 52 articles (4533 patients) were collected. The mean follow-up was 20.38 months. With regard to diagnosis, gender, age and BMI, adequate baseline comparability was detected. The MSV approach ranked better concerning clinical scores (the lowest visual analogic scale, the higher KSS and KSFS) and functional outcomes (the shortest straight leg raise, the greatest degree of flexion and range of motion). Concerning perioperative data, the MSV evidenced the shortest hospital stay, while the MPP the shortest surgical duration and lowest estimated blood loss.

Conclusion According to the main findings of the present study, the mini-subvastus approach for total knee arthroplasty demonstrated superior overall compared to the other approaches. Orthopaedic surgeons should consider this approach in the light of the evidence and limitations of this Bayesian network meta-analysis.

Keywords Total knee arthroplasty · Medial parapatellar · Subvastus · Midvastus · Quadriceps sparing

Introduction

While the overall effectiveness of total knee arthroplasty (TKA) is largely unquestionable, the best surgical approach is still to be determined. The medial parapatellar approach, introduced by Von Langenbeck [1], is still regarded as the standard. The main benefit of this approach is that it provides the best exposure of knee surfaces. On the other hand, it has been criticized for introducing massive damage to the articular capsule, patellar and quadriceps tendons, extensor apparatus, soft tissue and vascular structures. Minimally invasive approaches to TKA have been evolved for the purpose of preserving the extensor mechanism as much as possible [2, 3]. The first minimally invasive approach for knee arthroplasty was described by Repicci and Eberle [4] for implantation of a unicompartmental prosthesis. Then came techniques extending to TKA. The mini-subvastus (MSV) approach was introduced by Hoffman et al. [5] in 1991 as a way to minimize extensor damage and preserve the vascular supply to the patella. Furthermore, this approach avoided eversion of the patella, thereby reducing the risk of tendon and cartilage damage [2, 3]. In 1997, Engh et al. [6] described the mini-midvastus (MMV) approach. In addition
to the advantages of the MSV, this approach provided better exposure to all knee structures. Finally, Tria et al. [7] introduced the quadriceps-sparing (QS) approach in 2003 and Scudieri et al. the mini-medial parapatellar (MMPP) approach in 2004 [8]. The latter is a shortened version of the MPP. To our knowledge, no study has compared data from all these approaches to establish the best approach for TKA. Hence, the purpose of the present study was to perform a Bayesian network meta-analysis to compare these approaches and determine the most effective. We focused on perioperative data, clinical and functional outcomes.

Materials and methods

Search strategy

The present Bayesian network meta-analysis was carried out according to the PRISMA extension statement for reporting systematic reviews incorporating network meta-analyses of healthcare interventions [9]. To orient the literature search, the following features were defined:

- **P** *(population)* end-stage knee joint disease;
- **I** *(intervention)* total knee arthroplasty;
- **C** *(comparison)* MPP, MMV, MSV, QS, MMPP;
- **O** *(outcomes)* perioperative data, functional outcomes, clinical scores.

Data source

Two authors (FM and JE) independently performed the initial search. In October 2019, the main databases were accessed: PubMed, Google Scholar, Embase and Scopus. The following keywords were used in combination: total knee arthroplasty, total knee replacement, prosthesis, medial, quadriceps sparing, midvastus, subvastus, mini-medial parapatellar, KSS, KSFS, range of motion, flexion, straight leg raise, hospital duration. All pertinent titles and abstracts were screened, and if matching the topic, the full text was accessed. Bibliographies of the included studies were also cross-referenced. Disagreements between the authors were debated and mutually solved.

Eligibility criteria

All clinical trials comparing two or more approaches for primary TKA were considered for inclusion. According to the Oxford Centre for Evidence-Based Medicine, only articles with levels I and III evidence were considered for the present study. Articles were limited to English, German, Italian, French and Spanish. Case series, case reports, letters, expert opinions and editorials were excluded. No differences concerning the type of implants were made; only the surgical approach was pivotal for inclusion. Missing data under our outcomes of interest warranted exclusion. Disagreements were debated and mutually solved.

Outcomes of interest

Two authors (FM and JE) independently screened all articles resulting from the search. For each approach, study generalities and patient demographics were noted: type of study, number of procedures, duration of follow-up, surgical approach(es), percentage of female and osteoarthritic (OA) patients, mean age and body mass index (BMI). Data concerning the following outcomes of interest were collected: perioperative data (duration of surgery and hospitalization, total estimated blood loss), functional outcomes (range of motion (ROM), flexion, straight leg raise (SLR) [10]) and clinical scores (visual analogic scale (VAS) for pain, the Knee Society Score (KSS) and its related function subscale (KSFS) [11]).

Methodological quality assessment

The methodological quality of the present meta-analysis was evaluated using the PEDro appraisal score (http://www.pedro.org.au/english/downloads/pedro-scale/), which has been validated for this type of study [12]. The PEDro score is an aggregate of dichotomically assigned points given to studies based on the presence or absence of specific endpoints such as eligibility criteria, allocation, baseline comparability, blinding, follow-up, type of analysis, point estimates and variability. Values > 6 points are considered satisfactory.

Statistical analysis

The statistical analyses were performed by the senior author (FM). The baseline comparability was evaluated through the analysis of variance (ANOVA) test. Values of $P > 0.5$ were considered satisfactory to verify comparability. The statistical analysis was performed through the STATA software/MP 14.1 (Stata Corporation, College Station, TX). A Bayesian hierarchical random-effects model analysis was adopted for all the comparisons. We referred to the generic inverse variance statistic method for continuous data analysis with standardized mean difference effect measure. The edge network plot was performed to analyse connections, contribution weights between studies, and to detect direct and indirect comparisons. To evaluate loop-specific inconsistency, heterogeneity and related inconsistency factor (IF), the if test was performed. To evaluate for overall inconsistency, the equation for global linearity via the Wald test was used. If the $P$ value was $>0.05$, the null hypothesis could not be rejected and the consistency assumption could be accepted.
at the overall level of each treatment. The interval plot was performed to rank the estimated effect (EE) of the endpoints between them. Confidence and percentile intervals (CI and PrI) were each set at 95%. The funnel plot was performed to assess the risk of publication bias for each comparison.

## Results

### Identification of eligible studies

A total of 1715 articles were obtained from the initial search. Of them, 605 were duplicates. A further 377 were rejected because of poor levels of evidence. Another 86 articles were excluded because of language barriers: Chinese, Polish, unknown. Another 534 articles were excluded because they did not report quantitative data under the outcomes of interest. Thirty-eight were excluded because of uncertain data or incomplete results and 23 due to source of publication bias or excessive heterogeneous results. This last operation left 52 articles for review: 34 randomized clinical trials (RCTs), ten prospective cohort studies (PCS), eight retrospective cohort studies (RCS). The flow chart of the literature search is shown in Fig. 1.

### Methodological quality assessment

All included articles stated clearly their eligibility criteria and demonstrated satisfactory baseline comparability. A random and concealed allocation was performed in 32% of the studies. 8% performed a single blinding, and 15% had blinded assessors. Only a third of the included studies performed an adequate follow-up. Almost all the articles performed an adequate analysis, and the intention to treat was satisfied. In the end, the overall PEDro score was 7.42, detecting an optimal quality for the methodological
assessment. The PEDro scores across the studies are shown in Table 1.

**Patient demographics**

Data from 4533 patients were collected. The mean follow-up was 20.38 (range 3 to 109) months. In the MVV group, a total of 880 patients were analysed. 96% suffered from OA, and 67% were female. Their mean age was 68.64 ± 3.5 years, and mean BMI was 29.46 ± 1.7 kg/m². In the MPP group, a total of 2026 patients were analysed. 98% suffered from OA, and 69% were female. The mean age was 66.27 ± 7.9 years, and mean BMI was 29.29 ± 1.9 kg/m². In the MSV group, a total of 604 patients were analysed. 90% suffered from OA, and 70% were female. The mean age was 67.72 ± 3.1 years, and the mean BMI was 29.61 ± 1.5 kg/m². In the MMPP group, a total of 660 patients were analysed. 100% suffered from OA, and 66% were female. The mean age was 66.31 ± 2.5 years, and mean BMI was 28.00 ± 2.4 kg/m². In the QS group, a total of 474 patients were analysed. 99% suffered from OA, and 73% were female. The mean age was 70.13 ± 1.9 years, and mean BMI was 29.03 ± 1.4 kg/m². Among the studies, with regard to diagnosis, gender, age and BMI, adequate baseline comparability was detected (P = 0.8, respectively). Patient demographics for the included studies are shown in Table 1.

**Outcomes of interest**

Concerning perioperative data, the MSV approach demonstrated the lowest duration of hospitalization (EE: −5.63, 95% CI: −6.48 to −4.79), followed by the MPP approach (EE: −2.99, 95% CI: −4.61 to −1.38). The MMPP approach reported the highest duration of hospitalization (EE: −0.92, 95% CI: −2.03 to 0.18). The test for overall inconsistency scored P = 0.2. The MPP approach demonstrated the lowest value of total estimated blood loss (EE: 363.84, 95% CI: 286.42 to 441.26) followed by the MSV approach (EE: 820.47, 95% CI: 737.19 to 903.75). The QS approach reported the greatest value of total estimated blood loss (EE: 957.31, 95% CI: 801.26 to 1113.37). The test for overall inconsistency scored P = 0.05. The test for overall inconsistency scored P = 0.2. The MPP approach demonstrated the lowest VAS pain score (EE: −2.33, 95% CI: −3.37 to −2.30) followed by the QS approach (EE: −2.33, 95% CI: −3.37 to −2.30) followed by the MMV approach (EE: −1.03, 95% CI: −3.08 to 1.02). The MPP approach reported the highest value of VAS (EE: 0.50, 95% CI: −1.10 to 2.10). The test for overall inconsistency scored P = 0.05. The network results concerning the endpoint clinical scores are shown in Fig. 4.

**Discussion**

The main results of this Bayesian network meta-analysis encourage to perform the minimally invasive subvastus approach for total knee arthroplasty. Concerning clinical scores, functional outcomes and length of the hospital stay, the MSV approach outperformed all other approaches. Surgical duration and total estimated blood loss were lower in the MPP approach. The transitivity between studies was always satisfied, and the equation for global linearity via the Wald test found no statistically significant inconsistency among the studies, attesting reliability of the present results.

The intention of the minimally invasive approaches is to provide quicker recovery after TKA by preventing damage to the extensor mechanism. However, the MPP demonstrated a very short length of the hospital stay compared to the other minimally invasive techniques. Regarding perioperative outcomes, the QS approach reported the longest surgical duration and the highest value of total estimated blood loss. This
| References          | Type of study | PEDro score | Knees (n) | Follow-up (months) | Type of approach | Knees (n) | OA patients (%) | Female (%) | Mean age (years) | BMI (kg/m²) |
|---------------------|---------------|-------------|-----------|-------------------|------------------|-----------|-----------------|------------|-----------------|-------------|
| Aglietti et al. [13]| RCT           | 9           | 60        | 3.00              | MSV              | 30        | 60.00           | 70.00      | 28.08           |             |
|                     |               |             |           |                   | QS               | 30        | 60.00           | 71.00      | 28.07           |             |
| Aslam et al. [14]   | RCT           | 10          | 84        | 12.00             | MMV              | 42        | 100.00          | 30.00      | 68.80           | 30.60       |
|                     |               |             |           |                   | MPP              | 42        | 100.00          | 57.14      | 68.60           | 30.10       |
| Avci et al. [15]    | RCS           | 6           | 39        | 23.50             | MMV              | 19        | 100.00          | 78.94      | 64.53           | 32.02       |
|                     |               |             |           |                   | MPP              | 20        | 100.00          | 90.00      | 67.25           | 32.56       |
| Boerger et al. [2]  | PCS           | 5           | 120       | 3.00              | MSV              | 60        | 100.00          | 77.00      | 69.00           | 28.00       |
|                     |               |             |           |                   | MPP              | 60        | 100.00          | 75.00      | 68.00           | 29.00       |
| Bridgman et al. [16]| RCT           | 7           | 224       | 13.00             | MSV              | 113       | 48.00           | 70.10      | 34.60           |             |
|                     |               |             |           |                   | MPP              | 111       | 49.00           | 70.90      | 31.00           |             |
| Bonutti et al. [17] | RCT           | 9           | 102       | 24.00             | MSV              | 51        | 84.00           | 70.00      | 31.00           |             |
|                     |               |             |           |                   | MMV              | 51        | 84.00           | 70.00      | 31.00           |             |
| Chalidis et al. [18]| RCT           | 8           | 100       | 24.00             | MMV              | 50        | 100.00          | 92.00      | 70.10           | 34.60       |
|                     |               |             |           |                   | MPP              | 50        | 100.00          | 88.00      | 71.20           | 34.20       |
| Chiang et al. [11]  | RCT           | 10          | 75        | 24.00             | QS               | 38        | 100.00          | 90.00      | 69.70           | 28.60       |
|                     |               |             |           |                   | MPP              | 37        | 100.00          | 90.00      | 69.80           | 29.60       |
| Cho et al. [19]     | RCT           | 8           | 66        | 12.00             | MMV              | 33        | 100.00          | 96.00      | 65.50           | 29.10       |
|                     |               |             |           |                   | MPP              | 33        | 100.00          | 93.93      | 67.00           | 28.00       |
| Daboussi et al. [20]| PCS           | 5           | 80        | 3.00              | MMV              | 40        | 100.00          |            |                |             |
|                     |               |             |           |                   | MPP              | 40        | 100.00          |            |                |             |
| Feczko et al. [21]  | RCT           | 7           | 69        | 6.00              | MMV              | 36        | 95.00           | 63.88      | 65.14           | 28.26       |
|                     |               |             |           |                   | MPP              | 33        | 100.00          | 66.66      | 64.88           | 28.56       |
| Han et al. [22]     | RCT           | 9           | 30        | 24.00             | MMPP             | 15        | 100.00          | 66.00      | 26.90           |             |
|                     |               |             |           |                   | MPP              | 15        | 100.00          | 64.00      | 26.40           |             |
| Heekin et al. [23]  | RCT           | 9           | 80        | 24.00             | MMV              | 40        | 14.00           | 65.13      | 30.98           |             |
|                     |               |             |           |                   | MMPP             | 40        | 35.00           | 65.13      | 30.98           |             |
| Hernandez-Vaquero et al. [24]| RCT | 7 | 62 | 6.00 | MMV | 26 | 100.00 | 80.77 | 70.80 | 32.10 |
|                     |               |             |           |                   | MPP             | 36 | 100.00 | 80.33 | 70.50 | 30.80 |
| Huang et al. [25]   | RCS           | 6           | 96        | 60.00             | MMPP             | 35        | 100.00          | 85.71      | 69.20           | 27.00       |
|                     |               |             |           |                   | QS               | 31        | 100.00          | 93.55      | 69.30           | 26.90       |
| Jarvis et al. [26]  | RCT           | 6           | 53        | 6.00              | MSV              | 27        | 100.00          | 87.00      | 69.00           | 31.40       |
|                     |               |             |           |                   | MMV              | 26        | 100.00          | 61.54      | 74.20           | 29.80       |
| Jung et al. [27]    | PCS           | 6           | 40        | 58.40             | MSV              | 21        |                |            |                |             |
|                     |               |             |           |                   | MPP              | 19        |                |            |                |             |
| References                  | Type of study | PEDro score | Knees (n) | Follow-up (months) | Type of approach | Knees (n) | OA patients (%) | Female (%) | Mean age (years) | BMI (kg/m²) |
|-----------------------------|---------------|-------------|-----------|-------------------|-----------------|-----------|-----------------|------------|-----------------|-------------|
| Juosponis et al. [28]       | RCT           | 8           | 70        | 3.00              | MMV             | 35        | 100.00          | 85.71      | 72.00           | 27.95       |
|                             |               |             |           |                   | MPP             | 35        | 100.00          | 85.71      | 71.40           | 29.08       |
| Karachalios et al. [29]     | RCT           | 8           | 100       | 23.00             | MMV             | 50        | 92.00           | 62.00      | 71.10           | 32.00       |
|                             |               |             |           |                   | MPP             | 50        | 92.00           | 70.00      | 70.80           | 31.50       |
| Karpman et al. [30]         | RCT           | 8           | 59        | 6.00              | MMV             | 20        | 100.00          | 65.00      | 74.00           | 30.00       |
|                             |               |             |           |                   | QS              | 20        | 100.00          | 60.00      | 73.00           | 28.00       |
|                             |               |             |           |                   | MPP             | 19        | 100.00          | 53.00      | 73.00           | 29.00       |
| Kim [31]                    | RCT           | 10          | 50        | 12.00             | MMV             | 23        | 100.00          | 67.00      | 27.10           | 28.40       |
|                             |               |             |           |                   | MPP             | 22        | 100.00          | 68.00      | 28.00           | 30.00       |
| King et al. [32]            | RCS           | 5           | 150       | 1.50              | QS              | 100       | 95.00           | 52.00      | 67.00           | 30.00       |
|                             |               |             |           |                   | MPP             | 50        | 90.00           | 66.00      | 28.00           | 32.00       |
| Laskin et al. [3]           | RCS           | 5           | 58        | 3.00              | MMV             | 26        | 100.00          | 70.00      | 29.00           | 30.00       |
|                             |               |             |           |                   | MPP             | 26        | 100.00          | 68.00      | 29.00           | 30.00       |
| Li et al. [33]              | RCT           | 8           | 50        | 12.00             | MSV             | 25        | 100.00          | 64.00      | 25.80           | 25.80       |
|                             |               |             |           |                   | MPP             | 25        | 100.00          | 64.00      | 25.80           | 25.50       |
| Liebenstein et al. [34]     | PCS           | 5           | 38        | 2.00              | MMV             | 19        | 100.00          | 57.89      | 66.70           | 30.20       |
|                             |               |             |           |                   | MPP             | 19        | 100.00          | 52.63      | 67.60           | 31.50       |
| Lin et al. [35]             | RCT           | 9           | 80        | 2.00              | QS              | 40        | 100.00          | 67.50      | 69.60           | 28.10       |
|                             |               |             |           |                   | MMPP            | 40        | 100.00          | 67.50      | 70.20           | 29.00       |
| Lin et al. [36]             | RCT           | 9           | 100       | 24.00             | QS              | 35        | 100.00          | 86.00      | 26.30           | 25.90       |
|                             |               |             |           |                   | QS              | 30        | 100.00          | 87.00      | 70.00           | 25.90       |
|                             |               |             |           |                   | MMPP            | 35        | 100.00          | 86.00      | 68.50           | 25.90       |
| Liu et al. [37]             | RCT           | 8           | 90        | 24.00             | MMV             | 45        | 100.00          | 51.35      | 71.00           | 30.20       |
|                             |               |             |           |                   | MPP             | 45        | 100.00          | 62.50      | 70.00           | 31.50       |
| Maru et al. [38]            | PCS           | 6           | 77        | 3.00              | MMV             | 37        | 100.00          | 51.35      | 71.00           | 32.00       |
|                             |               |             |           |                   | MPP             | 40        | 96.00           | 62.50      | 70.00           | 30.00       |
| McAllister et al. [39]      | PCS           | 7           | 180       | 13.00             | MMPP            | 91        | 100.00          | 51.64      | 63.00           | 63.00       |
|                             |               |             |           |                   | MPP             | 89        | 100.00          | 49.43      | 63.00           | 63.00       |
| Mehta et al. [40]           | RCT           | 7           | 55        | 6.00              | MSV/MMV         | 26        | 100.00          | 73.17      | 59.80           | 29.60       |
|                             |               |             |           |                   | MPP             | 29        | 100.00          | 73.17      | 61.40           | 29.60       |
| Mukherjee et al. [41]       | RCT           | 8           | 100       |                   | MMV             | 20        | 100.00          | 66.66      | 66.70           | 29.60       |
|                             |               |             |           |                   | MPP             | 27        | 100.00          | 66.66      | 66.70           | 29.60       |
| Nestor et al. [42]          | RCT           | 10          | 54        | 3.00              | MMV             | 27        | 100.00          | 66.66      | 66.70           | 29.60       |
|                             |               |             |           |                   | MPP             | 27        | 100.00          | 66.66      | 66.70           | 29.60       |
| Nutton et al. [43]          | RCT           | 10          | 23        | 6.00              | MMV             | 11        | 100.00          | 33.00      | 73.00           | 31.10       |
| References               | Type of study | PEDro score | Knees (n) | Follow-up (months) | Type of approach | Knees (n) | OA patients (%) | Female (%) | Mean age (years) | BMI (kg/m²) |
|--------------------------|---------------|-------------|-----------|-------------------|-----------------|-----------|----------------|------------|-----------------|-------------|
| Pescador et al. [44]    | RCT           | 8           | 96        | 96.00             | MPP             | 12        | 100.00         | 50.00      | 70.00           | 29.30       |
| Pongcharoen et al. [45] | RCT           | 8           | 60        | 12.00             | MSV             | 45        | 68.88          | 71.20      | 28.40           |             |
| Rahman et al. [46]      | RCS           | 5           | 120       | 3.00              | MPP             | 30        | 100.00         | 69.69      | 67.00           | 26.00       |
| Schroer et al. [47]     | PCS           | 6           | 300       | 24.00             | QS              | 150       | 62.00          | 71.00      | 31.00           |             |
| Seon et al. [48]        | PCS           | 6           | 84        | 12.00             | MMV             | 41        | 100.00         | 80.48      | 64.20           |             |
| Dayton et al. [49], Stevens-Lapsley et al. [50] | RCT           | 8           | 41        | 3.00              | MMPP            | 22        | 100.00         | 54.00      | 64.60           | 30.50       |
| Tasker et al. [51]      | RCT           | 8           | 83        | 24.00             | MMV/MSV         | 19        | 45.00          | 64.00      | 31.30           |             |
| Tenholder et al. [52]   | RCS           | 6           | 118       |                   | MPP             | 40        | 45.00          | 63.00      | 67.30           |             |
| Thienpont et al. [53]   | RCT           | 8           | 300       | 24.00             | MMPP            | 40        | 45.00          | 63.00      | 68.20           |             |
| Tsuji et al. [54]       | PCS           | 5           | 20        | 0.50              | MMV             | 10        | 100.00         | 60.00      | 68.40           |             |
| Unnanuntana et al. [55] | RCS           | 6           | 64        | 60.00             | MMPP            | 31        | 100.00         | 80.00      | 69.80           |             |
| Unwin et al. [56]       | RCT           | 8           | 66        | 72.00             | MMV/MSV         | 32        | 75.75          | 67.00      | 70.00           |             |
| Varela-Egocheaga et al. [57] | RCT           | 8           | 100       | 36.00             | MSV             | 50        | 72.00          | 68.02      | 30.97           |             |
| Watanabe et al. [58]    | RCS           | 6           | 48        | 48.00             | MMV             | 25        | 84.00          | 80.00      | 71.00           |             |
| Wegrzyn et al. [59]     | RCT           | 10          | 36        | 2.00              | MSV             | 18        | 100.00         | 72.00      | 67.00           |             |
| Wülker et al. [60]      | RCT           | 8           | 134       | 12.00             | MSV             | 66        | 92.00          | 72.70      | 70.20           |             |
| Zhang et al. [61]       | RCT           | 8           | 82        | 12.00             | MPP             | 40        | 54.00          | 65.90      | 26.20           |             |
can be explained by the reduced joint exposure of minimally invasive surgeries compared with the traditional approach. Peersman et al. [63], in a retrospective cohort study including 6489 patients, found correlation between an increased surgical duration and an augmented risk of surgical site infection during TKA. Reduced visibility can considerably complicate component installation, prolong the learning curve and generate skin sloughs [52, 64]. The QS approach especially requires more attention to retractor positioning, since they damage bones (particularly when osteoporotic) and soft tissue [13, 30]. The advantage of the QS approach is that it can be easily converted to MMPP or MPP [13].

Concerning clinical scores (KSS, KSFS, VAS), the MSV approach performed better overall. The equation for global linearity via the Wald test evidenced no statistically significant inconsistency among the studies. Thus, the assumption of transitivity can be accepted. The MMV reported the lowest value of KSS and VAS, while the QS the lowest KSFS. Concerning functional outcomes (SLR, ROM, flexion), the MSV approach performed better overall. No statistically significant inconsistency was found through the equation for global linearity via the Wald test; therefore, transitivity between the studies is assumed. As expected, the MPP evidenced the longest SLR, while the MMV the lowest degree of flexion and the QS the lowest ROM.

One of the purposes of minimally invasive TKA is to reduce damage to the quadriceps tendon, in order to guarantee quicker recovery of the extensor mechanism function. The straight leg raise (SLR) is used to assess quadriceps restoration after TKA [65, 66]. SLR times were longer in the traditional MPP group and strongly improved in the other approaches, especially in the MSV approach, confirming reduced damage to the extensor mechanism in these approaches. Several studies have tried to quantify quadriceps destruction in minimally invasive TKA versus the traditional MPP using levels biomarkers indicative of muscle damage (e.g. creatine kinase, interleukin-6, myoglobin). However, their results are contrasting and controversial [67–69].

Comparing the traditional MPP to the other approaches for TKA, we highlight multiple advantages and disadvantages. First, all the other approaches provide a minimally invasive surgery. Second, they aim to preserve patellar vascularization [68], which can reduce the occurrence of patellar fractures, avascular necrosis, subluxations, dislocations, component loosening and rates of anterior knee pain [5, 7]. Third, they are supposed to promote quicker recovery of the quadriceps function and decreased post-operative pain [70, 71]. The MSV, along with the MMV, preserves the vastus medialis insertion [47, 72] and potentially reduces the risk of VMO denervation [71, 73]. Pagnano et al. [74] in a cadaveric study demonstrated that the VMO tendon inserts mostly down to the mild pole of the patella, thus proving that the MSV is the only approach able to preserve
the VMO insertion on the patella. Furthermore, the MSV proximally avoids an incision to the descending genicular artery branches (musculoarticular branch) [75, 76]. Fourth, the MSV and MMV almost never require a lateral release [72, 77]. Lateral retinacular release during TKA is not fully understood. It is meant to improve patellar tracking, but can also damage patellar vascularization and reduce joint stability [78, 79]. However, due to difficult execution, a longer learning curve and the need for special instruments, it has not been very popular [13, 80]. The difficulty of execution can result in ligament–patellar maltracking, increased rates of polyethylene wear, loosening, imbalance and instability [81, 82]. To assist the surgeon, the use of a mobile window can facilitate exposure of knee surfaces and dedicated instrumentation should be considered [28, 42]. Not surprisingly, previous studies confirm that the MPP exposure is related to an optimal component positioning [35, 83, 84]. This has discouraged many surgeons from performing minimally invasive TKAs, and the MPP remains the most common approach for TKA. Indeed, our results evidenced that the MPP exposure required less surgical duration and lower estimated blood loss. However, we hypothesize that these results are strongly influenced by the learning curve.

This Bayesian network meta-analysis has several limitations. As previously mentioned, due to reduced visibility and augmented difficulties of installation, minimally invasive TKAs can result in implant malposition. Notwithstanding, implant positioning has not been evaluated, thus representing
an important limitation of this study. Implant malposition relates to instability, loosening and consequent joint failure. Further studies should clarify this important endpoint. Another notable limitation of the present study is its lack of analysis for complications. This is due to a lack of data in the included studies under these endpoints. Further studies should implement analyses of complications and evaluate the feasibility of minimally invasive surgeries, especially when it comes to obese patients and patients with previous knee surgeries (e.g. high tibial osteotomies). Points of strength in this Bayesian network meta-analysis are the comprehensive nature of the literature search and the optimal baseline comparability, along with the high number of enrolled studies. To the best of our knowledge, this study represents the first study comparing multiple surgical approaches for TKA. Data from the present network analysis provide evidence in favour of the mini-subvastus approach for total knee arthroplasty. However, the present study represents a data statistical elaboration and, therefore, must be interpreted with caution.

**Conclusion**

According to the main findings of the present study, the mini-subvastus approach for total knee arthroplasty demonstrated superior overall compared to the other
approaches. Orthopaedic surgeons should consider this approach in the light of the evidence and limitations of this Bayesian network meta-analysis.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent For this type of study, informed consent is not required.

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Fig. 4 Results of the network comparison clinical scores
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