

# The role of wound closure in total knee arthroplasty: a systematic review on knee position

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## Abstract

**Purpose** Post-operative range of motion (ROM) is one of the most important parameters to assess, following total knee arthroplasty (TKA). The aims of the present systematic review were to analyse the available literature and determine if closing the knee in flexion or extension influences post-operative ROM, clinical outcomes, and complications following TKA.

**Methods** A systematic review was performed using the keywords “total knee arthroplasty”, “total knee replacement”, and “wound closure” or “joint closure” or “extension” or “flexion” with no limit regarding the year of publication. The review was limited to the English-language articles, and each article was evaluated with a modified Coleman Methodology Score (mCMS).

**Results** Six articles met inclusion criteria. The initial cohort included 202 TKAs in the flexion group and 201 in the extension group. Three hundred and ninety-seven TKAs were evaluated with an average follow-up of 8 months. There was no statistical difference (n.s.) between the two groups in terms of the average post-operative flexion. There

were no statistical differences between the two groups regarding post-operative functional scores and VAS scores (n.s.). The average mCMS was 70.9, indicating good methodological quality in the included studies.

**Conclusions** The findings of the present review did not show any statistically significant differences in terms of post-operative flexion ROM, functional scores, or complications related to the position of the knee at the time of joint and wound closure during TKA. There is no clear advantage to either closure method based on the currently available evidence, and therefore, this choice should be based on surgeon preference.

**Keywords** Total knee arthroplasty · Total knee replacement · Wound closure · Joint closure

## Introduction

Total knee arthroplasty (TKA) is one of the most common procedures in orthopaedic practice with satisfactory outcomes in terms of pain relief and range of movement (ROM) even at long-term follow-up [11, 13, 14]. Post-operative ROM is an important functional parameter that has great impact on quality of life following TKA [9]. Post-operative ROM following TKA is influenced by preoperative, intraoperative, and post-operative factors [4, 15]. Preoperative factors include aetiology, preoperative ROM [1], smoking, and diabetes [6]. Intraoperative factors include soft-tissue balancing mismatch, component malpositioning, and incorrect implant sizing. Post-operative factors include arthrofibrosis, heterotopic ossification, and inadequate post-operative rehabilitation.

Recently, rising attention has been paid to the role of soft-tissue repair and post-operative ROM following TKA. Several

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surgical options have been described, but the influence of these techniques on post-operative outcomes has yet to be demonstrated [5]. King et al. [7] were the first to introduce the concept of closing the knee in deep flexion (90°–120°). They stated that closing the knee in such a position would avoid stretching of the soft tissues and would lead to less patient discomfort. In addition, it would prevent shortening of the extensor mechanism and skin. On the contrary, closing the knee in full extension may lead to soft-tissue misalignment resulting in increased tension on the extensor mechanism when the knee is moved into deep flexion. This could also lead to decreased post-operative ROM and increased anterior knee pain. Several authors have subsequently investigated the role of knee position during wound closure. In particular, in the systematic review by Smith et al. in 2010, three articles met the criteria and were analysed. The study was limited by the small number of TKAs and the poor methodology. Due to a lack of clear evidence, the choice of closing the joint and wound has been based on surgeon preference. Having reliable and precise guidelines could be helpful in daily practice.

The aims of the present systematic review were to analyse the available literature and determine if closing the knee in flexion or extension influences post-operative ROM, and clinical outcomes, and complications following TKA (Table 1).

## Materials and methods

A systematic literature review using keyword terms and Boolean operators “total knee replacement” OR “total knee

arthroplasty” AND “wound closure” AND “joint closure” AND “flexion” OR “extension” OR “knee position” with no limit regarding the year of publication was performed. The following databases were accessed on 24 October 2015 PubMed (<http://www.ncbi.nlm.nih.gov/sites/entrez/>); Ovid (<http://www.ovid.com>); Cochrane Reviews (<http://www.cochrane.org/reviews/>), and Google Scholar (<https://scholar.google.com>). The full-text articles were selected or excluded according to the relevance of the abstract text and only English-language articles were included. In addition, the reference lists of the articles were manually searched to include articles not identified during the electronic search. Three hundred and thirteen publications were identified. Two authors (SC and EV) reviewed all of the abstracts. All peer-reviewed journals were considered in this review, and all relevant articles were retrieved. Prospective or retrospective studies reporting clinical outcomes were included in the study, whereas technical notes, cadaveric, and animal studies were excluded (Fig. 1). Ultimately, six articles met inclusion criteria. Two of these six articles reported the outcomes of the same series, so only the article with longest-term follow-up was considered for clinical outcome data leaving five articles for analysis. However, all six articles were included in the modified Coleman Methodology Score calculation (Table 2). This evaluation was performed according to the modified Coleman Methodology Score (CMS) [8], which has been demonstrated as a reliable tool to determine the methodological quality of studies.

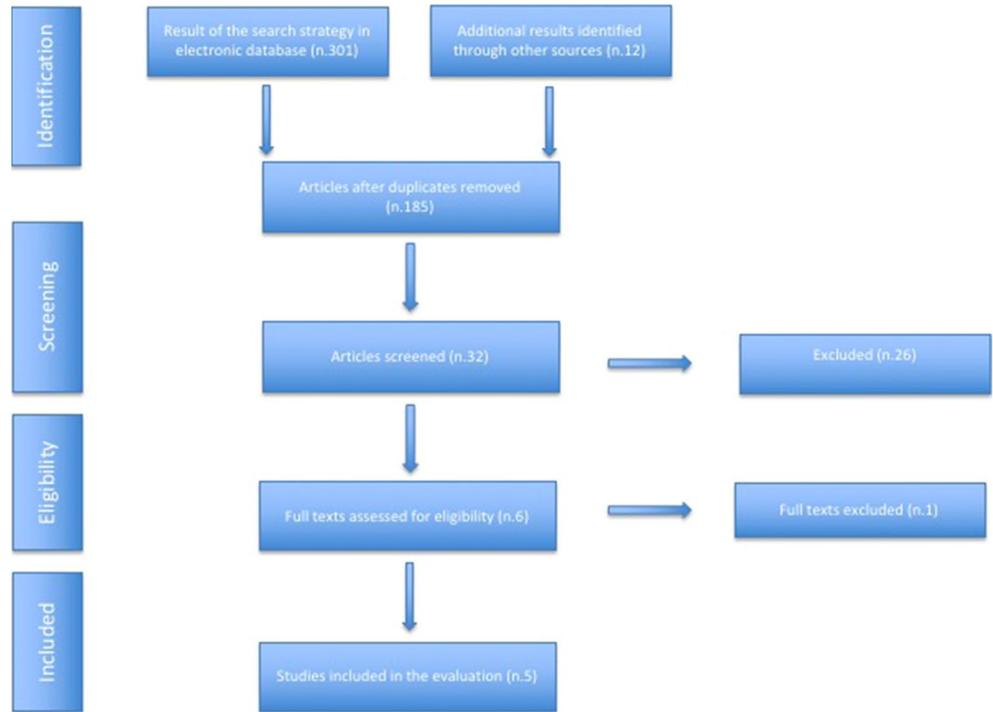
The modified Coleman Methodology Score consists of ten criteria divided in two parts (part A and part B), which assess the methodological quality of scientific studies. A

**Table 1** Demographic characteristics of the cohorts reviewed

Author	Year	Journal	Type of study	Initial cohort (Sg/Cg)	Mean patient age (yrs) (Sg/Cg)	Sex (M/F) (Sg/Cg)	BMI (Sg/Cg)	Degree of flexion (Sg)	FU (months)	Knees at FU (Sg/Cg)
Emerson	1996	CORR	Case series Prospective	56/52	69.2/72.5	21/35 18/34	31.0/30.6	90–110	6	56/52
Masri	1996	CORR	RCT	38/37	68.2/67.8	14/20 16/15	29.8/29	60–90	2–3	38/37
Emerson	1999	CORR	Case series Prospective Primary	56/52	69.2/72.5	21/35 18/34	31.2/30.6	90–110	12	56/52
Emerson	1999	CORR	Case series Prospective Revision	13/13	73/67	7/5 7/6	30.7/29.6	90–110	12	13/13
Kömürçü	2014	KSSTA	RCT	14/15	66.1/67.8	10/4 12/3	28.3/28.8	90	5–6	14/15
Wang	2014	JOSR	RCT	40/40	68.4/67.9	7/33 9/31	25/24.9	90	6	40/40
Motififard	2014	KSSTA	RCT	45/46	66.7/67.5	9/32 5/39	27.1/26.6	90	12	41/44

Sg study group (flexion), Cg control group (extension)

**Fig. 1** Flow chart of the study



**Table 2** Coleman methodology score calculated on the six articles included

Authors	Coleman 1	Coleman 2	Coleman 3	Coleman 4	Coleman 5	Coleman 6	Coleman 7	Coleman 1A	Coleman 1B	Coleman 1C	Total
Emerson CORR 1996	10	2	10	10	0	3	10	4	5	15	69
Masri CORR 1996	10	0	0	15	5	3	0	10	9	10	62
Emerson CORR 1999 primary	10	2	0	10	0	3	0	10	9	10	54
Emerson CORR 1999 revision	0	2	0	10	0	3	0	10	9	10	44
Kömürçü KSSTA 2014	4	2	10	15	5	5	10	10	8	15	84
Wang JOSR 2014	10	2	10	15	5	5	10	10	15	15	97
Motifard KSSTA 2014	10	5	10	15	5	5	0	10	11	15	86
Average	7.7	2.1	5.7	12.9	2.9	3.9	4.3	9.1	9.4	12.9	70.9
Median	10	2	10	15	5	3	0	10	9	15	69
Standard dev	4.1	1.5	5.3	2.7	2.7	1.1	5.3	2.3	3.0	2.7	19.0

perfect score of 100 represents a study design that largely avoids the influence of chance, various biases, and confounding factors. Although no cut-off for the definition of high- or low-quality studies has been previously set, a total score greater than 65 is usually accepted as the inferior limit for a high-quality study [16]. In the present study, the original score was modified to better match with the kind of examined studies. Therefore, item 2a reporting follow-up length changed from >24 months (5 points), 12–24 months (2 points), and <12 months (0 points) into >12 months (5 points), 6–12 months (2 points), and <6 months (0 points). This was been done since almost all of the studies had short follow-up (FU), which seemed to be appropriate to detect any differences in functional and clinical parameters. In the same way, item 5a reporting diagnostic certainty was changed to assessment through functional score. None of the series reported preoperative diagnostic tools (preoperative ultrasound, MRI or post-operative histopathology); therefore, we judged it to be more appropriate to highlight the quality of preoperative functional information.

## Results

The demographic characteristics of the cohorts reviewed are presented in Table 1. In total, 403 knees were included: 202 in the flexion group, and 201 in the extension group. The degree of knee flexion at the time of capsule and wound closure varied from 60° [11] to 110° [2, 3] in the different series, while the control groups consisted of capsule

and wound closure in full extension (0°). The average age in the flexion group was 68.7 years, while it was 68.2 years in the extension group. The flexion group included 68 males and 129 females, while the extension group included 66 males and 129 females. Body mass index (BMI) in the flexion group was 28.7 kg/m<sup>2</sup> compared with 28.3 kg/m<sup>2</sup> in the extension group. Appropriate active and passive physical therapy protocols starting on post-operative day 1 were utilized in all included articles. Overall, 397 TKAs were evaluated with an average follow-up of 8 months (six were lost to FU) (Table 3).

## Outcomes

The data from Emerson et al. [3] were included. Those of the intermediate follow-up study by the same authors [2] were included only if they were absent from the previous study. Preoperative and post-operative evaluations were performed with traditional outcome measures: flexion range of movement (ROM), visual analogic scale (VAS), Knee Society Score (KSS) and American Knee Society Score (AKSS) (Table 3). Secondary outcomes tools included hospitalization and length of rehabilitation programme.

## Primary outcome measures

Preoperative flexion ROM was available in all studies. Preoperative flexion ROM in the flexion and extension groups was 101.7° and 102.4°, respectively (n.s.). Post-operative flexion ROM in the flexion and extension groups at final

**Table 3** Data summary

Author year	Length of FU (months) (Sg/Cg)	Preoperative flexion ROM (Sg/Cg)	FU flexion ROM (Sg/Cg)	<i>p</i> value (Sg/Cg)	Outcome measure	Preoperative outcome (Sg/Cg)	Post-operative outcome (Sg/Cg)	<i>p</i> value (Sg/Cg)
Emerson (1996)	6	113.1 112.1	114.7 108.1	<i>p</i> = 0.02	na	na	na	na
Masri (1996)	2–3	107.9 104.7	104.7 103.1	n.s.	KSS knee KSS function	35.1/37.8 40.0/44.8	88.7/88.4 61.4/60.2	n.s. n.s.
Emerson (1999)	12 (primary)	113.1 112.1	117.9 112.9	<i>p</i> = 0.03	na	na	na	na
Emerson (1999)	12 (revision)	109 108	118.7 112.7	<i>p</i> = 0.03	na	na	na	na
Kömürçü (2014)	5–6	106.1 ± 10.4 111.1 ± 10.8	120.3 ± 10.1 119.9 ± 9.2	n.s.	AKSS	20.2/20.8	77.8/77.4	n.s.
Wang (2014)	6	82.1 ± 4.3 84.2 ± 3.7	115.0 ± 3.2 110.9 ± 5.0	n.s.	KSS knee KSS function VAS	46.2/46.0 47.4/48.8 8.0/8.0	91.2/90.6 92.5/88.7 1.2/1.1	n.s. n.s. n.s.
Motifard (2014)	12	92.1 ± 5.5 94.4 ± 5.9	119.0 ± 6.8 120.3 ± 5.4	n.s.	KSS knee KSS function	50.1/51.4 50.1/50.9	71.8/74.3 68.3/68.4	n.s. n.s.

FU follow-up, Sg study group (flexion), Cg control group (extension), AKSS American Knee Society Score British Orthopaedic Association satisfaction rate, KSS Knee Society Score, VAS visual analogue scale

follow-up was 116° and 113.2°, respectively. The difference was not statistically significant ( $p > 0.05$ ). All studies with the exception of Emerson et al. [2, 3] reported no statistical differences in flexion ROM between the two groups at final follow-up (n.s. for all studies). Wang et al. [19] reported statistically significant differences at 6 weeks and 3 months follow-up ( $p = 0.03$  and  $p = 0.04$ , respectively), but no differences at last follow-up, 6 months after surgery. KSS was reported in three series [11, 12, 19]. Preoperative knee scores in the flexion and extension groups were  $43.8 \pm 7.8$  and  $45.1 \pm 6.8$ , while the corresponding values in function scores were  $45.8 \pm 5.2$  and  $48.2 \pm 3.1$ . At last, follow-up examination knee score in the flexion and extension groups were  $84.0 \pm 10.6$  and  $84.4 \pm 8.8$ , while the corresponding values in function scores were  $74.1 \pm 16.3$  and  $72.4 \pm 14.7$ . Preoperative AKSS values were 20.2 in the flexion group and 20.8 in the extension group. Corresponding values at last follow-up examination were 77.8 in the flexion group and 77.4 in the extension group [8]. Preoperative VAS score was 8 in both groups [19], whereas at last follow-up it was 1.2 in the flexion cohort and 1.1 in the extension group (Table 3).

**Secondary outcome measures**

Two studies reported the length of stay in the hospital after the index procedure. All patients were discharged within 5 days in the series by Emerson et al. [3], while in the series by Masri et al. [11], the length of stay was 8.2 days in the flexion cohort and 8.8 days in the extension group (n.s.). Post-operative outpatient rehabilitation lasted 3.4 weeks in the flexion cohort and 4.9 weeks in the extension group ( $p < 0.001$ ) [2].

**Complications**

No differences in terms of local and general complications were reported in the different series. Masri et al. [11] were the only ones to report notable complication, although there was no statistically significant difference between the two groups (n.s.). They reported four manipulations for stiffness, three deep venous thromboses and one haematoma in the flexion cohort. In the same way, they had three manipulations for stiffness and two deep venous thromboses in the extension cohort.

**First series versus last series**

Some considerations rise when comparing first series [2, 3, 11] and last series [8, 12, 19] (Table 4). First of all, recent studies are all RCTs with high methodological quality (Coleman score 89), while first studies have lower quality (Coleman score 57.3). Secondly, the degree of knee flexion

**Table 4** Data summary of first and second series

	Final cohort (Sg/Cg)	Mean patient age (yrs) (Sg/Cg)	Sex (M/F) (Sg/Cg)	BMI (Sg/Cg)	Length of FU (months)	Preoperative flexion ROM (Sg/Cg)	Post-operative flexion ROM (Sg/Cg)	P value (Sg/Cg)	Sg KSS post-operative (knee/function)	Cg KSS post-operative (knee/function)	Coleman
First series (2,3,10)	163/154	69.9/70	65/98 62/92	30.7/29.5	8.1	110.8/109.2	114/109.2	n.s.	88.7/61.4	88.4/60.2	57.3
Last series (7,11,18)	95/99	67.1/67.7	26/69 26/73	26.8/27.8	7.9	93.4/95.6	118.1/117	n.s.	81.5/80.4	82.5/78.6	89

FU follow-up, Sg study group (flexion), Cg control group (extension), KSS Knee Society Score

was variable between 60° and 110° in the former series while it was 90° in the three recent studies. Thirdly, the pre-operative knee flexion was much higher in the first reports as compared to the most recent studies. Finally, when analysing the outcomes in terms of knee flexion, the difference between flexion and extension groups was around 5° in the first studies and around 1° in the recent reports.

## Discussion

The most important finding of the present study is the evidence that closing the knee in deep flexion during TKA does not significantly influence post-operative knee range of motion, functional outcomes, or pain compared to closure in full extension. In addition, no differences in complication rates were found between the two groups. Finally, the methodology of the available literature is good with an average Coleman score of 70.9.

The present review has some limitations. First of all, despite the use of several databases with different keyword combinations, it is still possible that some articles may not have been included in our search. In addition, only a small number of articles were found, and the major variables analysed showed poor statistical power. Thus, the conclusions of the present review are not absolute.

Post-operative ROM is one of the parameters associated with a good outcome after TKA [10]. However, post-operative ROM after TKA is usually affected by several parameters including patient characteristics, surgical factors, and rehabilitation [15]. The management of the surgical wound plays an important role, since reducing tissue adhesions has a positive influence on post-operative ROM [1, 18], and improper wound treatment or local infections affect post-operative knee function recovery [18]. King et al. [7] were the first in 1992 to hypothesize the positive role of knee flexion at the time of capsule and wound closure. Although they did not report clinical outcomes, they postulated that TKA closure in flexion was advantageous in the early rehabilitation period due to the reduced soft-tissues stretching. Since 1992, several authors reported their series showing contradictory results. However, the literature should be divided into early studies and more recent ones. Three studies belong to the early category [2, 3, 11]. These early studies lack reliable outcome measures, and the methodology was fair (average Coleman score 57.3). Emerson et al. [2] were the first to prospectively evaluate their cohort of 108 patients at 6 months follow-up. Outcome measures only included flexion ROM. Patients in the flexion group had a significantly quicker recovery of post-operative ROM, which was still superior at 6 months follow-up, in addition they required less home physical therapy. The same authors

reported the outcomes of the same patient population at an average follow-up of 1 year [3]. Masri et al. randomized 75 knees in 65 patients to receive either the knee closed in full extension or at 60°–90° of flexion after having received three different TKA implants [11]. At 2–3 months follow-up, no significant differences were observed between the two groups regarding ROM, KSS, or complications. The outcomes of these three studies have been critically evaluated in the review by Smith et al. [17].

Recent studies have better methodological quality (average Coleman score 89) since they are all randomized controlled trials and all report the outcomes in terms of ROM and reliable and sensitive outcomes tools (KSS and AKSS). They each compared a study group in which the knee was flexed at 90° and a control group in which the knee was held in full extension. None of the studies showed a significant difference in outcomes, post-operative ROM, or complication rates between the two groups at final follow-up.

Motifard et al. [12] enrolled 91 patients in a randomized controlled trial. Forty-five patients had knee closure at 90° of flexion while 46 had the knee closed in full extension. Outcome tools included ROM and KSS. Eighty-five patients were available at 12 months follow-up. No significant differences were reported in terms of ROM and KSS score.

Wang et al. [19] in a similar study evaluated the effects of knee flexion at the time of wound closure in terms of ROM, KSS, and VAS score. Eighty patients were randomly divided into two groups of 40 patients (knee closed at 90° or in full extension). At 6 weeks and 3 months, VAS score and flexion ROM were significantly superior in the flexion group, while no difference was found in KSS. At 6 months no statistically significant differences were observed for any of the outcome measures.

Kömürçü et al. [8] reported the outcomes of a prospective randomized double-blind trial on 29 patients. Fifteen had their wound closed in full extension, whereas 14 had it at 90° of flexion. All patients were reviewed at 21–24 weeks post-operative for clinical (AKSS and ROM) and isokinetic muscle strength measurement. No significant differences in the mean AKSS and ROM values were observed between the two groups, while a significant difference emerged in the isokinetic muscle strength differences and total work difference of the flexor muscle between the two groups. Therefore, the authors concluded that closing the knee at 90° of flexion had no influence on post-operative ROM or function, but resulted in improved flexor muscle strength.

The present systematic review is not the first one focusing on the influence of knee flexion on clinical outcomes and complications after TKA. However, it is the first study to report the results of randomized control trials;

therefore, it can be of great utility in current practice. The study is not without limitations. First of all, only a small number of studies with a limited number of patients were included in the study. Finally, despite using several databases with different combinations of appropriate keywords, it is possible that some papers may not have been included in our search.

According to the available data, closing the knee in 90° of flexion does seem not to guarantee additional benefits in terms of ROM recovery or function compared to full extension. In fact, although some of the first studies reported superior outcomes in the flexion group, the amount of knee flexion was highly variable (from 90° to 110°). Conversely, more recent randomized controlled trials were homogeneous in terms of knee flexion in the study group (90°), and they did not show any significant differences. The standard length of stay, the post-operative rehabilitation, and other circumstances likely changed from the earlier studies to the more recent studies. These are other possible factors that can influence the outcome independently from the wound closure. The reported advantage in terms of strength recovery is promising, but must be confirmed with further studies. Finally, the present review confirms that wound closure in flexion versus extension is not associated with an increase in early or late complications. Therefore, the choice of closing the capsule and wound in flexion or extension can be based on surgeon preference, as there is no clear advantage to either closure method.

## Conclusion

The findings of the present systematic review did not show any statistically significant clinical differences in terms of post-operative flexion ROM, functional scores, or complications related to the position of the knee at the time of capsule and wound closure during TKA. The reported increase in muscle strength with closure in knee flexion is promising data that must be confirmed with further studies. The choice of closing the capsule and wound in flexion or extension during TKA can be based on surgeon preference, as there is no clear advantage to either closure method based on the currently available evidence.

## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

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